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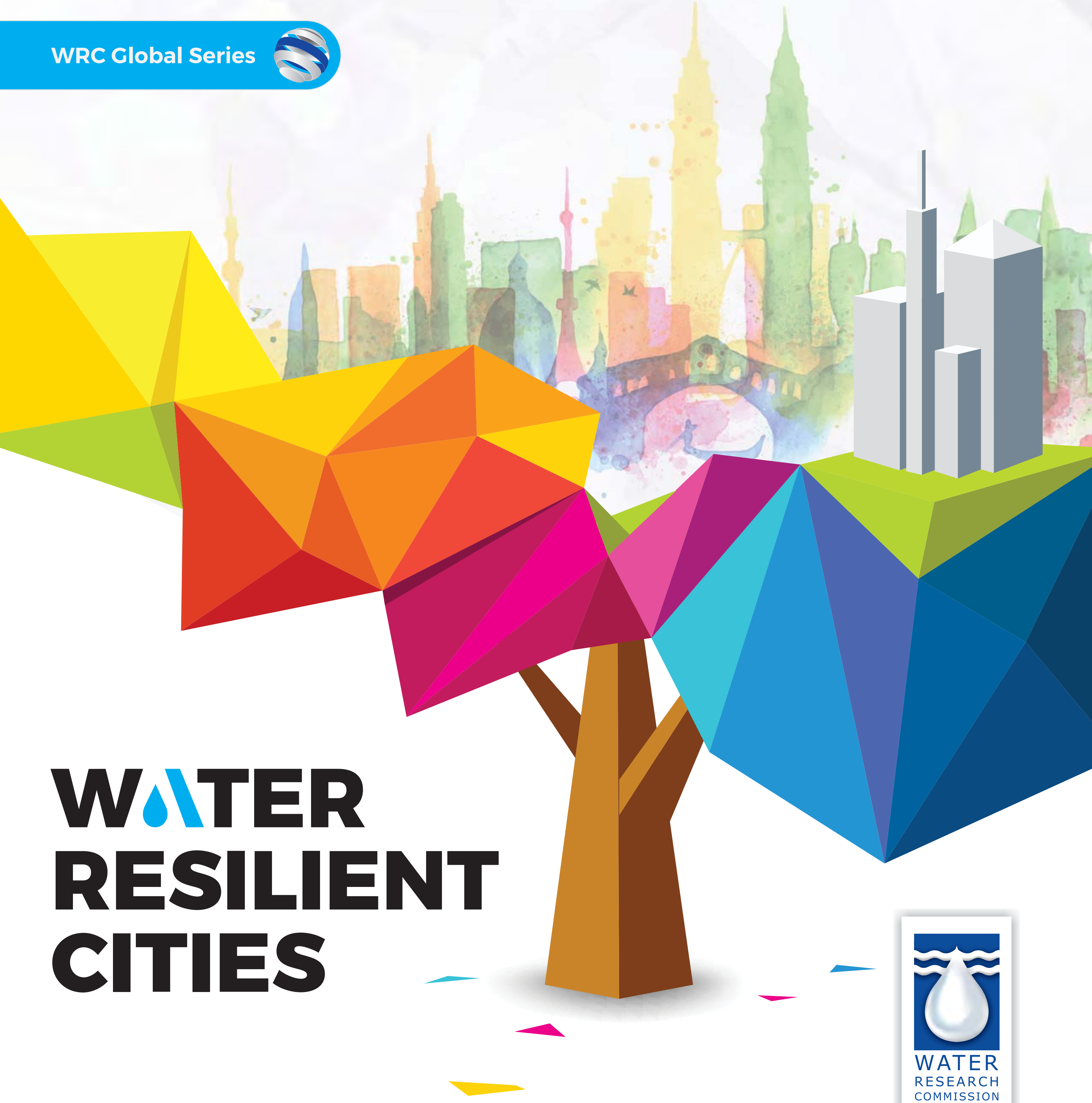

# WATER RESILIENT CITIES

WATER RESEARCH COMMISSION

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# FOREWORD

Throughout the ages the world's cities have been viewed as beacons of civilisation.

Half of humanity now lives in cities, making them important areas of service delivery. In addition, the world is urbanising at an unprecedented rate. By 2030, it is estimated that 5 billion people (about 70% of the Earth's population) will be living in urban areas. Urban growth is most rapid in the developing world, where cities gain an average 5 million residents every month. In Africa and Asia, the urban population is set to double in number by 2030 (as compared to 2000).

Mega cities (those cities with 10 or more million inhabitants) are increasing as a result of economic development and increased populations. Already these cities are home to 9% of the world's urban population. The number of megacities in the world is expected to increase from the current 28 up to 40 or more in the coming decade.

This exploding urban population growth is creating unprecedented challenges, among which provision for water and sanitation have been the most pressing and painful when lacking. Water systems are the lifeblood of cities, but they are increasingly coming under strain.

The United Nations reports that between 1998 and 2008, 1 052 million urban dwellers gained access to improved drinking water and 813 million to improved sanitation. However, the urban population in that period grew by 1 089 million people and thus undermined the progress. Today, one in four large cities are already facing water stress, and demand for water is only projected to increase.

City infrastructure has often not kept pace with the massive urban growth, leaving many people – especially those in informal settlements – without adequate access to services. Climatic pressures brought on by climate change also leave urban citizens vulnerable to droughts and floods.

The traditional response of governments was to expand existing water infrastructure. However, in an increasing number of cases, all nearby water resources have already been developed, leaving government officials with no option but to look further afield.

The quest for renewal and expansion of city water infrastructure offers various opportunities to revolutionise how urban water systems are designed and how they can deliver greater benefits to all. Resilience is what helps cities adapt and transform in the face of these challenges, helping them to prepare for both the expected and unexpected.

According to 100 Resilient Cities, urban resilience is defined as "the capacity of individuals, communities, institutions, businesses and systems within a city to survive, adapt and grow no matter what kinds of chronic stresses and acute shocks they experience."

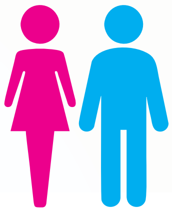
Building urban resilience requires looking at a city holistically: understanding the systems that make up the city and interdependencies and risks they may face. By strengthening the underlying fabric of a city and better understanding the potential shocks and stresses it may face, a city can improve its development trajectory and the well-being of its citizens.

*Water Resilient Cities* takes a peek at cities around the world, including South Africa, and the steps they have already taken to become more water resilient in the face of existing climate and population challenges. From water conservation and water demand management to sustainable stormwater and groundwater management, cities are exploring various alternative ways to ensure their water sustainability going into the future.

It is hope that his publication will serve as an example and an inspiration to others in pursuit of a better life for all.

**Every second, the urban population grows by**

# 2 people



# CHAPTER 01

# ONCE UPON A TIME, A CITY CAME TO BE

*There was once a place of astounding beauty, where the earth was spoiled with natural wealth in lavish abandon. The rich, black soil teemed with life; full of bacteria, fungi, mites and earthworms that toiled away, creating fertile grounds that supported sweeping plains. The landscape was strewn thick with a profuse variety of grasses and shrubs, scattered with leafy trees that playfully cast mottled shadows against a golden sun. When it rained, water dripped from the branches and leaves to the waiting earth below, meandering its way to ancient caverns and lakes that lay unseen beneath the surface.*

Above ground, the land sparkled with water. A lazy river meandered through; tinted the colour of strong tea by the ample nutrients it picked up along on its way to the meet the sea. The river's water was full of fish, and along its shores tiny insects and boisterous amphibians flourished. Overhead, birds swooped low over the water, and their chatter and song cut through the crisp air from before dawn.

People came to settle there. They grew their crops along the waterway, and let their animals roam to feed on the ample supply of food, available throughout the year. They caught fish from the river to eat, and lingered for long afternoons along its banks, cooled by the herb scented breeze. When the wind died down and days grew hot, the changing of the season was marked by the splashing and yelps of children in the water. They built their homes in the shade of the trees and planted gardens to enjoy the beauty that nature offered, on their doorsteps.

More people came. They built a school, and opened shops, inviting their neighbours from afar to trade. They laid down roads to help them get there, and many decided to stay.

The community grew as more people journeyed there to enjoy the abundance that the earth offered. They settled on the edges of the village, increasingly further away from the river until, with time, they stopped going there for water. Instead, they brought the river to them, channeling the water towards their homes and gardens so that they could still enjoy its benefits. They named the numerous streets they built, and used these to cover the systems they needed to take their dirty water away again.

Time passed, and more change came. The place was not a village anymore, but a town and later, a city. The river was still there but long forgotten. Its water was still coloured brown, but from dirt and waste emanating from the murky metropolis that now loomed from its banks into the horizon. Yet, as it has for centuries, the river dutifully chugged its load across the land towards its meeting place with the sea. As it went, it drew a blanket of poison and dirt along its banks, silencing the sprightly community of insects and amphibians in its wake.

Where the fields once were, there was now a checkered grey expanse made up of streets, pavements and houses. The trees were gone, and the soil covered. Where water once dripped from the sky, meeting the leaves to be passed to the ground below, it now fell straight onto bricks and cement, unable to penetrate the soil, but instead swiftly washed away to meet the gloomy river in the distance, gathering litter and waste on its way. Under the grey roads other things now teemed in the sterile soil – more tunnels to bring in more water from places further away.

People still continued to live in the city. They had jobs and worked in industries and factories. Their children played inside, never feeling the prickle of grass under their bare feet. Few had swum in a river, and none would eat fish from the dirty waterway anymore. The frogs have gone quiet, and no birds swooped overhead to announce the dawn of a new day. Instead, the dim air was permeated with dust and smelt of smoke.

Without noticing exactly when, or how, life became tough for the people that called the city home.

Towards the edges of the sprawling urban expanse, a woman woke. The sun had not yet broken through the grey sky, but she had to get up. Already, the queue outside would be meandering for many metres down the road towards the tap. Like everybody else, she had to get in line for her bucket of water too. She knew she had to get there fast, because they waited longer for the dribbling tap to fill the buckets every day. She still had to wash, make breakfast and perhaps a cup of tea before throwing the remaining water in the toilet to flush; rush to work, and get her child to school.

The past weeks, the time spent waiting for her turn at the tap had been tense. Rumours that the water would not last much longer were rife, but she still had hope that one day things could be different. She had to, because she did not know where she would go if the water ran out, she thought on her way outside. But on that day, things were different. The queue had collapsed into a frenzy of desperate people. She knew, as she turned around with her bucket empty, that the tap had run dry.

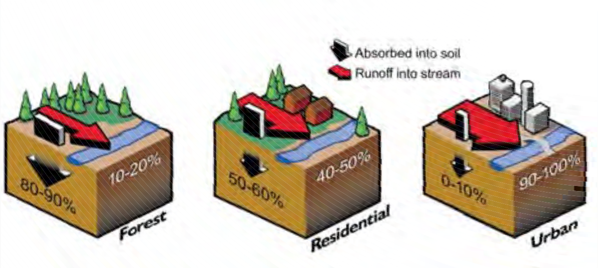
This scenario in its entirety might be fictional, but some aspects are already taking place in different places across the world. It's not impossible that it could become a reality one day. The purpose of the story is, however, to depict one of the major issues experienced on the planet today, and how we got there – that of water scarcity, especially in our urban areas. There are many factors that contribute to this, but the problem is exacerbated by the ways that our homes and neighbourhoods developed and our cities were designed. Unbeknown to us, we set ourselves up for disaster.

*Petro Kotzé*

# CHAPTER 02

# HOW WE BUILT OUR CITIES

*The management of water in our cities is traditionally an engineering concern. The first aim of water infrastructure is to guarantee that people have enough clean water available for everyday use. Sewerage systems are also built to ensure settlements are hygienic, allowing people to live in surroundings that keep them healthy. Drains are dug to swiftly transport rain away from the city before it can cascade down the streets and create floods, which happens because of the increase in hard surfaces, such as roads and sidewalks, preventing the water from infiltrating the ground.*




*Hydrology vs development: As development and impermeable surfaces increase, so does the amount of runoff.*

For all of these purposes, water has to be located, treated, transported, distributed, collected, treated again and disposed of. Water is often pumped to cities from great distances through intricate treatment processes, while stormwater and wastewater are swiftly guided out again into waterways. Most people that live in cities are unaware of the elaborate journey that water undergoes to get to them, and to be taken away again. A common assumption when living in a serviced city is that there will be water when the tap is opened and when the toilet is flushed. Another assumption is that the water will disappear again down the drain once dirty. Where it comes from, or goes, are questions that are rarely asked.

In general, there are common features to the establishments that deliver these services. They are often government owned and depend on large, centralised infrastructure. Water supply, sewerage and stormwater services are generally provided and managed independently from each other, through unconnected infrastructure. Decisions on how the water should be supplied to a community are made by the management authority, generally without consultation with the people or businesses on the receiving end. Because water users are mostly unaware of the complexities involved in the process of getting the water to their taps, they often view water as an unlimited resource, assumed to always be available in ample supply, whenever necessary.

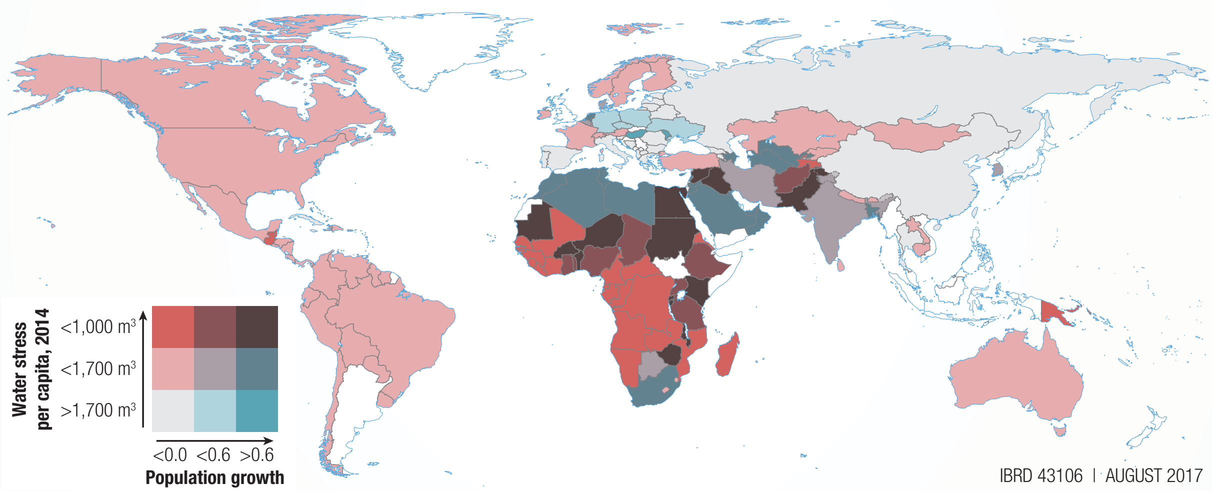
Though these engineering feats are doubtlessly impressive, some cracks are starting to show in our well-laid plans for the development of urban areas.

## OLD PRACTICES PAVE THE WAY FOR NEW PROBLEMS

There are an increasing number of reports from across the world where the supply of water in this traditional manner is becoming increasingly challenging. Renowned destinations are ever more being mentioned in the same breath as water scarcity and water crisis; a tide that is gaining momentum as the global population expands and more people move to urban areas, leading to more demand for water, while polluting more of it at the same time. International media have listed Tokyo (Japan), Bangalore (India), Beijing (China), Cairo (Egypt), Jakarta (Indonesia), Moscow (Russia), Istanbul (Turkey), Mexico City (Mexico), London (United Kingdom) and Miami (United States) as some of the large cities that will face extreme water shortfalls in future. This is but one indication that our customary management of water in urban areas cannot be maintained.

World Bank

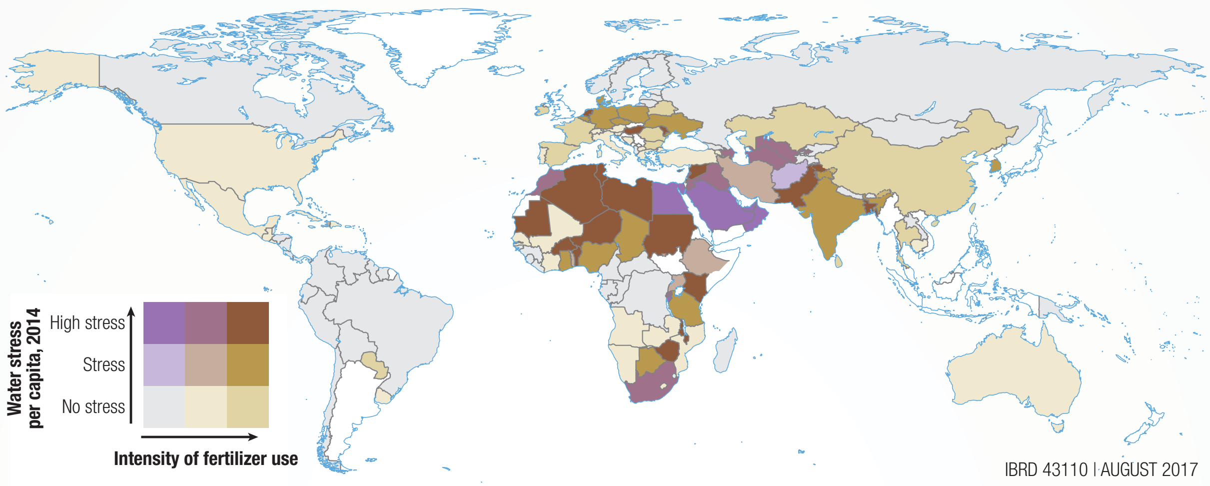
**MAP 1.1** **Per Capita Water Availability and Future Population Growth, 2050**




*Sources:* Freshwater availability data: FAO AQUASTAT database. Population growth estimates: United Nations Population Division, World Population Prospects, 2015 revision (moderate scenario), for the year 2050.
*Note:* Map 1.1 shows the intersection of water stress, measured as per capita water availability, and population growth. Data on water availability are missing for countries in white.

The answer to where our water will come from in future is complicated by rampant pollution of water sources – leaving water providers to work with both decreasing water quantity and quality to satisfy increasingly thirsty cities; to keep the people healthy; and to maintain economic development.

## MAP 1.2 Water Scarcity and Water Pollution, 2014–15




*Sources:* Freshwater availability data are from FAO's AQUASTAT database. Water pollution data were calculated by the International Food Policy Research Institute (IFPRI) using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model and national statistics on livestock and crop areas; these inputs are fed into a hydrological model to estimate nitrogen and phosphorus loading densities.
*Note:* Map 1.2 shows the intersection of renewable freshwater availability per capita and water pollution due to fertilizer use. Data on water stress are missing for countries in white.

Increasingly, water providers have to search for water further away from where the water is required. Today, importing water from outside the city's catchment area is commonplace. Where settlements used to get water from locally accessible rivers, fed by rain that fell in their catchment, development has often resulted in water being pumped instead from further away, while rainwater is being led underground to stormwater systems, out of the city. As cities are becoming disconnected from their local watersheds, dwindling water supplies can easily become a source of competition and conflict between different water users and management authorities.

This adds more layers of complexity to the provision of a basic need such as water. Additionally, more and larger infrastructure must be built to transport the water to where people want it, adding to the cost of providing water and maintaining the system. Concurrently, commonly experienced trials faced by water management utilities include crumbling infrastructure, and ever-emptying government, business and household coffers to foot the enormous bills to keep it functioning.

Furthermore, traditional methods of water provision rarely consider sustainability. While we are using more water, we are polluting the very systems that we rely on to provide us with this in the process; or, we are using it beyond the system's capacity to survive. International reports tell of strategic sources in many of the world's major water basins being depleted; groundwater resources being tapped empty and surface water supplies running dry.

In some developing countries, the water itself has come to represent social inequality. Poorer areas often suffer greater water stress and health risks in comparison to affluent neighbours. When water shortages hit, this situation is ripe for the birth of perceptions that governments have failed the people, and do not care for their plight, leading to even deeper resentment, tension and mistrust.

These issues already paint a bleak picture, but the situation is set to become worse in future.

## A FUTURE CERTAIN TO BRING MORE UNCERTAINTY

Petro Kotzé

*In some developing countries, the water itself has come to represent social inequality.*

Petro Kotzé

*Where settlements used to get water from locally accessible rivers, fed by rain that fell in their catchment, development has often resulted in water rather being pumped from further away.*

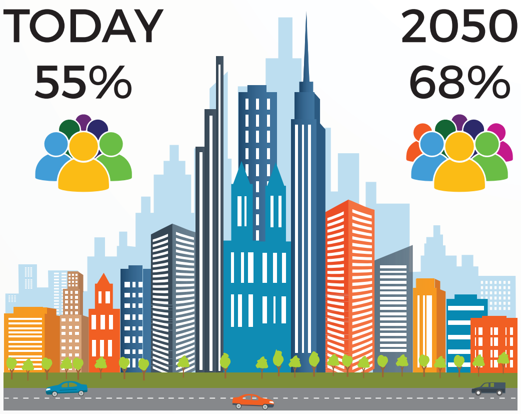
Petro Kotzé

*The increase of grey surfaces, such as roads and sidewalks, prevent the water from infiltrating into the ground.*

Petro Kotzé

*The world's population is increasing, and the brunt of this growth is felt in cities.*

A number of emerging threats will aggravate the problems inherent to the design of our water supply systems. For one, the world's population is increasing, and the brunt of this growth is felt in cities. More than half of us (55%) already choose to live in these cities, and by 2050, 68% of us will choose to make our homes in urban areas.




*Today 55% of people live in cities. In 2050 68% of people will live in cities.*

Translated into numbers, the amount of people on the move towards cities are staggering. According to the United Nations' (UN's) ***World Urbanization Prospects Report for 2018***, the rapid increase in the urban population entails a growth of 751 million people in 1950, to 4.2 billion in 2018. Projections add 2.5 billion people more to the planet's urban population by 2050. Almost 90% of this growth is taking place in Asia and Africa.

This increase in people and their movement towards urban areas, is taking place hand in hand with a reduction in availability of the most integral resource to keep people and the environment functioning – we are running out of easily available water of a suitable quality. The number of urban dwellers living with seasonable water shortages is expected to grow from close to 500 million people in 2000 to 1.9 billion in 2050.

We are thus approaching a future of unreliable water security with levels of water consumption already surpassing what is available in places. Yet, there is still another factor to keep in mind – the climate that we live in is also changing, adding more unpredictability to existing water insecurity. Forecasts paint a picture of worsening droughts and more severe floods becoming more common, as will extreme temperatures. This new climate reality is already taking its toll on many urban centers in the form of the unpredictable availability of water.

For example, in Australia the 2001 to 2009 Millennium drought devastated industries, the environment and communities, striking right in the populous southeast heartland of the country, home to Sydney, Melbourne, Brisbane and Adelaide. Cape Town made international headlines in 2018 when officials announced that they were running out of water, a situation fueled by an unprecedented three-year drought. The next year, cyclone Idai unleashed hurricane-force winds and heavy rains that flooded much of the centre of Mozambique, and battered eastern Zimbabwe and Malawi.

**The challenges of the future**

According to the World Bank, the five emerging challenges that increasingly affect many cities around the world, are among the most threatening events to water supply security:

- Sharp increases in urban water demand
- Depletion and deterioration of availability and quality of resources
- Climate change
- Changing priorities in historical sources
- Competition with other users

## TO CHANGE THE FUTURE, WE MUST CHANGE HOW WE THINK

The scenario is set for an uncertain and challenging future. To not just face it, but to try and prosper in it, we need to think differently about how we supply water to people. Increasingly, it is being recognized that our entire thinking behind the development of urban areas must change in order for people to flourish in a changing environment, and for the environment itself to be sustained. Instead of being pushed out of view, calls are being made for water, our most vital resource, to be returned to its rightful place at the epicenter of development plans for urban areas, and to be used as the catalyst to ensure a livable environment for residents.

This thinking is not entirely new, and though many challenges still remain to achieve this vision, consensus is growing internationally, and locally, that our urban areas must develop towards a new goal – that of a water resilient and livable city.

*Sources:*
*Water Scarce Cities: Thriving in a Finite World—Full Report. World Bank, 2018, Washington, DC.*
*Water Utilities of the Future – Australia's experience in starting the transition. CRC for Water Sensitive Cities, 2018*

# CHAPTER 03

# A VISION FOR A CITY WITH WATER AT ITS HEART

*Part of the problem with the design of our urban areas is that we have built ourselves closer to everyday necessities such as transport, but detached ourselves from water in the process. It's not uncommon for cities that suffer from water scarcity on the one hand, to also suffer from floods on the other. Residents that live in urban areas with water restrictions in place, might see rain fall outside their windows, but not see the benefits when they open their taps. Often, people in cities are surrounded by water, but not able to use it.*

Many cities are permeated by water in the form of underground pipes, but the quality of the water is not good enough for the purpose of the specific system that the water is in, and is thus channeled out of the city again; a lost opportunity washed away to the sea or a waiting waterway. In the process, the very environment that we depend on to provide us with clean water is polluted, resulting in even less water available to us to use, and for the system to remain functioning.

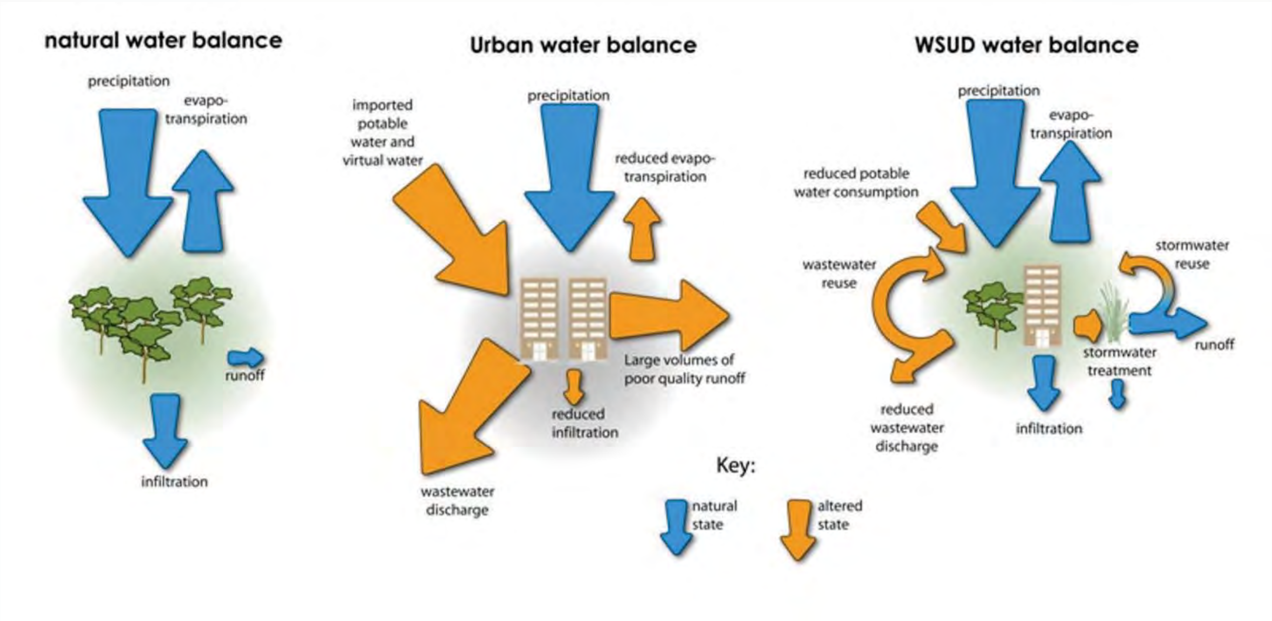
## RETHINKING HOW OUR CITIES ARE DESIGNED

*Petro Kotzé*

*What does a place look like where people want to live and work? Creating this space is the vision of a water sensitive city.*

Thinking around how we should develop our cities to be more sustainable started to take new shape in the early nineties in Australia. Urban drainage professionals there wanted to manage water differently, to take water both above and below ground in mind, while maintaining and even improving water quality, conserving water, and keep water-related environmental and recreational opportunities intact.

They called this new approach water sensitive urban design (WSUD). Though the concept initially focused on sustainable drainage of stormwater, it was fleshed out in the following years, developing into a vision for cities that considers the entire urban water cycle as a system, including stormwater, greywater and wastewater. From this new perspective, managers suddenly had more water resources to choose from, over and above the conventional options from over-burdened rivers, dams and groundwater. In this scenario, taps can run from a variety of water sources, including waste and greywater, groundwater, stormwater, desalinated seawater and even treated sewage effluent. Within this system, water can be recycled and reused for various purposes, depending on the quality of water (fit-for-purpose water).




*The influence of water sensitive design on the water cycle.*

The concept can be applied from household to catchment scale. In homes, there are opportunities for rainwater harvesting and greywater recycling. Neighbourhoods can be designed to use local surface or groundwater and to recycle water through the use of nature-based systems (see insert, *Back to our roots for solutions from nature*). At a city scale, roads and other infrastructure can be manipulated to become water catchments, for example.

WSUD thus addresses water security, but also goes further to consider the impact of achieving this security on the surrounding environment. This concept recognises that urban development takes place hand-in-hand with the development of the watershed that it is located in. Changes upstream in the catchment, such as a new mine or deforestation, might alter the water quantity and quality available to the city. At the same time, the quantity and quality of the water that is discharged from the city into the system will have an impact on users downstream. Urban development should thus be looked at as part of the developments that take place at catchment scale.

Though it started elsewhere, WSUD is already well-known in South Africa. It's not always recognised as such, but it is being applied at different scales throughout the country. Our long-standing record of the removal of alien vegetation in catchment areas by the Working for Water programme, is one example.

According to Jason Mingo, Western Cape government project manager, WSUD largely relates to water security, including both sufficient available water, and water that is of a suitable quality for economic growth and development. However, the concept goes even further, beyond these fundamentals, he says. Questions such as how you better connect communities within cities to water, and to connect the city itself better, should be asked (see block, ***Living with Water Sensitive Urban Design***).

**Living with water sensitive urban design**

According to the Cooperative Research Centre for Water Sensitive Cities (CRCWSC), WSUD allows residents to interact with the urban water cycle in ways that:

- provide the water security essential for economic prosperity through efficient use of diverse available resources;
- enhance and protect the health of waterways and wetlands, the river basins that surround them, and the coast and bays;
- mitigate flood risk and damage; and
- create public spaces that collect, clean, and recycle water.

Mingo points out that spaces should be multi-functional – to increase infiltration, mitigate floods and be productive spaces at the same time. The city itself must improve the living conditions of the people that call it home. Then, you have to ask how this multi-functionality can be improved while restoring the natural hydrological cycle. If WSUD is applied, it leads to the creation of what is known as a water resilient city. Depending on where you are on the globe, this development can also be referred to as low impact development (in the United States of America), leading edge technologies (China), cities of the future, resilient cities, livable cities and sponge cities (see block, ***China's sponge cities***). However, all of these refer to the vision of city that is at once resilient, livable, productive, and sustainable.

**China's sponge cities**

It's not hard to imagine the Earth's surface as a sponge, absorbing water into the soil, grasses and leaves; some of it channeled through the surface to rest underground in aquifers, and some being taken into the atmosphere again via evapotranspiration. Woodlands, grasslands, lakes and wetlands all detain water for the benefit of the system, and to prevent it from collecting, and rushing over the surface to form a flood.

When we build cities and cover the ground with solid surfaces such as cement and tar, the capacity of the Earth to manage water in this way is diminished, leading to many problems. China is one example of a country where much of this is happening, and increasingly so over the last decades of rapid industrialisation and urbanisation. Some of the problems include floods, as well as severe water shortages in cities, serious pollution of waterbodies, ever decreasing wetlands, over-exploited rivers and erosion.

In order to tackle these problems, the Chinese government is implementing innovative plans, inspired by the Earth's capacity to absorb water. The concept of "Sponge Cities" was put forward in 2013, with the objective of the bulk of rainwater in cities to be absorbed and reused. This will be done by developing and building infrastructure that improves water permeation, water detention, water storage, water purification, water drainage, water saving and reuse in cities. Excess rainfall is collected, and flood control integrated into urban planning.

To initiate this process, sixteen pilot cities have been approved across China. In one pilot city, Lingang, in Shanghai's Pudong district, infrastructure being built include rooftops gardens, wetlands that also create beautiful spaces for people while storing rainwater, and permeable pavements to store excess runoff water and allow evaporation for temperature moderation.

From 2015, all planned urban districts, industrial parks, development zones and new communities were to be designed and built according to these new standards. Renovation work in older residential areas should include similar initiatives to address floods, pollution and motivate for the collection and reuse of rainwater. This approach calls for the integration of construction and renovation work across towns and cities.

As with nature-based solution elsewhere, the Chinese Sponge Cities initiative is not without challenges. Some that have been reported on include a lack of expertise at local government level to coordinate and integrate such a complex set of activities, and financial constraints. Weak regulations and selective enforcement of the rules are further hampering efforts.

*Sources:*

- *Factsheet Sponge City Construction in China, by the Kingdom of the Netherlands*
- *www.theconversation.com, China's 'sponge cities' aim to re-use 70% of rainwater – here's how, published on September 5, 2017*

## A VISION FOR A CITY OF THE FUTURE

Both WSUD and water resilient cities represent significant shifts away from the traditional planning and design of urban areas to settlements in which water is integral to almost every feature of an urban landscape (see insert, ***Water scarcity prompts water self-sustainability in Singapore***).

"It's a different way of living," says Kirsty Carden, coordinator for the Future Water Institute at the University of Cape Town. "It's about how you can modify your environment so that you are still living the way that you want, even when you are faced with severe restrictions. It's about knowing that you can do, with much less."

*"There is a lot that a water management utility can do in the interim to start delivering benefits to the communities they serve, and build momentum for a more systematic change. It does not have to be a complete overhaul," says Kirsty Carden coordinator for the Future Water Institute at the City of Cape Town.*

According to the CRCWSC, a vision for a water sensitive city of the future is, simply put, a place where people want to live and work. The place or city itself can be a water supply catchment, and provide a range of different water sources at different scales, for many different uses. Such a living environment provides a healthy natural setting, and offers a range of social, ecological, and economic benefits. The people that live there have the knowledge and desire to make wise choices about water, are actively engaged in decision-making, and demonstrate positive behaviours such as conserving water at home and not dirtying water unnecessarily.

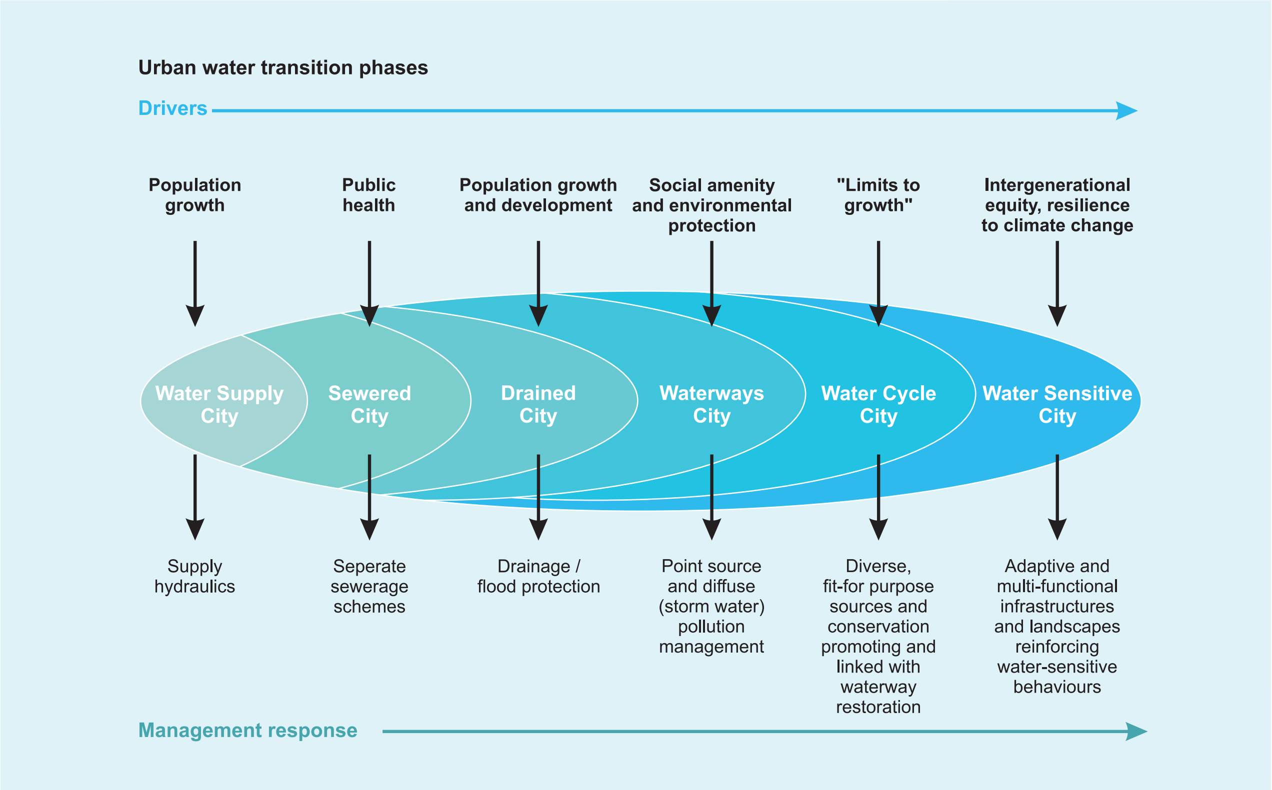
This vision cannot be achieved overnight. It is an objective that is worked towards over time, achieved in stages and through sustained efforts to change the very thought process behind how an urban area should continue to develop and grow into the future.

## HOW CITIES CAN EVOLVE TOWARDS WATERWISE DEVELOPMENTS

"Though WSUD came out of stormwater management, the idea has developed into one where the urban area moves through different states, to one where water is integral to its design; where water is top of mind," says Carden.

Commonly, the evolution of cities towards water resilient urban areas is presented as a continuum of six water management regimes.

The first three regimes represent the historical development of water utilities, each providing an increasingly wider range of services: a city that provides clean and sufficient water supplies; a sewered city that improves public health outcomes; and, a drained city that offers protection from flooding.




*Source: Brown et al. (2009) Urban Water Transition Phases.*

The next three regimes address issues such as environmental damage and threats to water supply security, and works with partners (including communities) to manage the entire water cycle.

One of the first changes to take place is that water managers start looking at where their water comes from (a waterway city). The health of their waterways and the environments through which they flow becomes a concern. Governance processes and regulations are put in place to manage the sources of pollution and to restore degraded rivers. Residents and other water users are engaged to identify their needs and preferences for services.

From here, utilities start to address concerns about water supply security (a water cycle city) and start identifying other water sources such as wastewater and stormwater. Those at the helm of water provision services start asking themselves how their work can add value to the communities that they serve, instead of just at what cost they can supply water.

Eventually, a water sensitive city can form. In this place, water is embedded as a critical element of city planning. Infrastructure is adaptive and multi-functional, communities partner with utilities to deliver services, and governance supports accountability and collaboration.

## A FRAMEWORK TO GUIDE THE TRANSITIONING

The realisation of such a vision is an immense job. Two international organisations at the forefront of providing guidance on how to get there are the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) established in July 2012, and the International Water Association (IWA). The CRCWSC is an Australian research centre that brings together many disciplines, world-renowned subject matter experts, and industry thought leaders who want to revolutionise urban water management in Australia and overseas.

The two institutions provide related pathways to water resilience. As example, the IWA provides 17 principles as a framework for cities to make this transition. The principles are structured along four increasing levels of action, and accompanied by five building blocks through which sustainable urban water can be delivered to a water wise community.

In this framework, sustainable urban water is defined as "all urban waters used and managed by water wise communities in cities connected to their basins, built in a way that is sensitive to water issues so that short-term risks are minimized, resources are preserved, and livability is increased through WSUD and regenerative water services for all."

The 17 principles, divided into four levels of action, are:

**First level of action: Regenerative water services**
1. Replenish waterbodies and their ecosystems
2. Reduce the amount of water and energy used
3. Reuse, recover, and recycle
4. Use a systemic approach integrated with other services
5. Increase the modularity of systems and ensure multiple options

**Second level of action: Water Sensitive Urban Design**
6. Enable regenerative water services
7. Design urban spaces to reduce flood risks
8. Enhance liveability with visible water
9. Modify and adapt urban materials to minimise environmental impact

**Third level of action: Basin connected cities**
10. Plan to secure water resources and mitigate drought
11. Protect the quality of water resources
12. Prepare for extreme events

**Fourth level of action: Water wise communities**
13. Empowered citizens
14. Professionals aware of water co-benefits
15. Transdisciplinary planning teams
16. Policy makers enabling water-wise action
17. Leaders that engage and engender trust

A successful strategy thus builds water-wise citizens, decision-makers, and professionals. It's not just about technology, but about people working towards a shared objective. The way the buildings and neighbourhoods are designed should be revisited, in order for consumption to be minimised, while maintaining high liveability. Improvements or modifications to water services should be implemented. For example, water loss must be reduced and water reused for different purposes.

## A VISION WITH CHALLENGES TO OVERCOME

Still, cities and other urban areas are complex, and so are the expectations of the rich variety of people that live there regarding what exactly 'livability' means. For some, it can include simply accessing safe drinking water and ablution facilities, but ideas about water security, effective transport systems, personal safety, recreational opportunities and community spirit all come to play, and this is only naming a few examples. Then, the importance of different aspects may carry more or less weight for different communities living in the same city.

**Characteristics of water management utilities that are starting to change**

Research in Australia has shown that utilities that are starting to make the change towards more water resilient developments display the following traits:

- **They change their internal operations and culture** to improve core service delivery, adopt new business models, show leadership and advocacy relating to new technologies and approaches, and increase the quality and depth of their community engagement
- **They partner with other organisations** in new ways to pool resources and experience, better manage risk, build capability and drive innovation. Partners can include water and non-water utilities such as energy providers, community organisations, local governments and private businesses.
- **They influence their authorising environment;** the legislation, regulations, policies and institutional settings that empower or constrain actions in order to foster innovation and empower action.

Tackling a paradigm shift such as this involves cost and risk. Unrelenting effort is required to maintain external partnerships. Furthermore, changing regulations and policies are significant undertakings, which require sustained commitment, even though the outcome cannot always be guaranteed to be positive. Facilitating these changes will take time, but the time to start is now (see block, ***Characteristics of water management utilities that are starting to change***).

There is a lot that a water management utility can do in the interim to start delivering benefits to the communities they serve, and build momentum for a more systematic change. It does not have to be a complete overhaul. "Incremental changes can make a difference," says Carden. Many cities have started to make this transition, as the examples and case studies in this publication aim to show.

Though this book is not an exhaustive study of the concept of water wise cities and its application, it aims to present some of the steps that are already being taken internationally and in South Africa to embrace a future in which we can be more assured of sufficient water. Another aim is to raise awareness of the need for new thinking around how we design the areas where we live to the benefit of ourselves, and our planet. The publication serves to show that some changes are a possibility, here and now.

Creating awareness of these concepts is particularly important in South Africa. The potential to apply these ideas in our country is vast, and the baseline has already been set by select water management authorities, municipal and other government departments, research organisations and South African residents throughout the country. Many would even say that it's key to the question of how we will solve our water scarcity problems, while creating countless, diverse benefits that will ripple out far beyond the scope of water provision alone.

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## BACK TO OUR ROOTS FOR SOLUTIONS FROM NATURE

*Petro Kotzé*

*Developing towards a water resilient city means that living conditions of the people that call the city home must be improved.*

Plants and natural systems are hard-working elements that keep the earth functioning. They purify air, absorb water, keep mountain slopes from crumbling apart and create the ideal habitats for other life forms, to name a few benefits. Increasingly, engineers are looking towards them for inspiration to solve problems associated with human developments, working with nature and using its strengths to their benefit, instead of trying to tame it. Following this approach, the purpose that the infrastructure is meant for can be achieved but, over and above that, social, environmental and economic benefits will be part of the results. If we work with nature when building infrastructure, instead of against it, we are also creating structures with the inherent capacity to respond better to natural processes such as climate change.

According to the ***UN World Water Report – Nature based solutions for water***, "nature-based solutions (NBS) are inspired and supported by nature and use, or mimic, natural processes to contribute to the improved management of water." These solutions can entail the conservation or rehabilitation of natural ecosystems or mimicking or enhancing natural processes in modified and artificial ecosystems. Interventions can be big or small; from the construction of a dry toilet, to the rehabilitation of a wetland or even bigger, such as catchment scale attempts to re-plant forests. Far reaching benefits are being achieved with just such a project in Durban, for example, where the Sihlanzimvelo Project is reinstalling the power of nature to the benefit of the municipality and its residents (see insert, ***Durban project to keep rivers and streams clean shown to have far-reaching benefits).***

Many terms are associated with NBS. Bioengineering, for example, is often used to describe the use of vegetation in engineering design to protect natural terrain and man-made structures from the problems associated with land degradation. Green infrastructure is another common term, but also describes the use of natural or semi-natural building material such as plants and trees. Biomimicry, again, refers to the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems.

### BENEFITS OF NATURE-BASED SOLUTIONS

Through green infrastructure cannot always take the place of conventional or grey infrastructure, there are many benefits to its use in comparison. In some places, there is simply no space left for large, built infrastructure, or to move the heavy equipment around necessary to construct it. Other places might be remote, so maintenance of crumbling grey infrastructure is a problem, while green infrastructure can grow stronger with time. Mostly, the two are most efficient when combined.

A key feature of NBS is that it delivers many added water-related benefits and often help to address water quantity, quality and risks simultaneously. Incorporating natural elements into a system can lead to a reduction of water pollution and floods, while water can be stored in underground systems (aquifers) to lighten the impact of drought. This has been successfully practiced for years at both Windhoek in Namibia and Atlantis in South Africa. As such, the resilience of the system overall is improved.

For developing countries, these options are particularly attractive, as the benefits can often be gained at a cheaper cost than with grey infrastructure options, are sustainable over the long-term and can be applied at different scales. Pioneering work has already been done to integrate plants and bioengineering into slope stabilisation efforts in the mountains and forests of Europe, North America, and South Asia, as well as on roads in Nepal's steep Himalayan Mountains. The practice is also widely applied to stabilise riverbanks, and has become standard practice in many road, river, and forest management departments worldwide. However, nature-based options are also very effective for urban developments.

## WHY NATURE SHOULD BE BROUGHT BACK TO CITIES

Though construction for the development of urban areas is not usually associated with green and natural systems, such solutions are of great importance to cities, especially when one of the development aims is to improve the quality of life for residents.

As in rural areas, problems of water quality, water availability and crises such as drought and floods in cities can also be tackled with green infrastructure, though often in combination with grey counterparts. In recognition of the benefits, examples are already prevalent in many cities across the globe, with large scale application of green roofs and buildings, for example, becoming more common (see insert, ***How green roofs allow Toronto to build a sustainable city while saving money).***

These plans mostly address multiple concerns. Green walls, roof gardens and vegetated infiltration or drainage basins support wastewater treatment and reduce stormwater runoff and flooding. Wetlands within urban environments lessen the impact of polluted stormwater runoff and wastewater, and immobilise pollutants, often performing better than conventional grey solutions. By improving water storage capacity in landscapes, including in soils and groundwater, the impact of drought can be cushioned and the impact of seasonal variability of water availability, lessened.

By improving water availability and quantity, natural systems can thus contribute greatly to improving the overall water security of an urban area.

## HURDLES TO NATURAL SOLUTIONS

Though natural solutions to many of the problems experienced in urban areas make sense, their application faces many hurdles. One is the overwhelming already-existing dominance of grey infrastructure, not only in terms of physical structures, but also representation in thinking and practices, policies, building codes and regulations. (see insert, ***Laying the building blocks for the use of green infrastructure in Vietnam).*** This dominance extends to civil engineering, market based economic instruments, the expertise of service providers, and consequently in the minds of policy makers and the general public.

This leads to NBS often being perceived as less efficient, or carrying more risk than built, or grey, systems. This lack of understanding is intensified by further lack of understanding of how to integrate green and grey infrastructure for managing water extremes, and an overall lack of capacity to do it. This lack of awareness, communication and knowledge extends across all levels; from communities to regional planners and national policy makers. Conversely, for natural systems to be used successfully, cooperation among multiple institutions and stakeholders are key, something that can be difficult to achieve.

*Sources:*

- *The United Nations World Water Development Report 2018 – Nature based solutions for Water*
- *Planning for Green Infrastructure: Options for South African Cities, by Juaneé Cilliers & Sarel Cilliers Unit for Environmental Sciences and Management North-West University, Potchefstroom (published by the South African Cities Network)*

## DURBAN PROJECT TO KEEP RIVERS AND STREAMS CLEAN SHOWN TO HAVE FAR-REACHING BENEFITS

"It used to be dirty, but they say that it has become a place to get to know neighbours and spend time together," says Geoff Tooley, Senior Manager for eThekwini Municipality Catchment Management. Initially, he says, this was not their main objective, but the communities have started to occupy and enjoy the space. Tooley is referring to results of the Sihlanzimvelo Project, a novel initiative taking place in Durban that is harvesting the power of natural infrastructure to solve numerous problems experienced by many municipalities.

It started with the cleaning of the rivers.

The eThekwini Metropolitan Municipal area is crisscrossed with approximately 7 400 km of streams and rivers, many carrying the consequences of rapid urban development with them. In 2009, the city announced that the majority of all watercourses in the municipal area were severely polluted, so much so that they were deemed unsafe for people. Rivers in the INK (Inanda, Ntuzuma and Kwamashu) and Umlazi areas, in particular, were badly affected. The rivers' water contained sewage, banks were dense with alien vegetation and culverts overflowed with litter.

The impacts were felt right from the river's edge to far beyond the city limits. Close to home, people were still intimately dependent on the rivers to water their food gardens. The litter caused blockages that led to floods. Riverbanks were eroding, reducing valuable small-scale agricultural land, washing silt down the waterways and endangering infrastructure. Some of these rivers flow to the sea close to some of Durban's busiest beaches, says Tooley, disposing filth on some of the area's prime tourist attractions.

A solution was essential but, when the municipality started a formal project to address the crisis in March 2011, the objectives were set to reach much broader goals than simply cleaning up the waterways. First, the project could cross municipal management sectors, combining the work usually conducted by at least eight different departments through the use of a single resource, says Tooley. Then, the problem could be used as an opportunity to create desperately-needed jobs and small businesses in the neediest communities, educating residents on the value of natural infrastructure in the process. Furthermore, in light of the threat of an increased frequency of flooding due to climate change, the project could contribute to the future resilience of the area, and work towards meeting the municipality's Climate Change Strategy goals.

## SETTING THE GROUNDWORK IN PLACE

"We started with the streams worst affected by pollution, waste and alien vegetation," says Tooley. Of these rivers, they selected those that flowed through the neediest communities. The city then collaborated with ward structures to facilitate the creation of co-operatives and gave them the opportunity to tender through an expression of interest for the work. In other words, the municipality were giving people tools to create small businesses in areas where the chances of employment were extremely poor. The co-ops were required to register as companies and to comply with all statutory labour requirements. Finally, 59 co-ops were employed, each consisting of seven to ten workers from local communities.

Members of the co-ops were then trained in necessary project-specific skills, such as alien vegetation control, occupational health and safety requirements and management of small enterprises, with ongoing support and mentorship provided by consultants who had to also employ and train assessors for the local community.

Tooley explains that each co-op was awarded 5 km of stream to clear and maintain, as well as a 3 m buffer on each side of the waterway. The work that had to be conducted is no mean feat. The co-op members remove alien vegetation and litter, debris and rubble from their allocated area. They keep culverts and stormwater systems clear, maintain minor erosion control along embankments, manage and maintain ditches to prevent water from stagnating and replant indigenous vegetation. This work is often done in remote areas, and co-ops have to deal with illegal dumping sites, sewerage systems that constantly get blocked and overflow into the rivers, and tenacious invasive vegetation that comes back time-and-again.

Regardless of these challenges 300 km of waterways have been transformed due to the work of the co-ops in this way, with benefits rippling far beyond the original scope that the municipality had in mind.

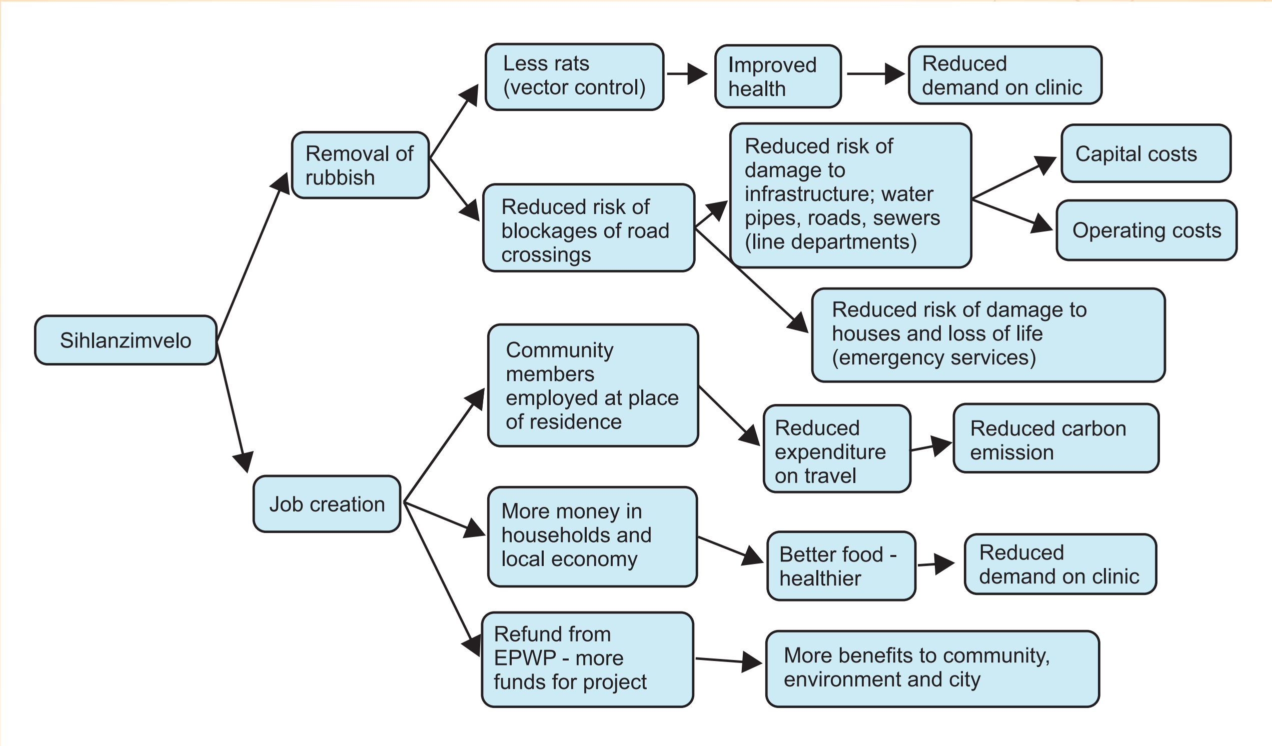
## BENEFITS OF THE PROJECT

The main goal of the project is the proactive management of watercourses in Durban. However, says Tooley, the knock-on benefits have proven to be vast, and include a broad range of social-economic and avoided cost benefits. The benefits of creating employment and businesses, removal of solid waste and alien vegetation have each led to a succession of benefits to the local residents, the broader community, the municipality and the environment (for example, see figure on the right).

The most tangible benefits are perhaps clearest close to the rivers. The presence of the teams on the riverbanks alone have led to the early and accurate reporting of sewage leaks, community awareness, reporting of wrongdoings and reduced criminal activities. This has led to faster and more efficient responses by operating teams, which translates to lower operating costs. Reduced crime has led to safer neighbourhoods, requiring less money to be spent on securing households, and making finances available for other opportunities.

Stable riverbanks and buffer zones and unclogged culvert crossings all lead to multiple benefits, which would otherwise inevitably have led to municipal spending that could have been of value elsewhere. For a developing economy, the economic impact is substantial.

People have also become empowered to engage actively with formal municipal processes, contributing to the improvement of society. Community members




*Benefits of the Sihlanzimvelo projects.*

better understand the value of natural infrastructure and the need to maintain it, which will eventually lead to a more resilient Durban.

Already heavily impacted by weather extremes such as floods and droughts, climate projections for the area that the eThekwini Metropolitan Municipality is located in, paints a more volatile picture for the future. This includes an increase in the severity and occurrence of extreme rainfall and storm events, sea level rise and increased storm surges, longer periods between rainfall with more intense and frequent droughts, more frequent and intense heat spells, more variability in the seasonality of rainfall and more violent storms.

The Sihlanzimvelo Project model has shown good potential to reduce the vulnerability of communities living along rivers in the municipality. Removing alien vegetation and solid waste decreases the risk of flooding that would have been caused by blockages and the likely destruction of infrastructure in the process. Healthy natural infrastructure provides a climate protection service that is expensive to come by with any other means.

## TAKING THE SUCCESSES FURTHER AFIELD

The long-term vision for the Sihlanzimvelo Project is to cover all the streams and rivers in the city with the same or similar model to work towards the ultimate goal of good quality water, a clean environment and a healthier more resilient city.

Over and above those already mentioned, it is foreseen that the rehabilitation of approximately 7 400 km of rivers and streams will have multiple and broad-ranging benefits. Reduced erosion will reduce the levels of sedimentation settling in the city's reservoirs and dams, prolonging their operational life. Sediment that enters Durban's harbour requires costly dredging, something that would decrease with healthier riparian zones. Whilst these benefits are undoubtedly imperative to pursue, says Tooley, the key focus of this project is still people and the environment. When the latter is improved, Durban's neediest residents will be more resilient in the face of an uncertain future, and they can face this future with the help of the services that the rivers they live next to can supply.

To do this, the municipality will need the help of other property owners. A large proportion of riverways fall outside of city-owned land, either on privately owned land or communal land holdings under the Ingonyama Trust. "The big goal is to cover every river in the city with some management model that will be a variant of what we're doing at the moment," says Tooley.

As a first step, the municipality has secured funding from the C40 Climate Finance Facility for a cost-benefit analysis. The C40 is a network of the world's megacities committed to addressing climate change. The aim of the analysis is to quantify the value of investments and the resulting benefits. By highlighting the financial benefits of the project, the hope is that more funds can be leveraged not only from city budgets, but also the private sector. With this information companies that extract water from the river can also eventually set up business plans that will allow them to access funding for similar projects.

There are more plans in the pipeline, such as the potential alternative uses for waste material in the form of recycling projects, biomass to gas projects and the possible conversion of alien vegetation to construction materials.

The impact of the project seems set to reverberate far into the future, not only for the communities that live next to the waterways, but the residents of Durban as a whole. As such, it is a tangible example of what can be gained when municipalities look towards nature to help solve typical man-made problems often experienced in urban areas.

And at times, it can start with something as simple as the cleaning of a river.

## HOW GREEN ROOFS ALLOW TORONTO TO BUILD A SUSTAINABLE CITY WHILE SAVING MONEY

Toronto, Canada's most populous metropolitan area, sits anchored on the northwestern shore of Lake Ontario. The city is incredibly diverse, with over 160 languages spoken among the roughly 2.7 million residents. Though it rests on a broad sloping plateau interspersed with rivers, ravines and urban forest, the skyline is marked by skyscrapers and high-rise buildings. Globally, the city is famed for being one of the most multicultural and cosmopolitan cities in the world, but it's also making waves for its innovative thinking behind how the city develops, in particular with the use of green roofs.

Toronto is the first City in North America to have a bylaw to that requires and governs the construction of green roofs on new developments. Since 2010, the roofs of new development or additions that are greater than 2 000 $m^2$ in floor area must include between 20% and 60% green roof space. Published with the bylaw, green roof construction standards and guidelines provide people with best practices, explanatory material and other resources. It provides information, for example, on the depth of growth media, and plants to choose from that are native or adaptive from the Southern Ontario area, appropriate for the local climate and building exposure, drought resistant to minimize the need for irrigation, and promotes for a variety of plant species to be cultivated.

Green roofs have many environmental benefits. They help to cool cities, and thus reduce the energy bills that would have been racked up to do this with electricity. By soaking up rainwater, they help to reduce flooding, as well as the pollutants and litter that would have entered the stormwater infrastructure with the water into the pipes. Plants improve air quality, the city is left looking more beautiful and with more biodiversity. Yet, one of the biggest motivations for Toronto's push for the implementation of green roofs was money.

The city's development of the 2006 Green Roof Strategy followed on results of a study that indicated that widespread implementation of green roofs in Toronto would provide significant economic benefits to the city. According to Shayna Stott, environmental planner at the City of Toronto, the study estimated benefits based on 4 984 ha of potential green roof implementation. Stormwater benefits amounted to an estimated infrastructure saving from $2.8 to $79 million.

A pollutant reduction benefit of $14 million could be achieved, and savings from erosion control measured $25 million. The total stormwater benefit was estimated to range from $41.8 to $118 million. Since the bylaw was passed, permits for approximately 420 green roofs for a total of approximately 400 000 $m^2$ of green roof area have been passed, says Stott. She adds that, after ten years of green roof installations, a triple bottom line analysis was to be done by end-2018 on costs and benefits of the green roof policy.

Except for the financial benefits and other mentioned above, Stott says that "green roofs are part of the toolkit required to make Toronto more resilient to the impacts of climate change, which will include hotter, wetter and more intense climate".

As such, green roofs are always factored into the required stormwater analysis for development applications to the city of Toronto. "They are a key strategy in meeting our requirements for water to be retained onsite," she says. While an analysis of the collective benefits of green roofs in the city is in the pipeline, the current benefits are already so clear that the programme is being expanded. "Because our requirements apply to new development only they are helping to mitigate impacts on those buildings but we still have stormwater issues related to the vast majority of buildings that existed prior to the requirement. We are in the process of increasing stormwater requirements and as such green roofs will play an even more important role in meeting the higher standards."

**What is a green roof?** According to the Toronto Green Roof Bylaw, a green roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. The bylaw defines a green roof as an extension of an above grade roof, built on top of a human-made structure, that allows vegetation to grow in a growing medium and which is designed, constructed and maintained in accordance with their approved standards. At a minimum, a roof should include a root repellent system, a drainage system, a filtering layer, a growing medium and plants, and should be installed on a waterproof membrane of an applicable roof.

**Types of green roofs:**
Green roof systems are generally classified as one of three systems, namely extensive, semi-intensive or intensive.

- **Extensive green roofs** have a shallow growing medium and generally use plant communities designed to tolerate the intense sun, wind and drought conditions of a roof environment. They are lighter, require less structural support and need less frequent maintenance. They cost less to build and maintain than intensive semi-intensive green roofs, and typical plants used are mosses and succulents.
- **Semi-intensive green roofs** need more maintenance than extensive green roofs, are more expensive and heavier. The growing medium is deeper, allowing for more landscape design options including grasses, herbaceous perennials and shrubs.
- **Intensive green roofs** have a deep growing medium, able to support a wide variety of landscape design elements and plant types such as perennials, bushes and trees. As such, it's more expensive to build and maintain than the first two options.

*Sources:*

- *Toronto City website (https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/green-roofs/biodiverse-green-roofs/)*
- *City of Toronto Guidelines for Biodiverse Green Roofs*
- *https://en.wikipedia.org*

# LAYING THE BUILDING BLOCKS FOR THE USE OF GREEN INFRASTRUCTURE IN VIETNAM

Petro Kotzé

The bioengineering pilot site at a roadside slope in Son La, Vietnam.

Petro Kotzé

The Son La riverside slope bioengineering pilot site after completion.

Petro Kotzé

Community members construct bioengineering interventions to protects a roadside slope from erosion in Thai Nguyen, Vietnam.

The Mekong region in Southeast Asia is an area of extreme natural events. Major floods, droughts and coastal storms affect the lives of millions of people here every year, but the impact is becoming more severe as the population grows and the landscape is developed, placing more roads and infrastructure in the path of destruction. Here, as elsewhere, climate change is also projected to increase the severity of extreme events across the region.

Roads and irrigation schemes in the mountainous region of northern Vietnam, in particular, are at risk of damage due to flash floods and landslides, and infrastructure laid to ruins due to slope collapse and erosion is already a common occurrence. The cost of maintenance and building new infrastructure is high, and is made more difficult because the areas are remote. Green infrastructure and bioengineering is seen to hold much potential to improve this situation, but it has seen little uptake in Vietnam. At the moment, most engineering techniques applied in this country rely on conventional grey infrastructure. Though these have the ability to withstand intense impacts, it comes at a high costs.

The uptake of bioengineering in Vietnam is hampered by an absence of centrally-approved standards for its application. Without these, engineers cannot legally incorporate such techniques into their design solutions. To initiate this process, a recent project constructed four demonstrate sites to promote bioengineering as effective measure to protect road and riverbank slopes. Bioengineering techniques included the use of local short grass, palisades, jute netting with grass seed and mulch, Vetiver grass lines, concrete blocks with grass and live fences, fascines, rock and bamboo lattices. Local vegetation such as golden dewdrop, blanket grass, tiger grass, and indigo berry were used.

Workshops and site visits throughout the process with relevant Vietnamese government officials and technicians aimed to introduce them to the concept of bioengineering, involve them in the site design and implementation process, and to show them first-hand how the methods are applied and work.

Many more benefits emerged from the project. Local community members were employed to build and maintain the sites, and could in future use the plants for fodder and wood. The techniques applied emerged to be cheaper than grey counterparts, and habitat for aquatic and other animals and birds were enlarged. After extreme events, the hope is that local residents could fix any damage themselves, saving time when integral assets like roads are lost.

**Six lessons from the project, *Promoting Climate Resilient Rural Infrastructure in Northern Vietnam*:**

1. **Include bioengineering at the earliest stages of project planning,** to avoid unnecessarily selecting more expensive conventional engineering measures and to maximize the overall benefits of the bioengineered design solution.
2. **High-risk locations should be identified as early as possible in project planning using proven vulnerability assessment and slope condition criteria.** Climate change is best considered at the pre-feasibility through to the concept design stage of planning.
3. **Apply geotechnical knowledge to identify and analyse specific slope problems using low-cost geotechnical investigation procedures.** Designing slope protection measures requires knowledge of parameters such as soil strength.
4. **Integrate grey and green measures to solve the problem.** Both bioengineering and conventional civil engineering systems are often required on the same site to provide the most cost-effective and durable solution to a slope erosion problem.
5. **Recognise the limitations of bioengineering.** Plants and landscaping cannot replace all of the functions of civil engineering systems, particularly when deep slope failures have occurred.
6. **Use local knowledge of plants,** to identify appropriate species, sources, replication methods and planting seasons.

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- *www.icem.com.au*

## WATER SCARCITY PROMPTS WATER SELF-SUSTAINABILITY IN SINGAPORE

PUB, Singapore's National Water Agency

*ABC Waters project at Kallang River- Bishan Ang Mo Kio Park in central Singapore, one of PUB's iconic ABC Waters projects where a concrete canal was transformed into a lush meandering river.*

Imagine standing at the edge of a lake dotted with a rich variety of birds, which swoop over the tranquil surface from the dense vegetation along the water's edge. It's weekend, and you are enjoying a lazy afternoon with your family walking along the paved way that runs like a neat pencil-line along the greenery. Now imagine that the lake is actually part of a water treatment operation. Tough to believe? In Singapore, this is no fantasy.

One of the most important steps towards the development of a water resilient and livable city is new thinking to solve old problems, and there are perhaps few other cities that have applied this better than Singapore.


*Marina Reservoir is Singapore's 15th reservoir and the first in the heart of the city. With a catchment area of 10 000 hectares, Marina catchment is the island's largest and most urbanised catchment.*

The city-state is at the leading edge of innovative water management strategies, and has developed diversified and sustainable water sources through its ingenuity. In the process, PUB, Singapore's National Water Agency, is using the opportunity to create a healthy and satisfying place to live and work. This is even more remarkable when one takes in mind the relative small amount of land and water that the city has to work with.

### A CITY THAT KNOWS WATER STRESS

Singapore receives an average 2200 mm amount of rainfall annually. This is well above the global average of around 1 000 mm, but the benefit is offset by the limited land available to catch and store the water. The islands that carry the city are also absent of natural aquifers and lakes. Water stress is such a certainty here that in 2015, the World Resources Institute identified Singapore as one of 33 out of 167 countries most likely to face extremely high water stress by 2040.

Yet Singapore's 5.6 million people continuously enjoy universal, affordable and efficient access to high-quality water, and they are likely to continue doing so far into the future. The road to get here has not been without challenges.

When Stamford Raffles landed in Singapore in 1819, one of the first tasks he ordered was to dig a well for water. To cater for increasing demand, the British soon started building a reservoir, later replaced by a system of wells as demand outstripped supply. Throughout the decades, this has remained a constant in the development of Singapore. The search for more water supplies was followed with increased development and followed by a growing population, resulting in the cycle being repeated again.

In later years, Singapore became dependent on Malaysia for water, securing a supply with import agreements. With Singapore's total water demand likely to double from the current 430 million gallons a day (or, 1 627 million litres per day) by the time the remaining water agreement with Malaysia ends in 2061, the city has decided to find other sources of supply, to ensure water security and sustainability well into the future. The decision has blossomed into a world-renowned water management strategy that rests on three principles.

First, the water yield of the city is maximised. The PUB, which manages water supply, used water and stormwater drainage, strives to collect every drop of rain that falls on Singapore. Second, water is seen as a resources that can be reused endlessly. Every drop of used water is reclaimed, and much of it turned into potable water again. Third, Singapore has turned its eyes to the most palpable source of water around: the sea. The strategy is personified in a diverse set of water sources, known as the Four National Taps.

## SINGAPORE FINDS NEW SOLUTIONS TO OLD PROBLEMS

The first tap is water from the local catchment. For this tap, Singapore has geared development towards becoming one of the few countries in the world to harvest urban stormwater on a large scale to be treated for potable consumption. With limited land space and ever-growing urban areas, a network of rivers, canals and drains have been employed to convert as much as two thirds of Singapore's land area into water catchment areas. In order to keep the water quality acceptable, the development of land is tightly controlled to prevent pollution. Stormwater is channeled to a system of 17 reservoirs before it is treated for drinking water.

The second tap is imported water, based on agreements signed with Malaysia. The 1961 Water Agreement between the Johor State Government and Singapore expired on 31 August 2011, but water is still imported under the 1962 Water Agreement, which allows the city to draw up to 946 megalitres/day from Johor River until 2061. Singapore is obliged to provide Johor with treated water up to 2% of the imported water.

However, Singapore's future water security is dependent on the development of the last two taps.

Tap three is highly purified reclaimed water known as NEWater. The water is produced from treated used water that is further purified using advanced membrane technologies and ultraviolet disinfections. Though safe to drink, the water is used mainly for industrial purposes, unless dry periods are experienced. Then NEWater is added to reservoirs to blend with raw water, which is then treated at waterworks before it is supplied to consumers as tap water. There are five NEWater plants supplying up to 40% of Singapore's current water needs. By 2060, NEWater is expected to meet up to 55% of water demand.

An underground superhighway for used water will streamline how Singapore collects, treats and disposes or reclaims used water. Called the Deep Tunnel Sewerage System (DTSS), its construction spans two phases, with Phase 1, 48 km long, completed in 2008. The construction of a second 40 km is in progress. By 2025, whenever Singaporeans flush the toilet, take a shower or wash the dishes, this water will flow into the used water highway, and channeled by gravity to one of three coastal water reclamation plants (WRPs) for treatment. When it is completed, the Deep Tunnel Sewerage System (DTSS) will shrink the land occupied by used water infrastructure by 50%, freeing up precious land for higher value uses.

In September 2005, Singapore turned on its fourth national tap when the SingSpring Desalination Plant opened in Tuas. Singapore currently has three desalination plants with two more coming up in 2020.

While the PUB is continuously working towards a sustainable supply of water, Singaporeans are also encouraged to use water wisely. Public education campaigns to drive water conservation, mandating water efficiency standards and pricing water to reflect its scarcity are ways to help to drive down household water consumption from 165 litres per day in 2003 to 143 litres in 2017. The new target is to reach 130 litres by 2030.

## EVER WORKING TOWARDS A MORE SUSTAINABLE FUTURE

The government is committed to greening the city, but PUB is also coming to the party, with a vision to turn waterways and reservoirs into beautiful recreational facilities for the public. More than 100 projects have been identified for completion by 2030 across Singapore. Called the ABC Waters (Active, Beautiful, Clean) programme, most projects integrate beautiful and practical green features, such as rain gardens to detain rainwater and treat it before discharge into waterways. The intent was also to bring people closer to water to raise their awareness of water so that they can help protect and conserve it.

PUB is constantly working towards ensuring that the Singapore water system remains adequate, sustainable and resilient. In his foreword for PUB's ***Our Water, Our Future*** publication in 2016, its Chief Executive, Mr Ng Joo Hee said, "This is entirely practicable as long as we remain coldly realistic about our circumstances and do not shy away from pursuing and employing hard-nosed policies. It will require that we apply our intellect and imagination, researching and testing continuously, and use science and technology to overcome our water challenges. And it will require judicious consumption and increased frugality on the part of Singaporeans and residents."

*PUB, Singapore's National Water Agency*

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# CHAPTER 04

# SOUTH AFRICA'S THIRSTY CITIES – FINDING PROMISE IN THE PERIL

*South Africa is a country of extremes. Firstly, there is the country's contrasting topography. This ranges from the breathtaking mountainous escarpment (the Great Escarpment) to the low-lying coastal zone. Then there are South Africa's dominant neighbours; two distinct oceans that orchestrate the climate and rainfall of the country they embrace. Along the western side of the more than 2 500 km coastline, the cold Benguela current rises from the icy depths of the Atlantic Ocean. It meets the warm Indian Ocean at Cape Agulhas, from which the temperate Mozambique or Agulhas current flows along the east coast.*

In general, the evaporation of the eastern seas provides generous rainfall, primarily in summer. In contrast, the Benguela current retains its moisture, causing desert conditions in the western part of the country. This part of South Africa is mostly semi-desert. A narrow coastal strip in the south receives all-year rainfall in the east and winter rainfall in the west. However, for the most part, and compared to many places elsewhere, South Africa is largely a dry country. The country receives an average annual rainfall of about 464 mm, in comparison to a world average of about 860 mm.


Petro Kotzé


Petro Kotzé

*Cape Town is surrounded by beautiful beaches, but clean water-supply has been a challenge throughout the city's history.*

South Africa is inhabited by a large and diverse group of people in terms of race, culture and religion. In addition to the country's 11 official languages a number of other languages are spoken, including Arabic, German, French, Greek, Gujarati, Hebrew, Hindi, Portuguese, Sanskrit, Tamil, Telegu and Urdu. In tune with trends elsewhere, the South African population is growing. Since 2005, the South African population has expanded from 48 to around 54 million people. An increasing number of people are leaving rural areas to seek their fortunes in the city, and according to projections, about 80% of the country's population is expected to be urbanised by 2035.

Ashraf Hendriks/Groundup

*The eradication of poverty remains one of South Africa's biggest challenges.*

Petro Kotzé

*Johannesburg's water supply is supplemented with water from the Lesotho Highlands Water Project.*

The population is marked by stark inequality. The poorest 20% of the population consume less than 3% of the total expenditure, while the wealthiest 20% consume 65%. This disparity is easy to spot – in many areas, suburbs with big yards and comfortable houses are in stark juxtaposition to nearby informal settlements where thousands of people are squeezed into shanty towns.

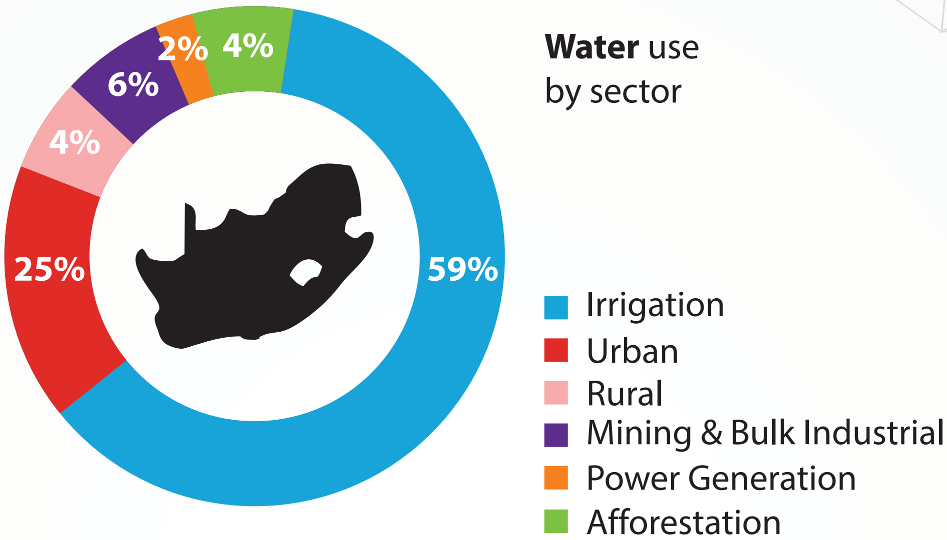
South Africans are also no strangers to drought. Years of extreme rainfall are often interspersed with drought. Until 2012, the country enjoyed 16 consecutive years of above-average rainfall in most of the summer rainfall areas. At that time, the last significant drought was a memory of over two decades old.

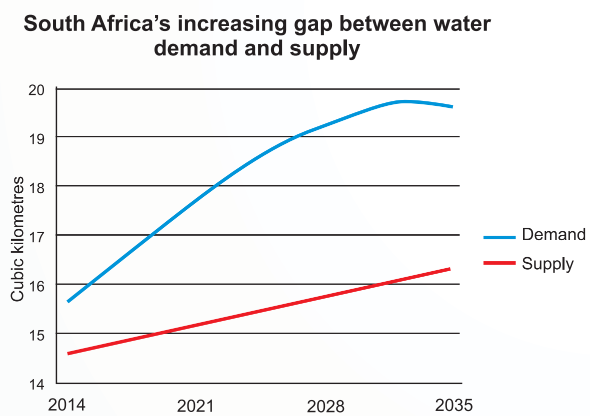
This period of flush water supply masked a number of problems that were fermenting in the background. All those people that moved to cities to improve their quality of life, enjoyed improved access to water services in the process. At the same time, the services and infrastructure necessary to provide the water deteriorated due to a lack of skills and capacity to maintain it. These were aggravated as the population grew, the gap between the so-called haves and have-nots enlarged and poverty rose.

When the next severe drought arrived, as it inevitably would, crisis hit. By November 2015, five provinces were declared disaster areas. By 2016, several towns and cities were close to running out of water. Livestock numbers plummeted and crops withered. Unimaginable a mere couple of years before, internationally renowned Cape Town announced that it was on the brink of running dry.

Though not the only cause, the drought highlighted a major concern to the future development of South Africa, one that many say has been hiding in clear sight for decades – we are running out of water.

## SOUTH AFRICA'S WATER CRISIS




*Total water withdrawals for all sectors forecasted to 2035 and total water supply, including yield increases from all large-scale water reconciliation strategies. (Source: ISS)*

Though commonly thought of as a situation where not enough water is available, water crises are fueled by a number of factors. South Africa's water crisis is commonly summed up as too little water or, too much; water that is too dirty and, available at the wrong place and time.

### TOO LITTLE

South Africans mostly depend on surface water for their needs. We typically get our water from a network of large dams. Most of our water is used to produce food, as the biggest amount of our water goes to the agricultural sector. Municipalities are the second-largest user, followed by the industrial sector.

Already, these three groups are consuming more water than our available water resources allow for. Yet all three sectors are set to demand for more water in the future. Forecasts by the Institute for Security Studies on long-term water supply and demand in South Africa predict that the gap between water supply and demand is set to grow. Though current water supplies are already almost fully allocated to different users, South Africans will still demand 17% more water than is available by 2030. Furthermore, this gap between supply and demand will not close, even if we are able to implement all plans for more water (like desalination and tapping into groundwater), and should we be able to use less water at the same time.

## TOO DIRTY

Water pollution in South Africa is rampant, leading to even less suitable water available for South Africans to use. Agriculture, runoff from irrigation, industrial effluent and discharges from mining and human settlements all contribute to our water quality problems. This is aggravated by crumbling infrastructure, lack of skills to fix it, lack of maintenance and failures of local municipal service delivery. Results include partially or untreated sewage flowing directly into the water resources that South Africans depend on for their livelihoods, and the country's economic development.

## TOO MUCH

Drought is not the only water-related crisis that happens in South Africa. The country is also often hit by flooding. Perhaps more so than drought, the destructive impact of floods is felt immediately. Roads, bridges and other infrastructure are damaged or destroyed. Precious land is lost to erosion and often, lives are lost in the process. Apart from the social impacts, floods carry hefty price tags. Following heavy storms and floods in October 2017 in Durban, for example, the eThekwini Municipality announced that the costs to repair resulting damages amounted to over half a billion Rand.

## WRONG TIME

South Africa's seasonal rainfall patterns result in several challenges for water supply. Cities like Cape Town, for example, are located in winter rainfall regions, far from other reliable supplies of water but still in need of water throughout the year. The economy of the winter rainfall areas in South Africa thus depends on water kept in storage facilities like dams, to last them through the dry summer months. This has substantial impacts on the ecology of local river systems, and the consequences have to be managed very carefully.

## WRONG PLACE

The country's economy is heavily dependent on the transfer of large volumes of water between catchments. Most of the largest engineering feats in the country's history involve the movement of water from areas where there is more than necessary, to places where there is not enough for development. The Orange River Project is still one of the country's major inter-basin transfer projects, and takes water all the way from the Gariep Dam to the Vanderkloof Dam and via the Orange-Fish tunnel to the Eastern Cape and Port Elizabeth. The Palmiet-Breede Pumped Storage Scheme supplies water to Cape Town. Water for the Greater Johannesburg area is transferred via the Lesotho Highlands Water Project and the Thukela-Vaal System.

*In an amazing feat of engineering, water is pumped uphill from the Thukela River system to serve the water needs of Gauteng.*

South Africa's current water supply challenges will be further fuelled by climate change. Considerable warming and drying are projected for the region, with an expectation of greater frequency and intensity of extreme weather events, such as heatwaves, flooding and drought. Poor and vulnerable communities are particularly at risk.

This situation calls for new thinking beyond traditional engineering solutions. Research institutions such as the University of Cape Town's Future Water Institute believe that the solutions lie within our cities through the exploration of initiatives such as water sensitive urban design (WSUD).

## URBAN SETTLEMENTS AS FUTURE SOLUTION TO WATER SCARCITY

"Urbanisation is creating an opportunity for doing things differently," says Kirstie Carden. "Creating more water supply, applying water demand management, undertaking efficient water allocation and adapting to water scarcity will allow us to start reducing the deficit between the water we have, and the water we will need in time to come." What's more, international trends suggest that WSUD offers a way to manage scarce and often deteriorating water resources, while adding economic and environmental value to cities.

For South Africa, the concept holds particular appeal. WSUD can transform urban areas to connect divided and separated communities and give all South Africans equal access to water.

## OPPORTUNITIES BEYOND SECURE WATER SUPPLY

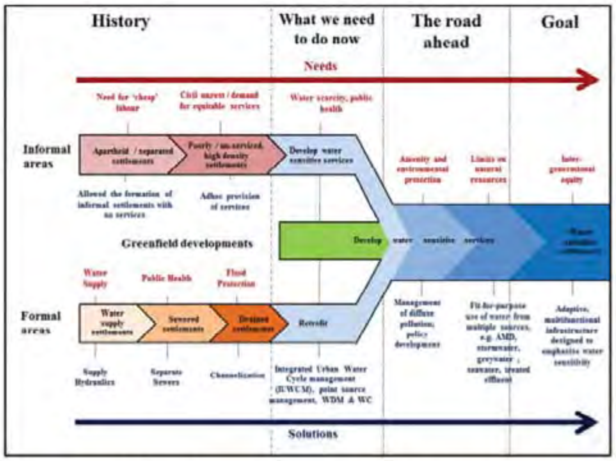
Water management in South Africa goes beyond the management of a secure supply of water to people and the economy. In many areas, basic water and sanitation services are still lacking. Any development plans here need to take cognisance of rural and informal settlements.

For this reason, reference to the word 'urban' has been removed from the term WSUD here. In South Africa, as defined by the Water Research Commission (WRC), water sensitive design (WSD) is "the integration of water cycle management into planning and design for the growth and development of communities, and is inclusive of urban, peri-urban and rural environments." WSD incorporates water supply, wastewater (including greywater), water resource management (groundwater, stormwater and surface water), and environmental and human protection as part of its integrated design concept for environments.

WSD is envisioned to enable local authorities to meet their developmental goals in all settlements where people live, irrespective of their scale and location. The term includes achieving universal access to basic services in a way that is resource-efficient, affordable and results in minimal environmental impact.

Petro Kotzé

*The concept of water sensitive design aims to incorporate 'alternative' water sources, such as stormwater, into the water-supply infrastructure of a city.*




**Framework for Water Sensitive Settlements in RSA, "*Two histories, one future*"**
(adapted from Brown *et al.*, 2009)

The figure provides a vision of how the transition of both formal and informal areas in South Africa to water resilient settlements can be made. First, fully-serviced formal areas that have stormwater infrastructure should focus their transition efforts on retrofitting and redeveloping developed sites in a water sensitive manner.

Once formal areas have begun this journey of retrofitting, and the necessary technologies have been tested, informal areas (currently developed as 'water supply cities' with limited sanitation) should be redeveloped in as water sensitive a manner as possible. Any development of informal settlements should attempt to 'leapfrog' the stages through which formal areas develop. This will eliminate the need to retrofit developed areas at a later stage. Using water sensitive technologies should also result in a range of secondary benefits for these communities.

Undeveloped areas should be developed in as water sensitive manner as possible from the start. Private developments, in particular, can be used by municipalities to ensure that development planning approval processes include the concept of water sensitivity.

There are several constraints to the development, redevelopment and upgrading of informal areas in a water sensitive manner, with budget constraints and limiting policies chief amongst these. However, the burden, benefits and responsibility of implementing WSD has to be borne by all residents, including those of informal and formal areas. Only then would it be possible to move forward equitably and continue to transition towards water sensitive cities. Therefore, the diagram emphasises the fact that enhancing water sensitivity in settlements has the potential to not only address issues of resource availability and environmental damage, but also to address related problems of social exclusion, equity and equality.

*Source: A water sensitive urban design framework for South Africa by Lloyd Fisher-Jeffes, Kirsty Carden & Neil Armitage*

Though the potential to use WSD to help resolve South Africa's water crisis is substantial, it is not without challenges. Many hurdles are similar to those experienced internationally, including a lack of skills to correctly apply the concepts, as well as champions to ensure that water sensitive design is at the top of mind when development choices have to be made.

Even where the required skills and champions are present, WSD options are rarely represented in local planning and policy processes, making implementation difficult. This is often the case because not enough people understand what implementing these techniques, the cost and risk involved, entails. A lack of data and research to support the uptake of these ideas into policy are slowing down the uptake of the concept.

Throughout the country, however, landmark work has been done to bring WSD to the attention of role-players, provide training to those that need it, and conduct research necessary for safe and sustainable implementation.

## SOUTH AFRICA MOVES THE CONCEPT OF WSD FORWARD

For the last few years, the WRC has been laying the groundwork for a new development trajectory for cities through the implementation of WSD towards the creation of cities that are resilient, liveable, productive and sustainable. WRC-funded research aims to assist the people that manage our water and our cities to successfully make this transition through the creation of a body of knowledge in this domain.

The WRC has produced a framework and guidelines for water sensitive design in South Africa, which provides a way forward for achieving water sensitive settlements. This includes a research component to build the knowledge and capacity required to adopt a long-term vision. A narrative sets the scene for engaging with stakeholders and decision-makers to plan for and manage the challenges facing the country's urban water sector. Finally, the implementation component addresses the trade-offs that might have to be made to best use a range of water resources (including surface water, stormwater and rainwater, seawater, treated effluent and greywater) for appropriate purposes. The purpose is to work towards the development of multifunctional urban areas that are resilient and adaptable to change, while development and equity issues are addressed.

A Water Sensitive Community of Practice Programme has also been initiated, with the aim of spreading awareness of WSD, sharing information on related activities around the country, and conducting training. Many of these activities have been directly targeted at the metropolitan municipalities around South Africa, with relevant personnel becoming important members of the Community of Practice. As a result, there is now a much more well-developed understanding and knowledge of the concept around the country, and uptake and buy-in are slowly improving.

Outside of the WRC, but working in collaboration with the institution, the transdisciplinary research institute at the UCT, Future Water, is addressing issues of water scarcity in South Africa largely through water sensitive design. The need for research development, demonstration and training has led to the development of the Water Hub, the first of its kind in Africa.

Still, the idea is not to define an approach that will suit all places in South Africa. Rather, each city or settlement should have its own vision to work towards to securing water supply to residents. What a liveable place entails, varies greatly and is for many a subjective concept, though it can in general be described to include the wellbeing of a community and the many characteristics that make a location a place where people want to live.

**The Water Hub**

Situated in Franschhoek, in the Western Cape, the Water Hub is a milestone for South Africa. Located at an abandoned wastewater treatment facility, the purpose of the hub is research, demonstration, training and recreation, connecting multiple elements of the urban and regional water cycle. New options for the treatment of contaminated water, including the use of natural systems and bioprocesses are explored here, through collaboration with government, research institutions and industry. In particular, the Water Hub promotes more liveable cities and towns, healthier rivers and wetlands and increased food security.

It is the first of its kind to demonstrate state-of-the-art techniques and technologies suitable for the African context. Another objective is for the training and skills provided to inspire a new generation of water leaders to forge new knowledge about green technologies in water resource management, in particular, in the context of rapid urbanisation and limited financial resources.

The Water Hub is a partnership between UCT, Stellenbosch Municipality and the Western Cape government. Its partnership with Future Water ensures a solid grounding in transdisciplinary collaboration.

*Source: https://www.thewaterhub.org.za/*

Such solutions vary greatly depending on the location and specific challenges. Visions would be completely different for any two cities. The different approaches taken in Durban (see insert) and Cape Town (see insert) towards becoming more resilient are perfect examples. This does not mean that we cannot learn from each other. Every settlement can learn from these examples in order to start or continue their own development towards a water sensitive, resilient and liveable place.

Furthermore, the generally accepted elements of WSD are discussed in more detail in the following chapters, including the so-called 'new taps' of water resources. These include water demand management and conservation, stormwater and rainwater harvesting, the use of wastewater (greywater and treated effluent) and groundwater and managed aquifer recharge. All settlements and cities can already apply some of these concepts in their journey towards becoming liveable places to the people that call them home.

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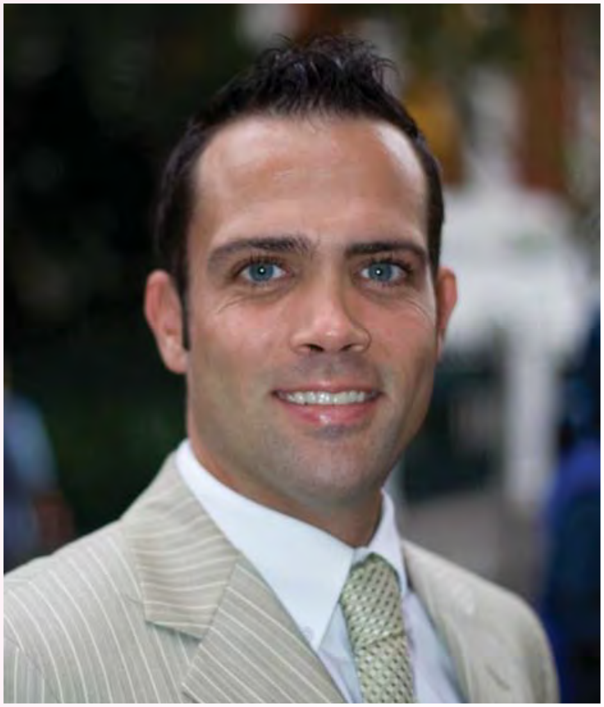
## A PARTNERSHIP BETWEEN ALL STAKEHOLDERS – CAPE TOWN'S ROAD TO RESILIENCE

*[Interview with Gareth Morgan, the City of Cape Town's Director for Resilience]*



*Gareth Morgan, City of Cape Town's Director for Resilience.*

"Over the last 100 years, Capetonians have had to overcome a number of shock events that threatened the survival of the city. This included the outbreak of bubonic plague in 1901, the reclamation of the foreshore in 1935, the struggle against apartheid from the 1950s to the 1990s and, most recently, the defeat of Day Zero in 2018.

To defeat Day Zero – the doomsday when taps would run dry and residents would have to queue for water – the City of Cape Town had to rely on the cooperation of its residents. City and government interventions to avoid Day Zero included drilling boreholes to tap groundwater, small-scale salt-water desalination plants, and a pilot reclamation plant to treat sewage and convert it to potable water (in other words, to recycle water). But the dodging of Day Zero was only truly achieved by the incredible water-saving efforts of Capetonians. The city became the first in the world to reduce its water consumption by 50% in just three years.

6000.co.za

*At the height of the last drought, Theewaterskloof Dam resembled a desert landscape.*

To build a resilient city, municipalities must accept that they cannot do everything themselves. They simply do not have all the resources or the capacity. To build a resilient city requires the activation of latent resources such as neighbourhood watches, community-based organisations, non-governmental organisations and businesses. And it requires empowered stakeholders who understand risk and how to reduce it.

Further, it requires more active and improved intergovernmental relations. A city government does not control all the functions in an urban environment.

For example, energy production, policing, rail and bulk water provision are functions of national government. A resilient city needs all these functions to work optimally. This means that national government must deliver on its functions less it place extra stress on the urban environment.

## RESILIENCE IS A JOURNEY THAT STARTED LONG AGO

Cape Town's journey towards a resilient city arguably started in the 1890s when the first water, drainage and sewerage infrastructure was installed and when the first municipal electricity supply for lighting was established. Since then the city has taken various actions against potential disaster, although the term 'resilience' might not have always been used. Since 2017, there has been a heightened focus towards mainstreaming resilience in the City of Cape Town. In the Integrated Development Plan for the City of Cape Town (2017 – 2022), 'resilience' features as a guiding principle.

Responses to climate change started gathering momentum in the early 2000s as the realities of the impacts of anthropogenic climate change started emerging from IPCC reports. In 2006, Cape Town published the ***Framework for Adaptation to Climate Change.*** This was followed in 2011 by Cape Town's *Action Plan for Energy and Climate Change*. At the time of writing the city's climate adaptation plan was being updated following an extensive hazards and risk analysis. The new plan is expected for release in 2020. The City Resilience Strategy, which encompasses both climate-related shocks and other shocks, such as infrastructure failure and cyber-attack, is expected to be approved by late-2019.

Regarding water, some of the most important projects that contribute to the Cape Town's resilience include the award-winning water conservation and demand management programme started around 2007. Cape Town was using about the same amount of water in 2015 as it was in 2000, despite more than a million new inhabitants during that period. The programme was heightened during the drought and Cape Town was able to reduce its water consumption by 50% within three years (2015 to 2018) without ever having to turn off the reticulation system. No city has ever achieved such a feat.

Another initiative is aquifer abstraction currently being developed for the Cape Flats aquifer, which can total up to 45 Ml per day by 2020, with associated managed aquifer recharge. A number of new water re-use projects are also being developed, projected to total up to 70 Ml per day by 2023. Alien invasive vegetation is being cleared around Steenbras and Wemmershoek dams using expanded public works programmes, and support for the Greater Cape Town Water Fund and partners to clear other parts of the broader catchment is ongoing. There are also various fire safety and winter readiness campaigns, including flood awareness, conducted annually.

## LOCAL KNOWLEDGE THAT IS CONTRIBUTING TO THE GLOBAL KNOWLEDGE BASE

Cape Town is a leading member of both C40 Cities and 100 Resilient Cities. City staff both host and participate in regular webinars with resilience practitioners almost on a monthly basis and regularly with practitioners from other cities. Examples include the C40 Inclusive Climate Action Workshop in New York in October 2017 (with Sydney, Durban, London), 100 Resilient Cities Water CoLab in Cape Town in September 2018 (with Los Angeles, Addis Ababa and Mexico City), 100RC Data CoLab in New York in October 2018 (with San Francisco, New York City and Manchester) and the 100RC Informality Network Exchange in Addis Ababa in December 2018 (with Accra, Addis and Lagos). Every month the Cape Town Resilience Department has a teleconference with the Chief Resilience Officers of Paynesville, Lagos, Accra and Addis Ababa.

C40 is a network of the world's megacities committed to addressing climate change. C40 supports cities to collaborate effectively, share knowledge and drive meaningful, measurable and sustainable action on climate change.

Along with Mexico City, Miami, Hull and Amman, Cape Town is participating as a pilot city for the development of the City Water Resilience Framework. Cape Town has made a significant contribution to the development of the tool, which will be available to cities around the world later in 2019.

## WHERE SHOULD A MUNICIPALITY IN SOUTH AFRICA START ITS JOURNEY TOWARDS A MORE RESILIENT FUTURE?

Municipalities must start with good data. Understand the whole of the city and where the most severe resilience challenges are. A good starting point is to deploy the City Resilience Index tool (see example below). Once you have done an analysis you will know where to place your efforts. Ultimately all South African municipalities have high vulnerabilities in informal settlements. The impacts of climate change (flooding, fire and heat) will be magnified by the chronic stresses that exist in informal settlements including poverty, unemployment and food insecurity.

## HOPES FOR THE FUTURE IN CAPE TOWN

In future, I would like change to have taken places across the three levels of community, the system and the government.

I would like to see Capetonians working together to continually enable healthy people, households and communities which are better able to respond to shocks and stresses; a city, including the whole of Cape Town, which is prepared on all levels to function in the face of uncertainty and future shocks, underpinned by individual, household and community resilience building efforts; and a city government, reflective after shock events, working with data providers, technology platform partners, modelers and researchers to constantly improve resilience considerations in planning and decision-making."

## TEN LESSONS FROM CAPE TOWN'S WATER CRISIS

1. Strengthen horizontal and transversal management between municipal departments
2. Invest in partnerships across the whole of the urban environment
3. Fully understand how the whole system works and who makes decisions in order to understand risks and accountability
4. Share information early and regularly in order to build public trust
5. Obtain external input and reviews to test models and assumptions
6. Build redundant capacity into the system to cope with disruption (e.g. alternative sources of water)
7. Be aware that it is difficult to fund responses to shocks such as drought from within municipal budgets. We need to engage national government on how to more rapidly respond to shock situations from a financial point of view.
8. Build adaptive management capacity among staff and decision makers to cope with stressful and rapidly changing situations.
9. Integrate robust climate scenarios into all planning decisions, especially the Municipal Spatial Development Plan and the Built Environment Performance Plan.
10. Take time to reflect and learn regularly so that new knowledge can be used to make system changes.

## Using the City Resilience Index to measure resilience

The City Resilience Index is designed to enable cities to measure and monitor the multiple factors that contribute to their resilience. Its primary purpose is to diagnose strengths and weaknesses and measure relative performance over time. The below are preliminary examples of the quantitative and qualitative assessments done by the City of Cape Town as published in their preliminary resilience assessment.


According to the profile, the three weakest dimensions are 'Empowered stakeholders', 'Comprehensive security and rule of law', and 'Collective identity and community support'. The interpretation put forward in the preliminary resilience assessment is that in the mass survey, participants were mostly concerned with issues that directly affected their livelihoods, and experts sometimes operate at a level where they have more knowledge of government action than ordinary citizens. By comparison, during the community conversations there were more negative perceptions based on lived experience during times of crisis.

The weakest dimension identified in the quantitative resilience profile is 'Diverse livelihoods and employment'. This corresponds most directly with the perceptions of the mass face-to-face survey – reflective of the impact of unemployment and poverty that is pervasive in Cape Town. The other four dimensions in the orange colour range are issues that directly affect citizens and overlaps with the outcome of the mass face-to-face survey. These are also all dimensions that have an impact on or are impacted by a lack of social cohesion. While 'Reliable mobility and communications' scores highly, there is some concern in the interpretation that this does not capture the informal sector well enough. This area will be explored further in the next phase of the project.


*Sources:*

*Resilient Cape Town – Preliminary resilient assessment*

## EMBRACING INFORMAL SETTLEMENTS AS PART OF THE URBAN FABRIC – DURBAN'S ROAD TO RESILIENCE

*[Interview with Dr Debra Roberts, head of the Sustainable and Resilient City Initiatives Unit at eThekwini Municipality in Durban, South Africa. Dr Roberts is also the city's first Chief Resilience Officer.]*

*Dr Debra Roberts, Head of the Sustainable and Resilient City Initiatives Unit at eThekwini Municipality in Durban.*

The 21st century is increasingly characterised by a set of unpredictable and complex challenges facing human and natural communities around the globe. Water stress and climate change are just the tip of the iceberg. We need to think about what is driving these changes if we are to be able to transform the way we respond to the causes and the impacts of this new set of multidimensional challenges. As a society, across the world, we have established a development model that's no longer safe for us or the planet we live on.
If we truly want cities where we have water, food security, equal access to opportunity and equity, places that are resilient and adapted to climate change and that are low carbon, we're going to have to do a host of things, very differently.

### DURBAN'S ROAD TO A RESILIENT CITY

Says Dr Roberts: "We developed our first Resilience Strategy, which was approved in August 2017. That was a really interesting journey for us. It took us over three years of hearing different views from a range of different stakeholders, including religious groups; cultural groups;

municipal employees; the business community and a range of critical thinkers. We started with the idea that we were going to pursue the nexus of biodiversity, water and climate change adaptation as the key resilience approach in the city, but our stakeholders took us in an entirely different pathway.

"We ended up with informality and especially settlements as the key issue that the city faces in dealing with resilience. The point that was made by our stakeholders was that if we don't find a new way of dealing with informality, it literally has the potential to undermine everything else. The second issue that was highlighted is how to better manage the twin forms of governance in the city i.e. municipal and traditional governance.

"We were quite surprised initially when these issues were prioritised. But when we stood back and looked at it, we realised that our stakeholders had a very clear view of the challenges facing African urbanisation. In fact, those two things, informality, and the intersection between westernised governance systems and traditional governance systems, are some of the key problems being experienced in African cities.

Dr Roberts points out that this sort of work highlights the causes rather than just the symptoms of a lack of resilience, and provides cities with the opportunity to ask bigger questions. Can we use the opportunity of protecting biodiversity to create jobs through catchment management and allow people in informal settlements to protect their own water supply and reduce their own risk from flooding?

"We could, for example, offer people employment in managing the vast natural systems that Durban still has. It's an enormous resource base and we have to think about how we use that to lay the foundation of the green economy, and to allow poor, unemployed people to enter it."

At the time of writing, eThekwini Municipality was putting the finishing touches on the implementation plan to go with the Resilience Strategy. Notes Dr Roberts: "We're largely focusing on the issue of informal settlements. The focus on the governance nexus will move more slowly as we continue to develop a better understanding of that issue. A strong initial focus of the implementation plan is on reconfiguring the governance structure of the municipality in order to enable greater transversal management, in order to facilitate the delivery of more resilient outcomes. One of the important steps forward is the creation of a unit focused on sustainability and resilience, placed at the office of the city manager so these issues can get the prioritisation required.

"Perhaps this is wishful thinking, but in five to ten years' time I would like to see informal settlements as a cross-cutting priority for every single line-function in the municipality. I would like to see a new approach to the way in which we handle ***in situ*** upgrading, considering new technologies and innovative materials and new ways of providing services so that our informal settlements become places where people can find a foothold in the city which is safe and less risky than the current; to give them the respect that every South African deserves. At the same time, to reduce their negative impact on the overall urban system."

The transformation of informal settlements and the acknowledgement that they are part of our urbanisation path is really what's involved. Informal settlements should not be things that everyone wants removed but rather a vibrant constructive, sustainable part of our urban fabric. This new perspective must be used to reimagine what the African city is going to look like.

## A RESILIENT CITY IN AFRICA IS A PLACE THAT EMBRACES INFORMALITY

Informality is the clearest message we have as a society that the kind of urbanisation path that we are following is simply not sustainable and resilient. Why do people build informal settlements? Because the city is not working for them. It's not allowing them access or affordable options in terms of housing and servicing. So people are literally building the city themselves. The poor and vulnerable are literally voting with their feet.

The pattern of urban development that we've followed in the past mimicked development patterns in the global north, and it's just not going to meet the needs of the African city of the future. When we talk about cities, be they water resilient, climate resilient or safe and sustainable cities we are generally thinking about the traditional 20th century vision of what a city should be, that is, with formal systems, roads, a city hall and a mayor. However, many cities in Africa are not going to be like that.

Africa has this confounding megatrend of informalisation happening at a macro scale. We have to get rid of all of the sacred cows or urban planning when engaging with what a sustainable and resilient African city should look like and rethink it within this new model. That's quite challenging. We have to re-envision the way we plan our cities.

## A RESILIENT CITY IN AFRICA IS A PLACE THAT EMBRACES NATURE

For much of the evolution of cities they've been places that exclude nature, not places that embrace nature. "From the work that we've done in Durban it's become very clear that if you're interested in increased adaptive capacity across a whole range of threats, you're going to have to improve the foundation on which the city is built. Cities, whether it's Durban, Cape Town, Khartoum, New York or London, are all built on natural ecosystems," reports Roberts.

"We now understand that if you want to have a hope of a sustainable, adaptive, resilient future you're going to have to have cities that are built to include nature and natural systems. This does not just entail trees alongside streets, but viable indigenous ecosystems. In order to survive, we must protect the ecosystems that deliver the ecosystem services that we rely on. That's particularly important in a city like Durban where a large majority of our municipal area is rural in nature. Communities are very directly dependent on these natural systems for services and often, rural communities get better services from the environment than they do from local government."

## A RESILIENT CITY OF THE FUTURE CALLS FOR DRAMATIC TRANSFORMATION

"We know that there's got to be dramatic transformations in the way we approach urban development in Africa, but no one yet has been able to piece together the entire picture of what that looks like," notes Roberts. The Intergovernmental Panel on Climate Change's ***Global Warming of 1.5 °C*** special report identifies four big systems that have to be transformed for a sustainable, resilient, safe, low risk world. They are energy, urban, land use and industry.

Very often urban areas provide the geography for energy, land use and industrial related activities, so the message is that if you're interested in water resilience, climate resilience and cities then you must think about entire transformation of urban systems at an unprecedented scale. "That requires an entire rethink of the role and nature of cities and their infrastructure. The greatest opportunity exists in the cities of the global south – in places like Asia and Africa – because we don't have carbon heavy infrastructural lock-in yet. We can skip some of the development mistakes of the global north and take entirely different urban development paths," says Dr Roberts.

## GOVERNMENT NEEDS TO CHANGE, BUT SO DO THE PEOPLE THEY GOVERN

The global economy is anchored in the geography of cities. Most future infrastructure is going to be built in cities, particularly those in Africa and Asia. Local government has to become a very different thing if it is going to harness the opportunity of this global scale infrastructural build. It has to become like a responsible big corporate, thinking about how to deploy the latest science, funding research and development, ensuring data management and playing a custodial role over the knowledge it generates. In many cases this is a new set of expectations for local government, especially in Africa, and many local governments have not thought about themselves in that way.

Maintains Dr Roberts: "As much as we expect governments, including our own, to change, you and I are also going to have to transform our lives. We have to look at the role that we play across those four transformative systems of energy, land use, urban and industry. For example, what am I doing about ensuring that the energy that I use is as sustainable and renewable as possible? And, if you don't have those options you will need to vote people in that will create those options for you."

## DIFFERENT CITIES, DIFFERENT VISIONS

This vision of urban resilience is a very different to the status quo we have now. It means creating a very different South Africa with a new pattern of urban development. Many voices need to be heard in creating this new resilience pathway. There is no standard recipe for achieving resilience, but rather there are many forms of resilience and though there are common threads the move to resilience will probably be unique for most cities around the world.

"There is enormous hope at the moment, and enormous opportunity, but it requires us all to do extraordinary things. There's nothing within the physical makeup of this planet that stops us achieving a world that is safer and more resilient, across climate and water. The big challenge and opportunity lies in the social and political will to change our systems, and to take risks. That's what we will live and die by. It's basically all on our shoulders now."

***Note:** Dr Roberts is also Co-Chair of the Intergovernmental Panel of Climate Change Working Group II, although she spoke in her capacity as an eThekwini municipality employee.*

*In its journey towards resilience Durban has had to embrace its informal areas.*

# CHAPTER 05

# PREVENTING A WATER CRISIS – WATER CONSERVATION AND WATER DEMAND MANAGEMENT

*When water is scarce, every drop counts. This has long been acknowledged internationally and in South Africa. In fact, an accepted, critical element of a future in which South Africa has a secure water supply, is to use the water that we already have access to, as efficiently as possible. According to the second edition of South Africa's National Water Resource Strategy (NWRS-2), "Every drop counts and we cannot afford to waste more water, anywhere".*

The concept is also noted in the National Water Act (Act no. 36 of 1998): "Water resources shall be developed, apportioned and managed in such a manner as to enable all user sectors to gain equitable access to the desired quantity, quality and reliable water. Conservation and other measures to manage demand shall be actively promoted as preferred option to achieve this objective."

Commonly, the practice is known as water conservation and water demand management (WC/WDM), and it has for many years received much attention locally and abroad.

## WHAT WATER CONVERSATION ENTAILS

*Municipalities lose about 1 080 billion litres of water each year through infrastructure leaks.*

Water conservation, and water demand management are two slightly different concepts, though much of what it entails overlaps. Water demand management is generally considered to be a part of water conservation. The latter, water conservation, includes policies, strategies and activities to sustainably manage freshwater resources to meet current and future water demand. It is defined as the "minimisation of loss or waste, the care and protection of water resources and the efficient and effective use of water" in the NWRS-2.

The same strategy defines water demand management as the adaptation and implementation of a strategy by a water institution or consumer to influence the water demand and use of water for economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability.

The general aim of WC/WDM is to conserve water by controlling how it is used, influencing how much people want and promoting its efficient use. There are many objectives, including losing less water in the system that transports water (see block, ***The water that gets lost along the way***). Another objective is to waste less water. A third is to protect the source of the water. A fourth objective is to ensure water is used as efficiently as possible once it reaches the user.

For WC/WDM to be effective, responsibility rests on the shoulders of both those that use water, and those that manage it. Two common activities are tweaking the water distribution system and influencing people's demand for water.

Tweaking the water distribution system entails reducing the leaks in the water distribution system by locating and fixing leaks, and lowering pressure in the system to decrease the amount of water flowing out of taps. Meters can be installed to curb or cut water and illegal connections stopped. An important action is to fix plumbing leaks in households.

To get people to use less water usually involves education and communication campaigns, installing good plumbing fittings and well-designed reticulation systems, prepaid meters, effective billing systems, regulations and by-laws, offering incentives to developers to build more water friendly buildings and maintaining the water infrastructure.

**Principles of WC/WDM**

According to South Africa's National WC WDM Strategy, there are three fundamental principles to achieving a balance between social equity, economic efficiency and environmental sustainability:

1. **Water institutions should endeavour to supply water in an efficient and effective manner by minimising water losses and promoting WC/WDM to their consumers.** Water institutions should ensure that they reduce the level of leakage in any water works or water services works to an optimal level. They must implement measures that promote WC/WDM to their consumers on an ongoing basis.

2. **Consumers should endeavour to use water efficiently.** South Africans should not waste water and should use water efficiently.

3. **WC/WDM should be considered as part of the planning processes for water resources, water supply and water services:** Implementing WC/WDM measures could provide more cost-effective and appropriate solutions to reconcile the gap between growing water demand and existing water resources or infrastructure. It can postpone the need for new large infrastructure such as dams and bulk treatment works. An integrated planning process should be used to decide on the resources, scope and prioritisation of WC/WDM activities.

**The water that gets lost along the way**

We are a country that moves water. Many of our major cities and industrial developments are located far away from the water necessary for their basic functioning and future development. As a result, much of South Africa's water-supply infrastructure is transboundary. This movement of water from surplus catchments to catchments where the water is required allows for mining, farming, and the location of cities at places where it would otherwise not have been possible.

Moving vast amounts of water across large distances involves massive infrastructure, including thousands of kilometers of pipelines, dams and treatment stations. The distribution of water across towns and cities themselves also requires extensive pipeline networks. These systems are not foolproof, and thousands of litres of precious water gets lost along the way, infiltrating back into the ground, most commonly due to leaking pipes. In South Africa, where systems are ageing and may not always be maintained, water leaks are a challenge.

Water that is lost in this way, or unbilled (due to illegal connections) is known as non-revenue water. In other words, though the water is already costing money to collect, treat and distribute, it does not bring in any revenue.

At present, around 37% of all water supplied to municipalities is lost (around 1580 billion litres a year). Most of this water is lost through leaks (25.4% or about 1 080 billion litres each year). To put this in perspective, all urban areas in the country use about 4 300 billion litres per year, so more than a third of the amount of water that we need to keep municipalities running is written off as non-revenue water. This amounts to more than R7 billion per year. This is not a uniquely South African situation. The worldwide average is 36.2%.

Digging deeper into the statistics creates a more concerning picture. Many municipalities in South Africa don't track their non-revenue water at all. In 2014, only 45% of municipalities could provide sufficient information to assess their level of non-revenue water, according to a WRC study. This means that 55% of municipalities are not even aware of whether or not they have a problem.

Ironically, this situation has created significant potential. Non-revenue water is a readily available and accessible source of substantial amounts of water that can be easily accessed to help relieve South Africa's water crisis.

Increasingly, managing the demand for water also includes creating awareness about the use of treated effluent in industry instead of water that is of a drinkable quality; rainwater harvesting on properties; and the development and provision of guidelines to help people us their greywater safely (to read more about the work being done in this regard in South Africa, refer to Chapter 7, which discusses wastewater management).

WC/WDM is a long-term approach to managing water. To achieve it, a combination of groups of people need to work together, including water users, those that manage the bulk water supply and those that manage the catchment. Supporting policies and a comprehensive legal framework are necessary. Then, the economic value of water has to be recognised. The human right for access to water for everyone, in particular the poor, must be secured. Institutions must work across the traditional boundaries that divide sectors. Perhaps most importantly, to save water in this way, we must start thinking differently about the value of our water.


**The 1-2-3 of water loss control**

The WRC has published a complete guide for municipalities on reducing water losses. Authored by Dr Ronnie McKenzie, ***Guidelines for reducing water losses in South African municipalities*** (**WRC Report no. TT 595/14**) encapsulates more than 20 years of knowledge and experience gained in the application and implementation of water loss control. The publication consolidates many innovative research tools, products and studies which have been generated over the years in response to the challenges associated with water loss management, as well as a number of projects and implementation of water loss management in South Africa.

## THE POTENTIAL OF WC/WDM IN SOUTH AFRICA

Petro Kotzé

*A Johannesburg Water vehicle with municipal employees on the job to fix leaks and save water.*

Petro Kotzé


*A campaign in Johannesburg, urging people to use less water, by the Department of Water and Sanitation.*

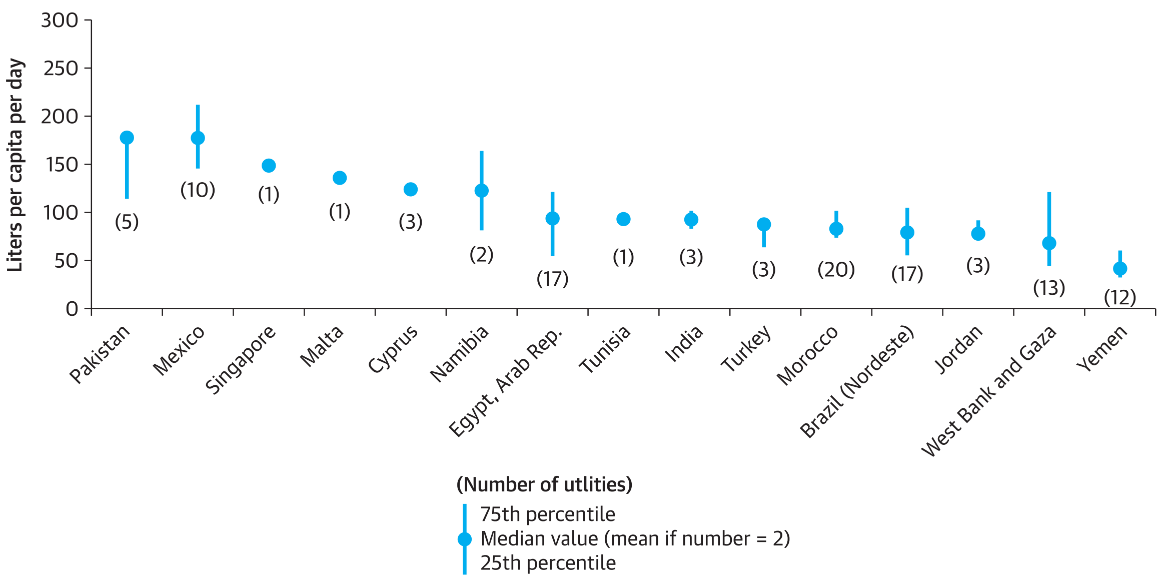
According to the NWRS-2, WC/WDM can play a major role in solving South Africa's water crisis. The benefit of plugging water losses goes even further. WC/WDM is necessary to develop key sectors of the economy; to win the battle against poverty and unemployment; and to ensure that the needs of the environment receive due priority. It can ease the tensions between essential water users, such as agriculture and mining, which have to compete for the same scarce, vulnerable resource.

According to the strategy, the most important sector where WC/WDM must be implemented is municipalities, even though this sector only uses about 23% of the country's freshwater resources. "The water savings within this sector would go a long way in balancing the demand and supply within catchments." WC/WDM interventions can amount to as much as a 571 billion litre reduction in demand by 2035, mostly by fixing leaks and getting people to use less water. The bulk of this reduction (22 billion litres) is expected to come from the Vaal River catchment, which includes the cities of Tshwane and Johannesburg.

According to assessments in 2007, WC/WDM has the potential to bring down demand in the Vaal River system by 15% by 2025. This translates to a reduction of water use per person each day from 330 to 290 litres. Though a vast improvement, this is still considerably more than the international average of 173 litres per person per day (see block, ***How thirsty cities are across the world***). Even more so, the potential for water savings through people using less water can be key to helping a city stave off the dire impacts of severe drought. A case in point is Cape Town, where residents were asked to reduce their water use to a mere 50 litres per person per day, in order to keep the city's taps running (read more about the city's green dot map and other 'nudges' used for Capetonians to use less water, in ***The map of Cape Town that helped nudge residents in the right direction***). According to the World Health Organisation, between 50 and 100 litres of water per person per day are necessary to ensure that most basic needs are met and few health concerns arise.

Achieving these targets to aggressively reduce water demand is entirely possible. However, it will require collective action and a change in the mindset of water consumers. It has been done before and as such, can be done again. Indeed, WC/WDM is widely recognised as key to the survival strategies of two cities that have very

**How thirsty are cities across the world?**




*Source:* IBNET.

The amount of water that people use in cities vary greatly. Access to running water, personal lifestyle choices and the size of properties are but a few of the vast list of factors that influence this. Nevertheless, drawing a comparison between the average daily water use of people in different cities is helpful to see what is potentially achievable. Of the 111 water scarce cities covered by the International Benchmarking Network (IBNET) and included in the World Bank report, Water Scarce Cities – Thriving in a finite world, the majority show residential consumption levels between 65 litres and 125 litres per person per day. Outliers include countries at both ends of the economic development spectrum, such as Singapore and the Republic of Yemen, and less predictable cities in Mexico, Pakistan, or Namibia.

*Source: World Bank. 2018. "Water Scarce Cities: Thriving in a Finite World—Full Report." World Bank, Washington, DC.*

recently experienced extreme drought. Long before the recent water crisis, the City of Cape Town had been running an award-winning WC/WDM programme. Similarly, San Francisco (California, United States) recently emerged relatively unscathed from extreme drought without tapping into new water sources. Both cities serve as examples of burgeoning urban areas in dry climates that are grappling with water scarcity, but emerging more resilient due to the successful application of WC/WDM, and moving forward towards the creation of water wise cities.

Read more about how these cities have achieved this in the following pages.


**Sources:**

- *National Water Resource Strategy – Water for an Equitable and Sustainable Future, published by the Department of Water Affairs of the Republic of South Africa (June 2013, second edition)*
- *Parched prospects II A revised long-term water supply and demand forecast for South Africa by Steve Hedden, published by the Institute for Security Studies*
- *National Water Conservation and Water Demand Management Strategy, published by the Department of Water Affairs and Forestry (August, 2004)*
- *Benchmarking of leakage from water reticulation systems in South Africa by RS McKenzie & CJ Seago, 2007 (***WRC Report no. TT 244/05***)*

## HELPING SAN FRANCISCANS TO USE WATER WISELY "COME RAIN OR SHINE"


*San Francisco is one of the most densely populated large cities in the United States of America, and is no stranger to drought and water-supply challenges.*

San Francisco is the cultural, commercial and financial centre of Northern California. One of the most densely populated large cities in the United States of America, San Francisco is no stranger to challenges to keep water flowing for the roughly 2.7 million people in the city and neighbouring San Francisco Bay.

SFPUC


*Launched in 2014, the San Francisco 'Water conservation is smart and sexy campaign' captured public attention and presented everyday water conservation tips and information about the drought.*

Delivering water 24 hours a day, seven days a week, is top priority for the San Francisco Public Utilities Commission (SFPUC), a public agency of the city and County of San Francisco. "However, our water system faces a number of risks," says Steven R. Ritchie, SFPUC Assistant General Manager, Water. "These include environmental requirements to leave more water in rivers for habitat and as a consequence, less for drinking; population and employment growth. This increases our demand for water;. Other risks inlude earthquakes, which can disrupt water deliveries, aeging infrastructure; climate change which affects the amount of water we get from snowfall; and drought, which reduces the amount of water available to us to serve our customers."

To keep the taps flowing, the SFPUC has been running a comprehensive WC/WDM programme for over 25 years. "Demand management continues to be an important component of our water-supply management approach," says Ritchie. This approach has resulted in significant water use reductions, and the city maintains one of the lowest average residential water uses in the State of California, and almost half the statewide average (see block).

*In 2013, (pre-drought) in-city residential water use per person per day in San Francisco and the Bay Area was approximately 185 litres (49 gallons). In 2017 (during drought), this dropped to 155 litres (41 gallons). After the drought, in 2018, the figure rose again slightly, reaching around 162 litres (43 gallons).*

## HOW SAN FRANCISCO SAVES WATER

"On an ongoing basis – rain or shine – the focus of our conservation programme is to help our customers use water wisely and avoid water wasted from leaks, old or broken equipment, and inefficient water use practices. Helping people use water efficiently saves them money, generally doesn't involve personal sacrifices, and protects our precious water supplies," says Ritchie.

The SFPUC's retail water conservation programme consists of a mix of financial incentives, technical assistance, and educational tools. The conservation measures included in the programme can be divided into two broad categories. The first, foundational customer assistance measure, include water-wise evaluations, reports and tools to measure a site's water use, free devices, and public education and outreach. The second is fixture, equipment, and landscape incentive measures. These can vary depending on plumbing code impacts and market saturation rates.

Some of the most significant reductions achieved by the SFPUC are pinned down to the replacement of old fixtures with water efficient models. Over the past 20 years, the replacement of old, high-volume toilets and washing machines have played a major role in reducing indoor water use. "Nationwide, the amount of water used for toilets and clothes washers in a typical home has shrunk from about 50% in the 1990s to about 40% today in houses that have new fixtures," says Ritchie.

Elements essential to the success of the SFPUC's programme include:

1. **Plumbing code requirements:** Most water savings are attributed to plumbing codes that require efficient fixtures such as toilets, aerators and shower heads;
2. **A rigorous process for estimating potential for water savings and evaluating the effectiveness of different conservation measures,** to determine what mix would be the most practical, cost-effective, and result in the most water savings and other benefits;
3. **A water conservation plan** that includes a timeline for activities, the necessary resources and budget, the ability to procure the staff, resources and necessary budget, and a plan to measure effectiveness and adjust accordingly; and
4. **An intimate understanding of the customers:** A good understanding of the population you are trying to reach and their water use patterns, and a thoughtful selection of conservation measures that helps meet these needs.

Still, there is more work to be done. The SFPUC anticipates that the most significant water-saving can still be achieved by replacing more old and inefficient fixtures and equipment; improving the efficiency of irrigation systems and increasing the amount of drought-tolerant plants in landscaped areas; helping the largest water users understand, monitor, and improve the efficiency of their water use; and helping water users to understand and monitor their water use and to address leaks and water waste in an effort to achieve and maintain efficient water use.

## WC/WDM IN EXTREME TIMES

San Francisco has maintained its level of service delivery even during extreme times. From 2012 to 2016, California experienced a record-breaking drought. A drought state of emergency was declared in January 2014, and lifted in April 2017, seeing both the region's driest and warmest year on record (2014), followed by the second driest and hottest (2015).

"During times of extreme drought when ongoing conservation may not be enough and we have to take more drastic measures, we use multi-faceted and extensive outreach and media campaigns, potential mandatory rationing and excess use fees, home water use monitoring tools, and water-saving incentive programs to help people reduce more," explains Ritchie.

During the mentioned drought state of emergency, the SFPUC launched a number of outreach efforts to inform San Franciscans about the need to save water, and the resources available to help them achieve that. Presentations were held at neighborhood groups and properties along commercial corridors were visited to spread the information. At the same time, statewide media carried extensive news about the drought.

The SFPUC also launched a multilingual 'Water conservation is smart and sexy' city-wide public education campaign to capture public attention and present everyday water conservation tips and information about the drought. The messages were conveyed through a combination of television, newspaper, billboard, bus, commuter transit station, and social media advertisements. The campaign encouraged individuals to adjust their water use practices and pursue water-efficient plumbing fixture upgrades. It also advised people to visit the SFPUC website to learn more about conservation services that are offered. Shortly after launching the campaign, SFPUC water conservation web traffic increased by close to 25%, and was extended to the wholesale service area as well.

"The outreach efforts were seen as very effective in motivating residents to use less water", says Ritchie.

**Source:**

- *Water Demand Management - Two thirsty cities' successful attempts to consume less water, published in The Water Wheel, July/August 2018*

## CAPE TOWN'S AWARD WINNING CAMPAIGN TO DRIVE DOWN WATER USE


*Poster campaigns helped spread the message to save water.*

Cape Town has been running its WC/WDM programme since the early 2000s, and has achieved ground-breaking results and international recognition. The programme received a C40 Cities Bloomberg Philanthropies Award in 2015, given to cities that are demonstrating climate action leadership. The awards have given recognition to more than 40 of the world's boldest projects, and Cape Town's WC/WDM programme counts as one of them.

*Widad Sirkhotte*


*During the drought South African Breweries permitted water collection from its Newland Spring.*

Before the introduction of the programme, water consumption in Cape Town was growing at 4.7% per annum – an amount that could not be sustained, especially since the city was still rapidly expanding. The number of people calling the Mother City home increased by more than 30% between 2001 and 2011. Yet, due to the success of the WC/WDM programme, water demand almost stabilised during that period. By the time the C40 accolade was awarded, water consumption growth had been reduced to less than 2% per annum, and water wastage reduced to 20%. This was achieved in part by using recycled water to irrigate public parks and green areas, city officials visiting more than 4 000 households for leak detections and repairs and replacing 258 km of water pipes to reduce pipe bursts and water leaks.

The programme was of immense value when the recent water crisis hit. The drought was extreme – some reports indicate that this was the worse drought experience in the last 300 years. The pre-existing WC/WDM programme was an important advantage for the city and allowed officials to formulate a rapid response. As a result, the city of Cape Town could facilitate a drop in water use by almost half in only three years.

## REDUCING WATER DEMAND BY MANAGING THE DISTRIBUTION SYSTEM

Though water restrictions contributed greatly to curbing immediate water demand, some of the most important work done was on the system that distributes the water. The biggest savings were achieved with advanced pressure management, resulting in an average saving of 70 megalitres a day. First initiated more than a decade ago, pressure reduction was accelerated and expanded, with automated pressure zones implemented across the metro. Pressure management saves water mainly by reducing water lost from leaks in municipal pipes and residential plumbing fittings, and reducing the likelihood of pipes bursting. It also leads to reduced water use as water comes out of the taps more slowly. Pressure management was generally extended to network zones with suitable infrastructure, though some were prioritised, such as where old infrastructure and high leakage rates were present, as the practice reduces leaks and bursts.

Cape Town has also been leading the pack in South Africa when it comes to water losses. At its current levels of 16%, the city is logging the lowest overall losses of any South Africa metro. Proactive management and the application of innovative technology were key to achieving this. The city fixes leaks for needy households, but also employs advanced equipment to locate leaky pipes. A robotic crawler fitted with an on-board camera, monitors water and sanitation infrastructure, identifying cracks, leaks and obstructions inside pipelines.

Household flow regulators have also been installed for many years, but were ramped up during the recent water crisis to include connections of high water users in order to restrict the daily consumption of a household and protect them against the impact of leaks. Nearly 300 000 water management devices has been installed over the past decade for these purposes. This has had a substantial impact on household water use, with demand declining significantly.

The City of Cape Town is also continuously clearing alien vegetation in the catchments and on city land. The city is heavily dependent on water from the mountain fynbos catchment areas, where rainfall often exceeds 2 000 mm per year (in comparison to the 300 mm that some parts of the city receives each year). On its way to the sea, the water drains into streams and rivers, and some is captured in dams to supply the city with water. Before the drought, as much as 98% of the city's water was from dams. A significant threat to this water supply is invasive alien plants, which consume more water than the indigenous fynbos. Studies have indicated that that investment in clearing and restoring the city's primary catchments will yield water at a cheaper rate than building dams, installing desalination plants, or drilling boreholes.

## REDUCING CONSUMER DEMAND FOR WATER

A key part of the city's WC/WDM programme is the development of ongoing and sustained awareness programmes. City of Cape Town officials have gone far to try and change the behaviour of the city's residents, urging them to value water and use less. To do this, the city maintains a multi-faceted, multi-platform water communication approach to drive demand down and to keep consumption at appropriate levels as the situation requires. This includes extensive messaging and education in a wide range of media and interventions, as part of a dedicated stakeholder engagement philosophy.

For one, the city maintains an extensive website where all water-saving and drought information is made available to anyone, including residents and other government departments, NGOs, schools, and small municipalities with fewer resources. The website hosts a resource toolkit, but materials are also delivered to various establishments.

*Sources:*

- *Water Demand Management - Two thirsty cities' successful attempts to consume less water, published in The Water Wheel, July/August 2018*
- *Water Outlook 2018 Report, Revision 25 - updated 20 May 2018, Produced by Department of Water and Sanitation, City of Cape Town*
- *www.c40.org*

## THE MAP OF CAPE TOWN THAT HELPED NUDGE RESIDENTS IN THE RIGHT DIRECTION

The drought that swept through Cape Town around 2016 to 2018 necessitated extraordinary measures to stop the city from running out of water. City officials asked residents to stick to dramatic water restrictions. Capetonians had to limit their household water use to to 50 litres of water per person per day.

Staring at his computer screen in his office at the municipality's Water Demand and Strategy branch, Ken Sinclair-Smith could see part of the problem. Section head Sinclair-Smith specialises in information management and analysis, geographic information systems and water modelling. "People were telling us that they could not possibly use any less water," he says, but analysis of water consumption for individual households showed large differences, even within the same streets. While people in one household would be limiting themselves to meet the restrictions, their neighbours might not. Some people were simply not doing enough.

Getting every household to stick to the restrictions was critical. Domestic use accounts for up to 70% of water consumed in the city of Cape Town (informal settlements use about 4% of water). To save more water, the key was to have residents use less. Not only are they the largest group of water users, but their savings would spill over into much smaller economic impacts than reducing bulk industrial users.

Seeing part of the solution clearly displayed in the figures and data that he worked with, Sinclair-Smith had a plan. It was a map.

### A MAP LIKE NO OTHER

Famous the world over for its relaxed and friendly locals and spectacular scenery, Cape Town was a tense place during that drought. In late 2017 it was very hostile, says Sinclair-Smith. In the press, a lot of letters from people in affluent areas blaming people in townships for wasting water were published, for example. Other articles put the blame on tourists. "It was very much a case of blaming other people; of someone else being the cause of the problem."

Launched in January 2018, the map addressed some of these issues by publically acknowledging households that saved water. Cape Town's water map or the so-called green dot map, indicated the water use of individual properties with different coloured symbols. The map was published on the City of Cape Town website where it was accessible to everyone. Light green dots indicated households that used less than 10 500 litres per month (or 87 litres per person per day for a four-person household) and dark green dots indicated households using less than 6 000 litres of water per month (the equivalent of just 50 litres per person). Grey dots were also used to indicate properties where individual household meter readings were unavailable, like sectional title properties or group housing, and properties without accurate water use information.

The final water map was designed as part of behavioural-nudging research conducted by the University of Cape Town Environmental Policy Research Unit. The city had also been working with the UCT researchers to test which interventions are best to 'nudge' domestic users to change their behaviour for better outcomes; in this case, reducing their water use.

The map applied social norms as 'nudge' to save water, by providing feedback on how residents perform in comparison to their neighbours. The map also demonstrated that compliance with the severe water restrictions imposed by the city was not just feasible, but already being done by friends and neighbours.

To begin with, the map made provision for red dots to indicate households that did not comply, but the final decision was to rather highlight positive behaviour. In an already volatile environment, the city did not want to contribute to any stigmatization of households. There were also concerns about infringement on people's privacy, but an assessment of the risk concluded that in the context of the water crisis, there were legal grounds justifying publication of the information. The severity of the potential catastrophe would constitute legitimate defences in any potential defamation proceedings.

## A ROCKY START

Sinclair-Smith says they received negative feedback initially, especially since the map went live before the accompanying media pack was approved and released. Due to the initial backlash in the media, the map nearly got pulled completely. On the flipside, Sinclair- Smith says this really helped put the map, well, on the map. "It got a lot of attention." And, when the official media statement was released, it got even more coverage, leading to the city's website almost crashing due to a sudden increase in traffic.

With the launch of the accompanying media campaign, "lets paint this city green", and extensive information on the website to contextualise the map, it quickly became a valuable and positive weapon in the city's arsenal to further drive down water use. By and large, coverage in the media became well cited and balanced, with further support from the public on various social media platforms.

In the months following the launch of the water map, water saving behaviour increased dramatically. By March 2018, half of the city's households were using only 6 000 litres or less, reaching the 50 litres target. A further 80% were using 10 500 litres or less. By May, 400 000 households were marked with the prestigious green dot. In total, Cape Town's overall water use dropped by 55% from pre-drought levels – the greatest water saving ever achieved by a metropolitan sized city.

## LESSONS FROM THE MAP

The exact contribution of the map would be hard to quantify. The drive to drop water use in Cape Town was a sustained drive from multiple directions at the time. For one, the mayor announced that Day Zero was likely to occur unless more people saved water. Higher water tariffs and more stringent water restrictions were applied. The city ran sustained communication campaigns to motivate people to continuously use less water, supported by easy and practical tips on how to do so on their website. Substantial savings were also achieved by further lowered water network pressure (also see the insert on Cape Town's award winning campaign to driver down water use, which outlines the city's long-term water conservation and water demand management campaign).

As part of the overall effort to decrease water use in Cape Town during times of crisis, the map is seen to have made an important contribution to encouraging behavioural change. There are many lessons to be learnt from the Cape Town Water Map for other cities experiencing a similar crisis, especially for those with high- and middle-income areas where water consumption needs to be lowered. For one, public acknowledgement and reward are powerful forces to drive behaviour change.

To create such a platform, especially one that can be controversial, collaboration across departments is essential. Support from a good communications team is integral, says Sinclair-Smith. In the case of the Cape Town Water Map, other stakeholders included the city's Water Demand Management branch, legal support services, information systems and technology, the Corporate GIS Department, finance and commercial departments. Prompt replies to public enquiries were also important. The city created a dedicated complaints line, especially to handle complaints and enquiries. Quick answers to resolve any questions prevented unnecessary escalation of complaints. Though quick to implement, and a low-cost intervention, he points out that the information systems necessary to have made the water map work effectively should not be underestimated.

Though the map has now been taken offline, the City of Cape Town is still relying on technology to share information with the public. "One of the most important tools that the city has had" is the extended weekly water report on its website that provides real time information to help reduce water consumption (another 'nudge'). This dashboard type report shows dam levels (measured by the National Department of Water and Sanitation) and indicates how much water is available for the region, and whether water restrictions are necessary. It also provides projected dam levels up to the end of the hydrological year (1 October). This gives people more confidence that the situation is being managed, says Sinclair-Smith.

They key, he says, is that during times of crisis you cannot only rely on enforcement for people's support. "When a water crisis hits, you need to bring the public along with you." Savvy use of technology and in Cape Town's case, the water map, were effective tools to help residents understand that, over and above interventions by the City of Cape Town, each and every person needed to follow the same road towards securing water supply for the city that they called home.

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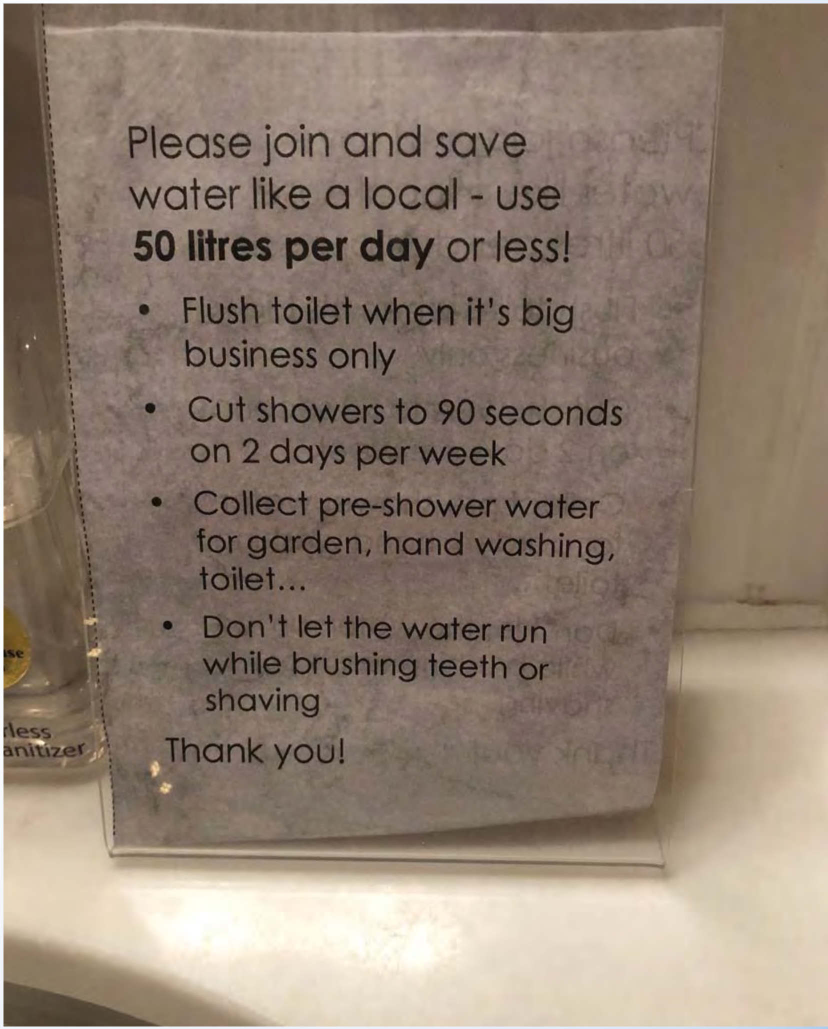


# CHAPTER 06

# REDESIGNING CITIES TOWARDS SUSTAINABLE STORMWATER MANAGEMENT

*One of the most disruptive functions of infrastructure in cities is also one of the least obvious to those who walk along its streets. Our cities upset the water cycle. As a basic premise a city is developed to prevent the natural flow of water from taking place. When people develop an area for occupation, vegetation is the first thing to be removed, usually to be replaced with surfaces such as roads, sidewalks and roofs. While the original land cover was porous and accepted water like a sponge, the latter is mostly impermeable.*

In simple terms, much less rain can infiltrate the soil; a docile and almost unperceivable process that maintains soil moisture and allows water to migrate to surface water or groundwater systems or evaporate back into the atmosphere. Instead, when rainwater hits a hard surface, it rapidly accumulates to run down the most suitable channel, like a street. In cities, rainwater thus becomes stormwater. Urban stormwater is defined as storm runoff from the urban environment and consists predominantly of runoff off areas such as roads, roofs, footpaths and parking lots during rainfall events. Storm runoff from pervious areas like gardens, lawns and vegetated open spaces also contributes when rainfall is intense.

It is reported that urbanisation can increase the runoff rate by up to 50% compared with natural conditions. In extreme cases, the peak flow can be as much as 6.8 times that prior to development.

In cities, unmanaged stormwater is dangerous. As a result, the first purpose of stormwater management and infrastructure is to keep people safe from flooding. Conventionally, water is quickly directed into streams or other natural water bodies via roads and storm drainage systems.

This system has resulted in a number of detrimental impacts the most concerning of which are those that are felt by the waterbodies to which the stormwater is channelled. Not only is stormwater dangerous because of the impact of its flow, but also because of what is in it.

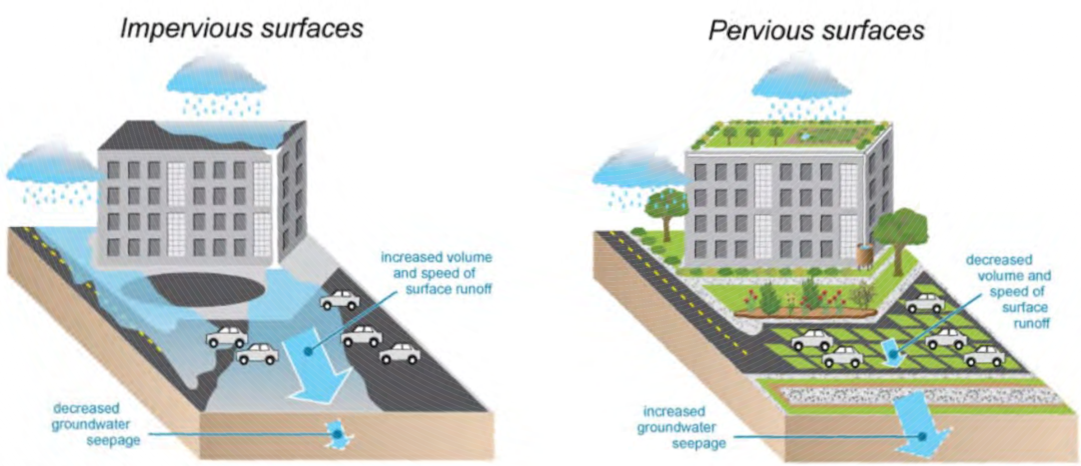
Stormwater is often highly polluted. Though rainfall usually contains very little contamination, this changes drastically as soon as it hits the surface of an urban development. Here, the water picks up microbial pathogens and other hazardous substances that can easily spread via the rivers, lakes and wetlands that the stormwater is destined for. In fact, urban stormwater has become one of the largest sources of contaminants to surface waters throughout the world.

Except for flooding and pollution, there is an array of knock-on effects arising from the replacement of green areas with grey surfaces and the resulting disruption of the water cycle. For one, heat from the sun is dissipated by water that is transferred from the land to the atmosphere by evaporation from the soil, and transpiration from plants. Plants also intercept heat from the sun. Because the vegetated and soil surfaces are reduced in built environments, cities are hotter. In order to keep living conditions comfortable, more energy is necessary to regulate temperatures in buildings, requiring vast amounts of water to generate.

The natural ebb and flow of rivers and other waterbodies is also disrupted as flow conditions change rapidly, leading to significant alteration of the supporting hydrology and ecosystems. Altered channel forms, erosion, siltation and reduced biodiversity are common conditions.

Though the priority for stormwater management is still predominantly to prevent flooding (the quantity of stormwater), it has become clear in recent years that the quality of stormwater should also urgently be addressed, as well as the preservation of the environment into which the stormwater is released.

An alternative approach to stormwater management is to consider it as a resource, and a valuable component of the urban water cycle. This element of Water Sensitive Design is referred to as Sustainable Drainage Systems (SuDS); an approach to (usually nature-based) infrastructure provision which is used to manage surface water drainage systems holistically in line with the ideals of sustainable development.




Impervious 'hard' surfaces (roofs, roads, large areas of pavement, and asphalt parking lots) increase the volume and speed of stormwater runoff. This swift surge of water erodes streambeds, reduces groundwater infiltration, and delivers many pollutants and sediment to downstream waters.

Pervious 'soft' surfaces (green roofs, rain gardens, grass paver parking lots, and infiltration trenches) decrease volume and speed of stormwater runoff. The slowed water seeps into the ground, recharges the water table, and filters out many pollutants and sediment before they arrive in downstream waters.

Conceptual diagram illustrating impervious and pervious surfaces. Impervious surfaces are hard and increase stormwater runoff, causing pollutant and sediment delivery in downstream waters. Pervious surfaces are soft and decrease stromwater runoff, which filters out pollutants and sediments before they arrive in downstream waters.
Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Chesapeake and Atlantic Coastal Bays Trust Fund, 2013. Stormwater Management: Reducing Water Quantity and Improving Water Quality. IAN press, newsletter publication.

In conventional development, infrastructure aims to increase infiltration and decrease runoff. Ironically, key to the sustainable design of stormwater systems is to bring back those characteristics of the water cycle that urban development most stringently aimed to conquer. In contrast to the traditional approaches of stormwater management, sustainable stormwater management embraces the natural water cycle. Additionally, with careful management, stormwater can be used as a valuable resource and viewed once again as a blessing to the community on which it falls.

## SUSTAINABLE DRAINAGE SYSTEMS

*The management of water in cities is traditionally an engineering concern. For example, one of the first tasks is to build a stormwater system, to transport rain away from the city before it can cause a flood.*

"SuDS put water back into the ground," says Prof Neil Armitage, Future Water Institute Deputy Director. Simply put, you get the ground to return to the permeability that you had before development, he says. Armitage explains that the functioning of the urban hydrological environment can be restored through various interventions. "It behaves like a natural system even though it does not look like a natural system."

SuDS is about reengineering our urban drainage system to achieve four things, he says. The first is managing stormwater quantity, with the aim of controlling the amount of run off as close to the predevelopment system as possible. The second relates to water quality, and using the system to treat water to an acceptable standard. The third aim is to change the system into something beautiful, and creating a place where people want to be. The fourth is to use it as method to improve biodiversity and the associated ecosystem services.

A common characteristic of SuDS is that they involve natural (green) infrastructure and aim to mimic the natural hydrological cycle as far as possible. In a water sensitive city, SuDS convey stormwater through a network of vegetation and waterways to create blue-green corridors of open spaces and productive landscapes, although these are also designed to detain water to protect communities downstream from floods.

## TYPES OF SUSTAINABLE DRAINAGE SYSTEMS

Another significant feature of SuDS in comparison to conventional stormwater treatment systems, is that SuDS are distributed as broadly as the places where stormwater is generated. Accordingly, the South African Guidelines divide SuDS into source, local or regional controls in reference to the distance from the stormwater source.

Source controls are interventions that are placed as close to the source of the stormwater as possible, generally within the boundaries of the property. For one, stormwater can be managed by establishing plants on rooftops (green or vegetated roofs). Or, runoff from rooftops can be captured and stored in tanks for reuse (rainwater harvesting). Another common application on a property is a soak-away or rain garden. These are excavated pits packed with coarse material that help to detain runoff and let it infiltrate into the soil. Permeable pavements achieve a similar purpose.

Local controls manage stormwater runoff as a second line of defence, typically in public areas such as roads and parks. Filter strips are vegetated areas to manage shallow overland stormwater runoff through filtration. Swales are shallow grass-lined channels to convey stormwater from one place to another. Trenches filled with large granular material can be built to receive stormwater runoff from adjoining residential properties. Instead of transporting the water away via a culvert and underground pipe network, the water is allowed to infiltrate into the ground instead. Applications like sand filters and bio-retention areas filter and clean the water while managing its flow.

Regional controls are large-scale interventions, often constructed on municipal land. Detention ponds are relatively large depressions that temporarily store stormwater runoff in order to reduce the downstream flood peak. Retention ponds or basins retain stormwater runoff. Constructed wetlands attempt to mimic the characteristics of natural wetlands through the use of marshy areas and aquatic-resilient plants. In the process they can provide more benefits associated with natural wetlands. They can be beautiful, create an open space for people to enjoy and become a productive wildlife habitat.

The design and nature of SuDS are in stark contrast to the characteristics of conventional, grey stormwater infrastructure. It entails veering far away from the known and trusted engineering solutions that we are familiar with. It's perhaps of little surprise that it has seen a relatively slow rate of adoption in South Africa compared with many other parts of the world, but should municipalities be able to overcome the range of socio-institutional challenges, the benefits are multiple and extend beyond the traditional purposes of stormwater infrastructure.

## ADVANTAGES BEYOND THE OBVIOUS BENEFITS

Two of the main benefits of SuDS are the management of stormwater quantity and quality. The application of SuDS results in a reduction of the quantity of stormwater, as water is retained on site and less water is available for runoff. Additionally, more water infiltrates the soil surface to recharge groundwater. This leads to reduced flooding.

It is also widely accepted that SuDS have the ability to improve the quality of stormwater. Depending on the type of control applied, pollutants can be captured and treated through physical, chemical, and biological processes. These functions are performed basically for free and if not, often at a reduced cost in comparison to traditional treatment processes. Analyses of life cycle costs have indicated that SuDS can be 5% to 25% more economical than conventional systems. On a small scale, controls such as green roofs lead to further cost savings due to a reduction in energy costs to regulate ambient temperature. On a larger scale, urban microclimates can be improved.

Healthy waterways further help to maintain healthy biodiversity, creating more pleasant areas to thrive in for people and water-dependent animals and birds. The greening of cities and the preservation of natural features can add to the aesthetics of an area, creating healthier and more resilient urban environments. This can have a positive knock-on effect on property values. The benefits of stable riverbanks and decreased erosion are many. Less infrastructure and agricultural land are endangered, for example, and less silt is released downstream, increasing the lifespan of large infrastructure such as dams and ports.

Over and above these advantages, sustainable stormwater management also advocates for the reuse of stormwater. Increasingly, stormwater is seriously being considered as an alternative, major water source for use by cities. According to WSD principles, stormwater harvesting can be used as a tool to improve water security and resilience to climate change in urban areas. It is seen to be an abundant source of water that can be used for the greening of cities and retaining water in the landscape. Plus, as mentioned, the potential knock-on benefits of protecting valuable waterways from excessive pollution and ecosystem degradation are substantial. With increasing concerns about water security, this source of water has also attracted attention as a potential source of potable water supply.

## STORMWATER AS A NEW TAP OF WATER

The concept of urban stormwater harvesting is slowly starting to see popular uptake. In the majority of Australian cities and towns, for example, stormwater is now accepted as a valuable alternative water source where it is popularly used for irrigation of communal green spaces. In South Africa, stormwater remains a resource almost entirely untapped, though there are increasingly examples from across the country where stormwater runoff is being harvested from large parking lots and commercial properties.

The first major permeable paving scheme in the Western Cape was constructed at the Cape Town Grand Parade next to the Town Hall. The eThekwini Municipality launched a Green Roof Pilot Project. Century City in the Western Cape manages a system to collect stormwater runoff and channel it into a series of detention ponds.

Still, a wide range of factors stand in the way of the broad-scale adoption of SuDS. These include resistance to innovative approaches, fragmented and underfunded water management institutions, a lack of political will, and a shortage of the necessary capacity to operate and maintain the harvesting process.

This is slowly changing as the magnitude of the country's water crisis is becoming clearer, and calls for action more urgent. During the 2016 drought the concept was thrust in the spotlight as part of a suite of alternative water resources under investigation to supplement traditional urban water supplies. Mostly, the view is that the most realistic option would be to store stormwater runoff for non-potable uses like irrigation and flushing toilets.

Though stormwater can be treated to drinking water standards, this option can be costly. However, there is one example of successful, large scale harvesting of stormwater that has been ongoing in South Africa for decades. The award-winning Atlantis Water Resource Management Scheme has proven that reuse of stormwater is feasible, though it is a complex system dependent on expert management (see insert, ***The city that was water wise ahead of its time***).

Part of the hesitance to embrace stormwater harvesting as a viable alternative water resource is because is carries substantial risk. As much as stormwater is a danger to the environment that it is released into, it can be hazardous to people that come in contact with it.

## THE RISKS THAT LURK IN STORMWATER

We really have only a limited understanding of the dangers that lurk in urban stormwater runoff. What is certain is that stormwater contains pollutants, some of which are harmful to humans. Pathogens and micro-pollutant concentrations in stormwater are not well understood, with even less information available about how factors such as rainfall patterns and soil types impact this. It is now accepted that sewage contamination of stormwater is common, carrying with it the number of chemical pollutants abundantly present in untreated sewage such as artificial sweeteners, caffeine and pain medication (e.g. paracetamol and ibuprofen), to name a few.

Inappropriate waste disposal and hygiene habits contribute to the quality of stormwater. Further to raw sewage, household greywater is common, adding food remains, fats and greases, animal blood and tissue to the list of ingredients. The stormwater systems themselves are thus breeding grounds for human disease-causing organisms (pathogens), and attract disease vectors like flies, rats, mice and cockroaches.

Moreover, one of the biggest headaches of stormwater management is solid waste, in particular vast amounts of litter that commonly block the systems. This allows polluted stormwater to accumulate and stagnate, becoming a toxic substance that multiplies the health risks to people and the environment.

Though often touted as a wasted source of water, the way that stormwater runoff is produced by our cities and settlements simply does not allow us to approach it without trepidation. Additionally, the opportunities to realise its potential vary greatly from city to city – as much as the rainfall patterns, topography, geography and land-use vary from one to the next. Each city and settlement thus has to forge its own way forward, choosing elements of SuDS most suitable to their context and, many are. Most cities and towns featured in this publication have made progress with harnessing the potential of stormwater to contribute to their water security. Singapore, Toronto, Atlantis in South Africa (as described in this chapter) and Chinese cities being reinvented as sponge cities are all examples.

In South Africa, some of our largest metropolitan areas have taken steps towards implementing the sustainable management of stormwater, each harnessing the challenges and opportunities unique to their location. Cape Town, Durban and Johannesburg have each walk a substantial way in this direction already, as is described in more detail in the following sections (see inserts on stormwater management in Durban, Cape Town and Johannesburg).

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## THE CITY THAT WAS WATER WISE AHEAD OF ITS TIME - THE ATLANTIS WATER RECHARGE MANAGEMENT SCHEME

In fiction, Atlantis is a city that fell out of favour with the deities and sank to the bottom of the ocean. In South Africa, the town of Atlantis had similarly volatile dealings with the powers that be at its inception, but rather it will go down in history books as a place that rose above one of its biggest challenges. Placed far away from water, Atlantis has become an example of a water wise city long before its time.

Atlantis was established as a growth point according to the apartheid-based development plans of the then-government. Located 50 km north of Cape Town along the west coast, it was to be a coloured-only town with incentives to attract industries. Judging by sight alone, the area displays an almost complete lack of water. Yet, in part due to its unpractical location, it has become an award-winning example of a water resilient city long before many others caught onto the concept. At Atlantis, the traditionally perceived wastewater streams of stormwater and treated effluent were used as major resources of water to create a water secure settlement until some 25 years after it was founded, when additional water was eventually piped into the town from further afield.

### WATER OUT OF SIGHT, BUT NOT OUT OF BOUNDS

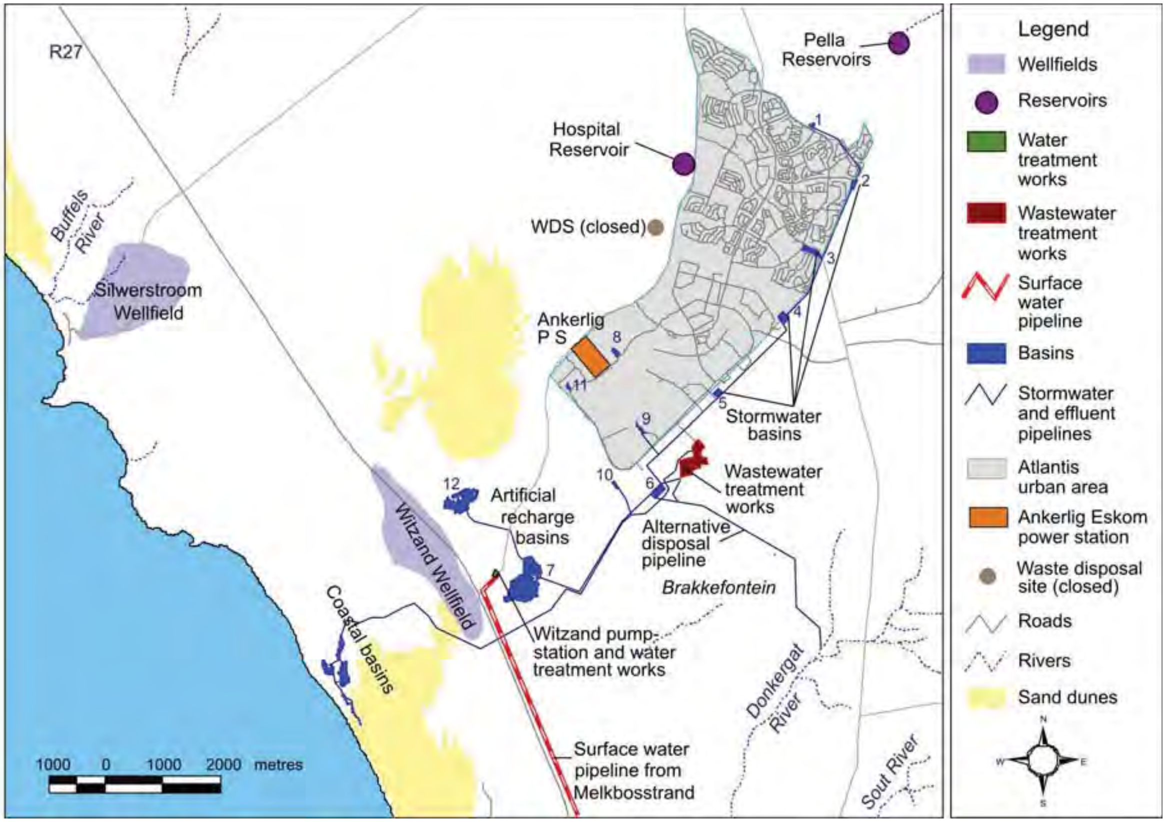
The development of Atlantis started in 1976, planned for growth up to 500 000 residents. Government provided incentives to industry in order to further attract development to the area. Water was initially supplied from a local spring (the Silwerstroom) and boreholes, but it was always understood that these sources would not be sufficient over the long term. The challenge was that Atlantis was located far away from most other feasible sources. The closest was the Berg River 70 km away, where the Misverstand Dam was commissioned to accommodate water demand from Atlantis. This was, however, far too far in the future to ease the then concerns of water supply.

Town planners and engineers had to make another plan. For a solution, they turned their eyes underground. Atlantis experiences a semi-arid type climate with the majority of the 450 mm annual rainfall received between the months of April and September. Up to 30% of this water drains into the aquifers that the town has abstracted its water from since its establishment. The town actually rests on the Atlantis aquifer, a groundwater system that covers an area of about 130 km$^2$ inland from the Atlantic Ocean to the town itself. The groundwater enters the aquifers through the sandy surface, in particular, at the bare sand dunes, and then flows towards the coast down a relatively steep gradient.

The aquifer originally drew the attention of town planners because of changing legislation regarding the discharge of wastewater to the sea. It used to be a common method of getting rid of wastewater along South Africa's coast, but by the 1970s public disapproval increased. At the same time, government started seeing the practice as a waste of valuable water. This eventually led to a change in legislation that necessitated municipalities to make alternative plans with their wastewater.

At Atlantis, the recharging of stormwater and treated wastewater into the aquifers via the sandy soils started in 1979. Unusual for the time, it was also to here that town planners and engineers turned their attention when novel plans had to be made to ensure a secure water supply for the town. They decided to shift their focus to recharging and recycling water in order to increase the yield of the aquifer sufficiently to meet the long-term water needs of the town.

This decision resulted in major developments. First, the addition of stormwater to recharge the system and eventually, the separation of domestic and industrial effluent to allow for recharge of the highest quality water in the areas of greatest importance. As a result, the Atlantis Water Resource Management Scheme (AWRMS) could make use of treated domestic effluent, all of the domestic stormwater, and most of the industrial stormwater for recharging the aquifer. Throughout, the undertaking was also that no water of a lesser quality should be put back into the aquifer. As a result, the town was supplied totally from groundwater for over two decades, while enhancing the local environment in the process.




*Layout of the Atlantis Water Recharge Management Scheme.*

## THE ATLANTIS WATER RECHARGE MANAGEMENT SCHEME (AWRMS)

In a nutshell, the AWRMS is a great example of managed aquifer recharge, or MAR, in practice. MAR is an indirect water recycling method through the transfer of surface water underground and the subsequent storage in an aquifer either via infiltration from basins, dams or ponds or through injection boreholes. In this way water can be stored during wet periods or when there is a surplus, and abstracted during dry periods. The practice also conserves water and the environment. It negates the need for dams, and because it is stored underground, minimal water is lost to evaporation. In addition the water is relatively safe from contamination and the porous medium (in this instance, sand) through which it infiltrates acts as a filter for improving water quality.

Part of the relative ease with which the practice has been applied at Atlantis is due to town planning. The layout of the town allows for the separation of stormwater from the industrial and residential areas as well as separate treatment of domestic and industrial wastewater. Stormwater and industrial wastewater are channeled into separated systems to each undergo sufficient treatment.

Domestic wastewater undergoes full treatment and is sent towards a series of maturation ponds. Stormwater from the residential areas is collected in a system of detention and retention basins and blended with the treated domestic wastewater before being discharged into the main recharge basins for artificial recharge of the Witzand wellfield.

The stormwater from the industrial area is more saline, and is discharged into different recharge basins along the coast, from where it seeps into the ocean through the subsurface. This also helps to mitigate potential seawater intrusion into the aquifer.

Water for the town residents and industries is then abstracted from the Witzand and Silwerstroom wellfields. The first contains a blend of natural and recharged water, and the second contains natural groundwater. It is estimated that the groundwater abstracted as part of the AWRMS represents a blend of 30% water derived from recycling and 70% natural groundwater. The performance of the water recycling system at Atlantis has shown itself to be relatively robust with respect to the elimination of contaminants, and based on present knowledge, the recycling of the water does not present a threat to the drinking water supply.

## A COMPLEX SYSTEM REQUIRED EXPERT MANAGEMENT

The AWRMS is a complex, large-scale system that depends on specialised management. Long-term sustainability of the system depends on proper maintenance of all components, requiring a multi-disciplinary approach. The challenges are many.

Emerging contaminants and varying quality of groundwater throughout the system are some of these challenges. The erratic quality of urban run-off and wastewater add further trials. As fine sediments and organic material settle on the bottom of recharge basins over time, clogging leads to decreased infiltration to the aquifers. If too much water is extracted from the aquifer the water levels drop, allowing air into the system and disrupting the balance of the natural ecology at the borehole site and potential fouling of the water. Uncontrolled abstraction by illegal small and medium scale users, and invasive alien plants affects prediction of what exactly the sustainable yield is. The natural characteristics of the aquifer material, such as calcrete and calcareous sands affect the groundwater quality, creating a hardness to the water. Furthermore, the Atlantis aquifer is unconfined and thus vulnerable to pollution from several other sources.

## LOOKING BEYOND ATLANTIS

The planned water supply to Atlantis from the Berg River system was never realised, and since 2000 the town's water supply has been linked to the Cape Town distribution system, with limited quantities of surface water available from a reservoir at Melkbosstrand. The town also never reached the maturity and potential that was originally envisioned, and it was later amalgamated with the metropolitan area of Cape Town. A 2011 census reported a population of just over 67 000 residents.

Still, the town stands as a good demonstration of stormwater harvesting and treated sewage effluent reuse at scale. Ultimately, the Atlantis Water Resource Management Scheme has proven itself as an innovative and highly successful scheme that supplies bulk water both for drinking and industry and has shown that these types of recharge schemes are feasible.

A pioneering innovation at the time, it resulted in new thinking regarding stormwater and wastewater systems in the Western Cape and beyond. For one, it led to the concept of 'natural groundwater recharge' being included in the City of Cape Town draft stormwater by-laws. Furthermore, lessons from Atlantis contributed to the development of the Departments of Water Affairs and Forestry's National Artificial Recharge Strategy in 2007.

The city of Atlantis has a checkered past but it has shown that bulk reuse of stormwater and wastewater is possible, and sustainable. As such, the legacy of Atlantis has not become one of the failures of the past, but rather an example of how to meet the future.

## THE ROAD OF STORMWATER IN CAPE TOWN

*Cape Town's stormwater system is a combination of built stormwater infrastructure and natural systems. The rain that falls on the city itself mostly drain as stormwater into the sea.*

*Milnerton lagoon, part of the city's natural infrastructure for stormwater management.*

Cape Town is a place like no other, as is evident in the millions of local and international visitors that stream to the city's famous shores each year. A large part of its attraction is the natural environment that it's built on – not only the famous Table Mountain, the endless beaches and the icy sea, but also a vast array of rivers and wetlands. In Cape Town, life takes place in close collaboration with nature, and the city is intimately dependent on its ecological services.

"Cape Town is very unique," says Richard Nell, Head of Strategy Specialist Support for the City of Cape Town's Catchment, Stormwater and River Management Division. Nell explains that Cape Town actually sits on 21 catchments, which are the mainstay of its stormwater system. Though the city mostly depends on rainfall for its water supply, this is imported via a supply system of six dams outside the municipal boundaries. The rain that falls on the city itself mostly drain as stormwater into the mentioned rivers to the sea.

The system that keeps the city safe from flooding is actually a combination of built stormwater infrastructure and natural systems. The backbone of the stormwater system is approximately 1 920 km of rivers and 7 800 man-made and natural wetlands. Built infrastructure includes 5 100 km of pipes, 500 km of channels and canals, 10 stormwater dams, 892 detention ponds, 35 pump stations and 64 rainfall and flow monitoring stations.

The challenges that the city faces regarding stormwater management, are similar to the problems experienced by cities across the globe. Nell lists some of these to include ageing infrastructure, failure of small pump stations and "development that gets ahead of itself". Urban growth is outpacing the capacity of the stormwater infrastructure, he says. In Cape Town, challenges like these are exacerbated during the winter rainfall season, when water from the stormwater system can overflow into the sewage treatment works and overload the infrastructure.

Pollution is another problem. Litter, garden waste, dog faeces and industrial pollution are but some of the endless list of things that contribute to contamination.

Nell says that they also often encounter some forms of sabotage. People put things like mattresses and lawnmowers down the system which causes blockages and overflows, he says. "Throughout the city there are huge pollution problems."

Though the bulk of the city's stormwater management to date has focused on managing runoff quantity and quality, the municipality was one of the earliest in South Africa to embrace the principles of SuDS, towards becoming a water sensitive city.

## STEPS TOWARDS A SUSTAINABLE DRAINAGE SYSTEM

These efforts started around 2005, says Nell, and resulted in the promulgation of two policies in 2009 both of which took their lead from the water sensitive cities concept in Australia. ***The Management of Urban Stormwater Impacts Policy*** aims to "minimise the undesirable impacts of stormwater runoff from developed areas by introducing Water Sensitive Urban Design principles and SuDS to urban planning and stormwater management in the Cape Town metropolitan area." The second, ***The Floodplain and River Corridor Management policy*** recognises the importance of watercourses and wetlands to the stormwater management system, the city's biodiversity network, and recreational and economic opportunities. The objectives of this policy are to reduce the impact of flooding on community livelihoods and regional economies, safeguard human health, protect natural aquatic environments, and improve and maintain recreational water quality.

Nell says that the concept of SuDS was initially a tough sell, and the uptake slow, especially from technical experts. "Roads engineers traditionally look at stormwater as the enemy, and that's a difficult mindset to change." Since then the municipality has progressively been taking steps to incorporate the concept further into development plans. For one, the management of catchments and stormwater was moved from the previous Roads and Stormwater Department, to fall under the jurisdiction of Water and Sanitation. "In the past we use to issue directives against the sewage department, but now we collaborate with them," says Nell.

While the city's stormwater bylaw and the two policies are under review, a green infrastructure plan is in process to help sustainable management of valuable natural infrastructure. A comprehensive water resilience strategy is also being written, that will identify resilience challenges and opportunities for the city.

Though the municipality has been working away at more sustainable stormwater management for years, the topic was thrust in the spotlight during the recent water crisis, when stormwater was punted as an untapped water resource going to "waste" seeing as very small amounts of stormwater is currently put to use. Nell puts a rough estimate at less than 10%. However, he points out that changing this is not as simple as it may seem.

## HARNESSING THE STORMWATER POTENTIAL IN CAPE TOWN

The biggest problem of stormwater harvesting in a winter rainfall region is that you're receiving the water when you don't need it, he says. The water thus needs to be stored somewhere until necessary, usually in a dam or reservoir, large infrastructure for which very limited space is left in Cape Town.

Storing the water is not the only challenge. First, it has to be captured. Some of the municipal rivers are short, with small catchments, leading to quick runoff during rain. Should you try to capture the water upstream, time to do so is even more limited, while attempts to capture the water close to the outfall leaves the upstream system vulnerable to floods. Furthermore, the infrastructure underlying the city has been built to accommodate water pumped from outside, limiting its capacity to transport a sudden increase of water supply from sources within.

While storage and transport are issues, so is water quality. Seeing as Cape Town's main water supply is from outside the city, this is also where the potable water treatment plants are located. Should water be harvested in the city, it would call for construction of suitable treatment facilities too.

There are small stormwater harvesting schemes currently active in the city for purposes of irrigation as one example, but Nell says the challenges particular to Cape Town has led to the general idea that stormwater harvested here would not be stored, but rather be treated to a suitable quality to be returned to the rivers, in order to abstract less water from dams. Taking this in mind, the city is in the process of writing a stormwater harvesting strategy.

**Bringing Capetonians back to the rivers**

One of the biggest thing we have to get right is to attract people back to the rivers, says Nell. "The minute people see rivers as an asset they will care for them better." Nell mentions places like the Kruger National Park and Singapore as examples. Though these are vastly different environments, they are both places where rivers are revered, and favourite destinations for visitors to relax and enjoy. As a result, there is strong public sentiment for their conservation. "In Cape Town many of the rivers and wetlands have become places where people don't want to be." Instead, the rivers are used as dumping grounds, rather than public spaces to enjoy and conserve.

This will be addressed in the strategies under development. "We are working towards livable urban waterways," says Nell. This includes creating places where people can grow gardens and spend their leisure time. "We want to open up canalised rivers to create blue green corridors throughout the city," he says. These will create pleasing spaces for people to enjoy, while serving practical purposes like water quantity and quality management.

The difficult thing is to change people's mindsets, he says. Should the municipality be able to do this, both within the public domain and governmental spheres, Cape Town too can become a place where the rain is embraced once again.

# DURBAN'S JOURNEY TOWARDS SUSTAINABLE STORMWATER MANAGEMENT

*The eThekwini municipality's Environmental Planning and Climate Protection Department initiated a Green Roof Pilot Project, which consists of two adjoining flat-topped roofs at eThekwini Engineering Services, planted with different varieties of vegetation in small, tailor-made planting trays.*

Petro Kotzé

*Randeer Kasserchun, Deputy Head of the municipality's Coastal, Stormwater and Catchment Management Department.*

eThekwini Municipality

*Solid waste is one of the biggest challenges to stormwater management at the eThekwini municipality.*

The eThekwini Municipality is located on the East coast of South Africa overlooking the Indian Ocean. The municipality spans an area of approximately 2 555 km$^2$ and is characterised by a rich and diverse biodiversity distributed over a steep and dissected landscape. The area contains 98 km of coastline, 18 major river catchments, 16 estuaries and 4 000 km of river. The city of Durban itself lies low in the catchment. It lies right at the bottom in fact, in the vicinity of the mouth of the Umgeni River.

Durban's location is at once a blessing and a curse. It has ensured access to the city's world renowned beaches, but places it squarely in the way of rainwater on the way there. Durban is thus familiar with flood events.

This creates a number of unique challenges, accentuated by the demographics of the people that call it home. The bulk (around 68%) of the municipal area is considered rural with pockets of dense settlement. About 10% of the rural areas comprise commercial farms and metropolitan open space, while the rest is made up of hilly, rugged terrain with dispersed settlements. The remainder of the municipal area (approximately 32%) is urban and dominated by residential, commercial and industrial land uses. Large numbers of informal settlements are scattered across the city, in particular towards its borders and often on steep land or flood plains. The hilly terrain, expanding urban environment and increase in informal developing areas have resulted in a populace vulnerable to the numerous detrimental impacts of stormwater, including floods, erosion and pollution.

## MANAGING STORMWATER IN DURBAN

To keep its residents and the city infrastructure safe from the impact of stormwater runoff, the municipality maintains just over 3 600 km of stormwater pipes, over 171 300 manholes, 620 km of culverts and canals and 19 detention ponds. There are also a number of attenuation ponds that slow down the flow of water during floods but mostly, the stormwater system collects the rainwater and transports it directly to the rivers and the sea without treatment.

As is the case with most cities across the world, the system is designed to cater for the probability of floods, reflected most tangibly in the size of the pipes that the water has to go through. The system is built according to the return period of floods – or the estimated average time between floods. This statistical measure is typically based in historic data over an extended period of time.

In Durban, the system is designed to cater for minor and major floods. Inlets at the side of the road, for example, are designed for a one in three-year return period (a small storm). Major systems like canals are designed for one in 50-year return periods or much bigger storm events, says Randeer Kasserchun, Deputy Head of the municipality's Coastal, Stormwater and Catchment Management Department. "When you get a storm that exceeds the design capacity, you expect flooding," he says. In this way, Durban has been maintaining a relatively acceptable balance with the stormwater that it generates. In general, the impact of rain is negligible, but sometimes more rain falls than what the capacity of the system can handle, and this results in floods. However, the system is increasingly feeling the pressure of a changing environment, swaying the balance in favour of those times that the system cannot achieve its primary purpose anymore.

## DEVELOPMENT AND THE URBAN STORMWATER SYSTEM

For one, the eThekwini municipal area is home to a rapidly growing population. In 2001 it was 3.09 million, growing at an average of 1.13% each year to reach 3.44 million in 2011. By 2016, the population was some 3.6 million people. Projections place numbers at 4.4 million by 2030, though high rates of in-migration make the exact number difficult to project. Housing and services in the municipality is increasing accordingly, but will have to be cranked up more in future.

The high levels of developments and urbanisation within the catchments has led to a dramatic increase in the velocity of river flows, resulting in flooding, bank erosion and destabilization of riverbanks. "People expect all of that extra water to go into a pipe, but it was designed to only cater for a specific proportion of water," says Kasserchun.

Except for the quantity of stormwater runoff involved, its quality is a big headache to managers. In particular, trash has become a forceful foe to reckon with. "For us, the biggest problem is pollution," says Kasserchun. We have both soluble and non-soluble contaminants in the water, so while water quality is a challenge we also get huge blockages caused by litter, thus impacting negatively on the stormwater system capacity, he says.

eThekwini Municipality

*Increased the velocity of river flows, resulting in flooding, bank erosion and destabilisation of riverbanks throughout the eThekwini Municipality.*

The results are showing in Durban's rivers and estuaries. In 2010, an estimated 40% of rivers were considered to be in a poor condition and only six (or just over 3%) were classified as near natural. Only about 10% of the total municipal estuarine areas were classified to be in good condition. The results are due to impacts from multiple sources, but the poor quality of stormwater is an important contributing factor.

The effects are felt far and wide. The rivers become highways that transport stormwater pollution to Durban's famous beaches, a huge drawcard for the tourism-dependent city. And, says Kasserchun, the poorest of the poor, often still directly dependent on the services offered by the rivers and streams that they live next to, is frequently most harshly affected.

## TOWARDS SUSTAINABLE MANAGEMENT OF STORMWATER IN DURBAN

The municipality has been driving various initiatives to manage the quantity and quality of stormwater generated by the area under its jurisdiction. Building regulations ensure that stormwater runoff from individual properties is reduced, says Kasserchun. The stipulations are provided in the municipal ***Guidelines and Policy for the Design of Stormwater Drainage and Stormwater Management Systems***, which places the onus of managing and reducing runoff in the hands of the property owner that is contributing to the increasing impermeable surface area of the city with his development.

Historically, municipal infrastructure provided for conventional piped stormwater systems designed on the basis that not more than 40% of the area of the residential properties would be hardened. This is no longer the norm since many properties have extensively hardened their sites with patios, canopies, entertainment areas and pool surrounds. Commonly, there are now more driveway and parking areas and larger garages. All of these improvements increase the stormwater generated from the sites, necessitating the onsite management, harvesting and retention of rainwater. Now, the owner of any development connected to the eThekwini municipal stormwater system, of which more than 40% of the surface is hardened, must manage the excess runoff generated from his site. "We would not approve your development if you do not adhere to this stipulation," says Kasserchun.

The policy stipulates preferred options to manage stormwater runoff, as well as options to retain it, or harvest it. The guidelines then provide direction for the best way to do this. Soakpits (which allow rainwater to infiltrate into the groundwater table, or to tanks for reuse) are suggested as the better, responsible and preferred option of management. Guidance for a range of other controls is also supplied, such as attenuation ponds and stormwater harvesting tanks. In this way the municipality is actively driving the promotion of rainwater harvesting for use in gardens, to flush toilets and wash cars, for example. The guidelines accordingly stipulate that paving, surfaced driveways, pool surrounds and so forth should mostly drain to buried tanks unless the topography allows otherwise.

Green roofs is seen to hold great potential in Durban. The municipality's Environmental Planning and Climate Protection Department initiated a Green Roof Pilot Project (GRPP) in 2008 to assess the effectiveness of green roof habitats in Durban to reduce temperatures and stormwater runoff, and results proved to be very promising. As part of the initiative, guidelines for the design of green roof habitats was developed.

Large-scale harvesting of urban rainwater across the city is however hampered by its location. "We are right at the end of the catchment, so for us to catch and use large-scale stormwater runoff we'd probably have to pump it upwards again for storage somewhere," he says. Not only would this result in added costs and infrastructure, but it's also not practical to create a dam in Durban.

Sustained campaigns have also been driven to improve the quality of stormwater runoff across the municipality. For one, nets have been constructed at some of the main catchments of the area to capture the vast amounts of litter before it washes downstream. Here, Kasserchun sees one of their biggest challenges to change people's mindsets about their contribution to challenges that the municipality has to manage. The municipality now runs regular clean-up and awareness campaigns throughout the municipal area, with staff regularly visiting communities to conduct educational campaigns. "Our catchment management education work is extremely important." Kasserchun says they also focus heavily on schools. "We aim for the messages to be taken home by the children from school," he says. "When a parent wants to throw their cigarette butt out of the window, the hope is that the child will tell them not to do that."

Moreover, Durban is busy using the work necessary to keep its rivers and catchments clean as an opportunity to create jobs and inviting living spaces for people.

In this way, the city is taking small and consistent steps towards the large goal of becoming a resilient and livable city. In the process, their outcomes and achievements can already serve as example of how other cities and settlements can follow them there.

## JOHANNESBURG STORMWATER MANAGEMENT


*City of Johannesburg's Deputy Director for Open Space Planning, Jane Eagle.*

*Challenges to stormwater management in the city include blockages and infrastructure failure.*

Founded in 1886, Johannesburg is one of the world's youngest major cities, but the metropole grew up fast, quickly taking on enormous proportions both in size and impact. Expanding from a tented camp, to a town of tin shanties, it soon morphed into a city of modern skyscrapers to become the commercial, industrial and financial hub of South Africa.

Joburg straddles a major watershed, the Witwatersrand, from which rivers flow either into the Indian Ocean to the east, or to the Atlantic Ocean in the west. Potable water for the city's over-4 million residents is imported (purchased in bulk from Rand Water) and pumped about 50 km from the region of the Vaal River. This source, again, is supplemented with water transferred all the way from Lesotho via the Lesotho Highlands Water Project – Africa's largest ever water transfer project. Rain on the city itself usually falls in short, sharp showers in the summer (between September and April) and the area is known for thunderstorms and occasional hail.

As with cities elsewhere, the approach to stormwater drainage in Johannesburg has been to convey runoff as rapidly and efficiently as possible. Here, it happens via a combination of man-made infrastructure and natural features towards 12 river systems and 106 dams within the municipal boundaries. This is complimented with detention or retention ponds, as well as wetlands and other natural features that retain water.

The ongoing rate of development has not been without consequence, and the stormwater system in particular, as well as the environment that it has an impact on, is showing the strain. The entire system is described as being under severe stress, with many parts functioning close to or beyond peak capacity. Inadequate maintenance and budget constraints contribute to the crisis with estimated annual clean-up costs associated with rain and stormwater (as reported in 2007/8) spiraling to R25 to 30 million, the bulk of which is for clearing of stormwater drains from major blockages. Most natural features have been severely degraded over the years, with wetland areas progressively in-filled and drained to accommodate the ever increasing demand for urban development. In addition, portions of natural watercourses have been canalised in an attempt to address degradation. All surface water quality within the city has been severely impacted by urbanisation, blocked sewers, aging infrastructure and litter transported by stormwater.

Coupled with an increase in hard surfaces, the runoff patterns and peak flows of rivers in Joburg have also been dramatically altered. Though the city suffers from water scarcity at times, it is thus also familiar with floods. Already, the problems associated with the quantity and quality of stormwater in Johannesburg has a substantial detrimental knock-on impact on the health and safety of its residents, but infrastructure is set to be further impacted by climate change, likely to aggravate existing issues, including increased volumes of stormwater and flooding overloading the already overburdened system.

The alarm has been raised, and numerous reports have highlighted these, serious concerns regarding the city's stormwater (and sanitation) systems.

However, where there are big challenges, there is large room for improvement, and Johannesburg has encapsulated these in policies that are laying the groundwork for progress towards increased water resilience through stormwater management.

"Stormwater is an untapped resource that can help to offset potable water supply or supplement and reduce the pressure on the stormwater system downstream", says Jane Eagle, the City of Johannesburg's Deputy Director for Open Space Planning, that falls under the Department of Environment and Infrastructure Services. "To me it is underrated, and offers many solutions," she says. The flagship work that has been done in this regard in Johannesburg is encapsulated in the stormwater bylaw and draft design manual.

## LAWS AND REGULATIONS FOR STORMWATER IN JOHANNESBURG

The Stormwater Management By-laws were promulgated in 2010, and addresses some of the key issues regarding stormwater management in the city. The ***Stormwater Design Manual*** recently developed takes these further and emphasises the retention and attenuation of stormwater at source, stipulating that the developer must attenuate runoff if the development covers more than 500 $m^2$ with impermeable surfaces. The draft ***Stormwater Design Manual Guidelines*** provides detailed requirements for stormwater attenuation and for discharge into the receiving environment. The city has also just embarked on a feasibility study for regional attenuation for supplementing water supply.

"We are making headway," says Eagle. The stormwater design manual contains "quite revolutionary stipulations", including requirements for attenuation at all scales and for ensuring that runoff meets certain quality standards, reducing the negative impact on the receiving environment and improving the health of the City's rivers. In this way, sustainable stormwater management is also seen as key to creating a more resilient Johannesburg in the face of climate change. This includes the basic principles of increased infiltration to decrease runoff and reduce the impacts of floods.

Critically, the guidelines also addresses the quality of stormwater generated by a property. "It gives you the option to look at complex filters contained in natural systems and green infrastructure," says Eagle. "We are making a call for more green solutions which mimic natural systems," she says.

However, though the groundwork has been laid by the Stormwater Management Bylaws, among others, the benefits have been hampered by slow implementation. Eagle says there are a number of challenges to overcome to ensure that there is compliance.

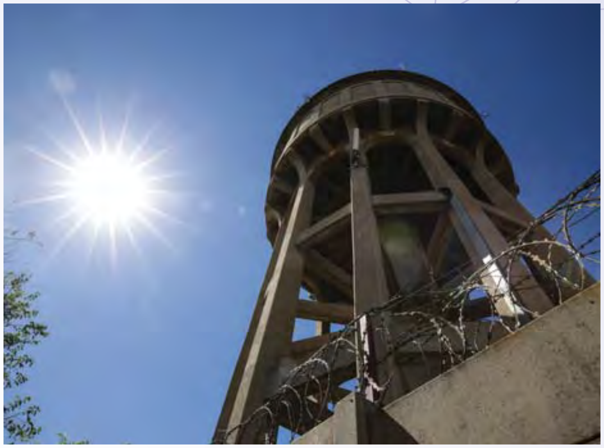
For one, implementation of the policies is held back by a fragmented institutional model, as the provisions need to be applied by both the Johannesburg Roads Agency, as well as Environment and Infrastructure Services Department. Not only are roles and responsibilities unclear, but the mandates are often conflicting. Traditionally, stormwater was regarded as only the domain of roads departments or entities as they have a responsibility to keep the city safe from flooding, and to ensure that stormwater is efficiently conveyed off sites and roads.

Increasingly, however, stormwater and urban drainage is a concern also for Environment and Infrastructure Services due to the substantial impact that stormwater runoff has on the receiving environment and natural systems. "Building relationships are important, but this requires ongoing effort" she notes.

Another challenge is a lack of knowledge on the bigger-scale application and impacts, as well as the skills and experience both in-house and within the profession to correctly apply this and to develop innovative, integrated solutions in terms of a changing paradigm. There are also practical and real challenges in regard to maintenance. Pilot sites to test and demonstrate effective application of concepts are necessary, but currently lacking.

A range of roleplayers also need to be brought on the bandwagon. "Engineers, architects and property developers need to be convinced of the validity and co-benefits of these concepts and then take the baton and run with it," says Eagle. There is thus also a need for champions.

As is the case with all of the cities mentioned here, the transformation of mindsets as key to achieving any success. "I'm not saying sustainable stormwater management is easy," she says. "The question is rather, if we take the rate of development, the increased scarcity of water, and the lurking dangers hidden in our current urban infrastructure in mind, if we can afford not to try."



*Water to keep the greater Johannesburg are running is pumped from far outside the city.*

*A sidewalk garden.*

# CHAPTER 07

# RETHINKING WASTEWATER FROM PROBLEM TO OPPORTUNITY

*There are many reasons why people choose to move to cities, from seeking better living standards to improved access to services. According to the United Nations, between 1998 and 2008, 1 052 million urban dwellers gained access to improved drinking water and 813 million to improved sanitation – numbers that are projected to grow.*

Globally, the Sustainable Development Goals have provided a blueprint to achieve a better and sustainable future for all. In a global effort to achieve these, countries, cities and industries have committed themselves to a future with universal access to safe water and suitable sanitation. At present, the balance of access to these services is slanted towards cities. Of the 39% of the global population (2.9 billion people) that use a safely managed sanitation service, most live in urban areas; as much as three out of every five people. Two out of five people in rural areas across the globe have access to piped water, while four out of every five people in urban areas enjoy this privilege.

The more people have access to water, the more water is necessary to feed the system and is abstracted from natural resources. As the amount of water used by people increases, so does the amount of water being contaminated. At the same time, more and more urban areas and settlements are having difficulty with guaranteeing water security to residents. As this is happening, it is becoming clear that we are letting valuable water slip away.

Our perception of wastewater must change. An entire rethink of the traditional wastewater treatment model is necessary. In this new paradigm, 'dirtied' water is not a problem to be managed, but rather an opportunity to be harvested for the shared benefit of the water user, water management utility and the environment. While wastewater also emanates from industrial sources in cities and settlements, this chapter mainly discusses domestic wastewater.

## WHAT IS DOMESTIC WASTEWATER?

As mentioned in chapter 4, roughly 23% of South Africa's freshwater is used by municipalities. This water is the oil that keeps the machinery of households running, though it mostly only passes through – entering the house as clean water of a quality fit for drinking, and then swiftly exiting the property again after it has been used, since it is now perceived as being dirty and, often, dangerous to our health. Most commonly, water that travels along this route is used to flush toilets, shower, bath and wash laundry and dishes.

Vast volumes of water are also used outdoors for gardens, although this water does not leave the property as waste. Rather, this water finds its way back into natural system. Some water evaporates, or infiltrates back into the groundwater table. A small amount of water could also run into the stormwater system; when water runs down paving after washing cars or from over-watering gardens.

The water that does not enter the natural or stormwater systems after it has been put to work, the so-called wastewater, is what is progressively understood as one of the new taps of water resources to be developed. In fact, some would say that used water is our most under-exploited resource of available water. The practice of reusing wastewater is already common in some countries, while others are taking steps in that direction. Singapore, for example, sees wastewater as one of the central pillars that its future water security is built on, and is already using it to supply part of the city's water needs. In Australia, this change is being made by private developers (see block, ***A development that took wastewater treatment off the grid***). Wastewater has also been part of the mix of water supply to Atlantis for decades.

In general, the wastewater produced by households can be divided into greywater and blackwater. Blackwater is water from toilet waste, and is commonly collected via sewer systems. This water is characterised by high concentrations of potentially disease-causing microorganisms, high organic loads (animal and plant remains) and high concentrations of nutrients, is typically dark in colour and smells. Although more controversial, especially from a users' perspective, the reuse of treated effluent is becoming more common. In Windhoek, for example, the practice has been ongoing for decades (see insert, ***The potential in our sewage***).

Greywater is mostly untreated wastewater from all household uses except for toilets, although water from kitchen sinks and dishwashers is sometimes excluded. Also referred to as greywater, sullage and light wastewater, it contains some nutrients and microorganisms but usually at a much lower strength than blackwater, so its reuse is slightly easier to navigate.

The quality of greywater influences what it can be used for. Since testing the quality of greywater produced in a household is in general not practical (it requires specialised equipment), it is often classified according to where it is generated. In South Africa, greywater is divided into light (class 1 and class 2) and dark (class 3) greywater, as follows:

- Class 1a: Bathroom greywater – greywater sourced from showers
- Class 1b: Bathroom greywater – greywater sourced from basins and baths
- Class 2: Laundry greywater – greywater sourced from laundry basins and washing machines
- Class 3: Kitchen greywater – greywater sourced from kitchen sinks and dishwashing machine.

## THE APPEAL OF WASTEWATER REUSE

The first obvious appeal of household wastewater is that it increases the amount of water available for us to use. As mentioned earlier, urban areas use vast amounts of water; as water use increases so does the volume of wastewater increase. Should wastewater be used instead of freshwater, the sources that the freshwater is abstracted from are also conserved. As such, pressure on freshwater resources is reduced. It has been reported that, in some cases, residents of developments that make use of wastewater can save up to 50% of potable water compared with those that don't.

**A development that took wastewater treatment off the grid**

Instead of the traditional route, developers of the Currumbin Ecovillage in Australia decided to search for new and sustainable solutions to their wastewater treatment challenges. The village is not connected to the main sewer network, so all wastewater treatment and reuse needs to be done on site. The award-winning solution has created a community that has an extremely low impact on the environment, on local and regional sources of water, and on local waterways. It is the first example in Australia of an urban development that remains 'off-the-grid' for water, including the collection, treatment and reuse of wastewater.

The Currumbin Ecovillage is a 147-lot development over 1 000 km$^2$ of land in the Gold Coast Hinterland in southeast Queensland. The development contains community title blocks which range from 400 to 1400 m$^2$. A sewage treatment and water reclamation plant that makes use of membrane filtration and ultraviolet (UV) disinfection to treat the wastewater from the development was constructed on site. The plant accepts and treats all wastewater which is then provided back to the houses in a purple pipe for toilet flushing and to use outside. Excess water is used to irrigate the common property in the development.

The fully decentralised solutions selected for Currumbin cannot be applied directly to mainstream urban developments, but the use of a decentralised wastewater treatment plant to treat and supply recycled water back to households can be replicated in areas where connection to the main sewer network is difficult or expensive.

Although the upfront cost of the treatment plant is more than its conventional counterparts, the ongoing costs to the residents are less, and the knock-on benefits are ample. Less pollutants enter waterways, and the use of recycled water for local irrigation supports a cool and green urban development. Residents are also able to reduce their potable demand and thereby save their rainwater other purposes.

*Source: www.watersensitivecities.org.au*

Not only does the use of this water help to build security in our water reserves, but it can also result in improved water quality if the wastewater with its typically high nutrient loads is prevented from entering into the environment.

These nutrient loads can also be put to use elsewhere. Using wastewater is appealing not only because of the water, but what it contains. Used water is enriched with energy, organics, phosphates, nitrogen, cellulose and other resources, and recovering these nutrients and the energy embedded in the water is an opportunity waiting to be seized. These can, in turn, lead to financial gains that can cover some of the operations and maintenance costs (see insert, ***New Cairo wastewater plant***).

Using wastewater, instead of getting rid of it, thus opens up a host of opportunities to address water security, improve public health and lead to socio-economic development.

## WHAT CAN WE USE IT FOR?

Because of the potential risk to human health, recycled and treated wastewater in South Africa has historically mostly been used to water recreational facilities such as sports fields, city parks or plants that are not meant to be eaten. In rare cases this water is used irrigate fodder, but this is regulated by strict guidelines in order to protect people and the environment from any potential detrimental consequences.

This situation changes when water becomes scarce. When limited other options are available, greywater in particular is commonly used for gardening, especially in middle to upper income suburbs. In lower income, informal and peri-urban areas, people tend to use it to also water vegetable and fruit gardens, though this is not done without health concerns. (See block: ***The risks of using greywater***). Still, greywater can contribute to food security in low income settlements, offering both water and nutrients for crops.

This difference in greywater quality and use, depending on people's living arrangements, is an important consideration in South Africa, since urban growth here is shaped by both formal development and vast informal settlements.

In fact, the development pathway of a settlement has vast implications for its greywater. Not only do people living in formal urban areas tend to use greywater for different functions than residents in informal areas, but the quality of the greywater produced from these areas differ greatly. This has substantial implications for the potential reuse, and management of greywater in South Africa.

### The risk of using greywater

The management and use of greywater can pose significant risks. Depending on where it is from, or if the water has been treated or not, it can contain a cocktail of chemicals and contaminants that can lead to illness and disease. The quality of greywater varies as much as the places and households from where it comes. The number of people living in the house, their lifestyles and ages also have an impact on the quality of the greywater that is produced from the house. Homes with babies, small children and pets produce greywater that contain higher counts of faeces and urine, for example. Households with inhabitants suffering from acute diseases such as gastroenteritis, eye / ear infections or jaundice can produce greywater with considerable pathogen loads. Even if the kitchen sink water is excluded, soaps and detergents, fabric softener, medicines, disinfectant, bits of food, pesticides, cosmetics and fibers can make their way into greywater. Saliva, sweat, body oils, hair, blood and some urine and faeces matter are all part of the potential mix of greywater content. As such, the choice to use it should bear the significant potential risks to both people and the environment in mind.

For one, the pathogens in greywater can potentially cause disease when people come in direct contact with the water, or eat food that has been irrigated with it. The high sodium content from soaps, shampoo, body wash and other substances can result in soil degradation, potentially causing long-term problems. Zinc from some hard soaps can accumulate in the soil, eventually leading to groundwater contamination.

Children, people with compromised immune systems, the malnourished, elderly and pregnant women are all more likely to become ill from consumption of contaminated water or exposure to gardens, lawns and sports fields that have been watered with it. In South Africa, this collection of people is a sizable portion of the population.

In addition, consideration should be given to the potential for sewer blockages if greywater is used instead of being released into the system.

## DIFFERENT HOMES, DIFFERENT GREYWATER CHALLENGES

Petro Kotzé

*Households with pets, children the elderly or the ill all produce greywater of varying qualities, and has an impact on where the water can be reused.*

Petro Kotzé

*As a general guideline, wastewater should not be used to irrigate those parts of the garden that people come in regular contact with.*

In a formally developed area, water enters the home, is used and is transported away again. During drought situations greywater might be collected with a bucket from the shower or bathtub and used to flush the toilet or water the garden.

In comparison, the journey of water in an informal settlement is very different. First, the basic infrastructure to remove used water from the household is often non-existent, though the household might have access to some means to bring water into the house, like a communal tap or a river. In South Africa, this is very common, since the government has put much effort into meeting targets for basic water supply and sanitation. To do this, low-income settlements have been connected to municipal water sources on a massive scale, frequently without adequate attention to greywater management, even in areas without sewerage infrastructure.

In informal settlements water often needs to be collected away from the home at a communal source and carried back. This is hard work and takes time, so water is used multiple times. When there is no suitable infrastructure to remove used household water, the greywater is generally thrown out on the ground outside the house, where it can mix with other forms of waste. This is especially the case where settlements are densely populated. Here, large volumes of dirty water accumulate in streets and other areas used by people. This leads to a myriad of potential harmful impacts on people's health, the direct environment that they live in, and the broader environment that the water flows towards.

Because this water is so seriously polluted, some refer to the greywater generated from unsewered, informal settlements as dark greywater. This water is often more like blackwater than greywater, and is hazardous because of the pathogens and chemicals it contains. It's not possible to reuse this water without extensive treatment. In general, the consensus is that this water should really only be diverted to a sewer, to be managed in the same way as blackwater.

## GREYWATER MANAGEMENT IN INFORMAL SETTLEMENTS

Petro Kotzé

*Water provision, and the resulting wastewater, differ vastly depending on where you live in South Africa. In informal settlements, water is often collected from a communal point such as a shared tap, while adequate wastewater management systems are sometimes lacking.*

The potential health consequences of reusing greywater from unsewered, informal settlements overshadow the potential benefit, especially since the amounts generated are not vast. In comparison to the amount generated by developed areas, it is relatively small.

Studies have estimated the total volume of greywater generated in the unsewered areas of South Africa at just over 500 million litres per day or, about 185 billion litres per year. This is equivalent in volume to a medium-sized dam such as Voëlvlei near Cape Town, or roughly 50% of the average water demand of Cape Town before drought (following the recent water crisis it equals about 75% of the city's daily demand). From a national perspective, this amount of water would not make a substantial difference to the country's water security – especially taking the potential impact on people's health in mind.

*Petro Kotzé*

*A typical shared toilet facility in an informal settlement in South Africa. Once the sewage infrastructure fails, the wastewater often mixes with greywater to form a toxic mix of water that is dangerous to people and the environment.*

*Because this water is so seriously polluted, greywater generated from unsewered, informal settlements are also referred to as dark greywater.*

In fact, in informal settlements the challenge is not how to make better use of wastewater. Rather, the most important task is managing the water in such a way as to not endanger the health of people and the environment. Due to the particular challenges of building large infrastructure in informal settlements, space being one, it provides the opportunity to leapfrog development stages and use new, novel technologies instead (see insert, ***Can green infrastructure be used to solve greywater problems in South Africa's informal settlements?***).

The paradox here is that in poor rural settlements, and in urban and peri-urban settlements around the major metropoles of South Africa, greywater has the potential to help keep people fed, healthy, and remain socially functioning citizens. This is especially true since household farming here is common, and remains an intimate part of the habits, cultures and livelihoods that rural people bring with them when they decide to move to cities.

Still, any such advantages must be very carefully balanced against the risks, especially in areas where there are people vulnerable to infections, such as malnourished children and HIV positive persons. South Africa's vast informal settlements are home to many that fall into these categories. The more realistic challenge is thus to identify conditions and limitations under which greywater could be used to the benefit of people and the environment.

At least locally (in South Africa), the most promising source of greywater to add to the country's water security at the moment is the low-density, high-income areas where more greywater is produced, and health concerns are less pronounced. (See block, ***Using greywater in the suburbs***.)

> **Using untreated greywater in the suburbs**
>
> In serviced homes in South Africa, untreated greywater is most suitable for activities such as toilet flushing and irrigating sections of the garden where there is limited contact with people. Most commonly, water is collected from the shower or bathtub for these purposes. However, there is still potential for health risks when toilets are flushed. Water drops may be aerosolised and land on nearby surfaces, or dispersed into the air and transferred through hand to mouth contact, if proper hygiene practices are not followed. Greywater can also be used for small-scale irrigation, as long as appropriate barriers to risk are in place. Since installing such systems are complex, large-scale adoption in urban catchments are not common.

An especially promising domain for institutionalising greywater reuse at this stage here in South Africa, and internationally, is large buildings such as office blocks, public buildings and hostels, where greywater can be collected and treated for reuse under proper supervision.

## PROGRESSING TOWARDS WASTEWATER USE IN SOUTH AFRICA

General consensus is that as a starting point, the aim of managing wastewater is to improve health, conserve water and protect the environment and then, where possible, recycle and reuse it.

In South Africa, the recycling of water for any purposes, whether it is domestic, agricultural or industrial is strictly regulated. By and large, our laws are not aimed at regulating reuse of wastewater. Mostly, our laws aim to protect and conserve the country's natural water resources. Thus, the goal is largely to return treated wastewater to the natural water environment in order to recover as much of the volume of water originally extracted, and ensure that this reclaimed water does not harm the natural ecological status of the receiving waters.

Substantial research has, however, been undertaken towards developing guidelines for greywater management and use locally, much of it guided by the WRC. Mostly, work has focused on the management of greywater from sewered and unsewered areas in order to keep South Africans, and the country, healthy. A large body of work on the reuse of greywater in South Africa is also developing. This work has focused on greywater use in unsewered settlements, guidance for sustainable use of greywater in small-scale agriculture and gardens, and the use of greywater for toilet flushing in high density buildings.

More recently, guidelines for the use of greywater in South Africa were published. These address the risks involved when managing and using domestic greywater, and pave the way for the wider uptake of greywater reuse in South Africa.

Much work still remains for the full suite of benefits of greywater use, as well as treated sewage, to be realized. Like other aspects involved in the development of a water resilient settlement, the potential for wastewater reuse is as much dependent on technology and management intervention, as it is on shifting perspectives, and making space for new thinking to evolve.

## THE PARADIGM SHIFTS NECESSARY TO SEE THE POTENTIAL IN WASTEWATER

For many, it is already clear that the way that we have been managing wastewater is not sustainable. The linear model of traditional water treatment, in which water is extracted from the source, treated and used before the wastewater is treated and disposed of, needs to change. A new, circular model is called for, in which less water is extracted by reducing the water used and consumed. In this model, water is recycled and reused for different purposes depending on the quality of the water, allowing the water resources to recover.

In order to see this become a reality, a number of things need to change. For one, the purpose of wastewater treatment plants need to be reimagined as a place where water and other resources are recovered. Traditionally, wastewater treatment plants focus on the removal of contaminants and pathogens in order to safely discharge the water to the environment. A new world view calls for it to be a facility to recover components in wastewater for beneficial purposes. The water itself can be reused for agriculture, industry, and even human consumption, while nutrients such as nitrogen and phosphorus can be recovered. A remaining potential is energy generation from biogas that can lead to climate change adaptation.

These processes can lead to job creation, and contribute to the health of the population. Financing and business models that take advantage of these potential income streams should be developed, that take the long-term operation and management of assets in mind.

Planning should also move from focusing on individual wastewater plants for individual municipalities to bigger scale thinking that considers the basin. Instead of ad hoc planning, integrated regional planning should take place, taking in mind the benefits and impacts of wastewater management across multiple sectors, and incorporating climate risks and socioenvironmental considerations.

For example, players across the fields of water, food and energy should collaborate in order to truly benefit. For one, deriving income from bioenergy generation may not be possible if the electricity sector has no incentive to promote its use. Regulations of the health and agricultural sector, to name another example, might prohibit the reuse of water, or the use of biosolids for fertilizer, in which case none of the benefits to any sector can be realized.

As such, regulation, policies and incentives across sectors must be aligned. At the same time, the institutions that ensure that such laws and policies are applied, must have clear and enforceable sanctions. In San Francisco, for example, for the country's first legislation to allow for alternative water sources to be used in buildings, the process needed to be streamlined across city departments (see insert, ***San Francisco employs right of law to embrace wastewater for a more resilient future***).

This process is complex, but internationally many steps have already been taken to make aspects of this a reality, as the examples and case studies in this chapter shows.


*Sources:*

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## THE POTENTIAL IN OUR SEWAGE

*The city of Windhoek, in Namibia, has been using reclaimed water for decades.*

For obvious reasons, sewage is unappealing. Drinking sewage is for many, an unfathomable idea. Yet, while most of the world is still debating whether treating domestic sewage to drinking water standards is acceptable, Windhoek has been tapping potable water from this source for decades. Last year (2018), Namibians marked the 50th anniversary of the first direct potable reuse plant in the world, the Goreangab Water Reclamation plant. Due to its success, a second plant was completed in 2002, the New Goreangab Reclamation Plant, putting improved water treatment technology into practice.

There are three approaches to the use of treated sewage – all of which are becoming more prevalent. Direct potable reuse is when sewage is treated to drinking-water standards and fed into the water distribution system. This is what is practiced at Windhoek, a process that has since seen uptake in other countries, including South Africa; a water reclamation plant serves a similar purpose in Beaufort West, for example. Indirect potable reuse is when treated sewage effluent is discharged into river systems, where it mixes with river water, and is then abstracted and treated to potable standards, as is being done in Singapore during times of drought. The last option, treated effluent reuse, entails the treatment of the sewage to standards allowing it to be discharged, but is then used for purposes other than drinking such as irrigation or industrial use. An example of where this is happening is right on our shores, both in Cape Town and in Durban. The Durban Water Recycling Project (commissioned in 2001) treats effluent and industrial wastewater to near potable standards for sale to industrial customers for direct use in manufacturing processes. The so-called sewage-to-clean-water plant can reportedly free up sufficient drinking water for approximately 300 000 people.

All three options can make a substantial difference to the water security of a town or city, as has been shown in Windhoek. Namibia, the country of which Windhoek is the capital, has the dubious distinction of having the lowest average rainfall in the Southern African region. Droughts are common, and in general, water is scarce. For decades already, all naturally available water sources in the centre of the country (where Windhoek is located) have been tapped to the maximum.

The city has committed itself to exploit the maximum amount of reclaimable and fresh water from all sources it has available in order to meet the ever-increasing demand. In Windhoek, every drop of water counts, and even the moisture in sewage cannot be allowed to go to waste.

The plant was brought into operation in 1968, following severe water shortages before the extension of the state water supply scheme could be completed. The plant is fed from two sources, the Gammams Sewage Treatment Plant and the Goreangab Dam. The plant can be split into two streams, one stream used for effluent from the sewage treatment plant and the other used for the treatment of Goreangab Dam water, though the raw waters can also be blended and treated as a single stream.

Following another severe drought in 1997, it was decided to build a new reclamation plant with more capacity to cater for increasing demand. The construction of this plant follows on review and analysis of the first, so all lessons and best-practices could be applied. The old plant is now treating effluent for use in irrigation of parks and sports fields.

Since 1968, no negative health effects have been detected as a result of the use of reclaimed water in Windhoek. Though the treatment of wastewater for direct reuse in a drinking water system poses extraordinary challenges, the case of Windhoek is living proof that it is possible and even necessary. As further international examples of sewage reuse for different purposes emerge, the case is increasingly being made that it could form part of resilient water supplies to cities and towns of the future.

*Sources:*

- *www.wingoc.com.na*
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## WASTEWATER TREATMENT PLANT PAVES WAY FOR NEW LEGISLATION, AND FUTURE COLLABORATION WITH PRIVATE FUNDERS

*Despite its location next to the Nile River, water supply is a challenge in parts of Egypt.*

When wastewater treatment plants in Egypt's new urban areas started buckling under the pressure of rapid growth, the government turned to the private sector for help. To do this, legal and regulatory structures had to be changed, setting the building blocks in place for more such collaborations in future. The results have proven to hold benefits beyond simply the management of wastewater.

Traditionally, urban development in the water-scarce Arab Republic of Egypt is concentrated along a corridor hugging the Nile River and Mediterranean Sea. However, as the population grew, overcrowding necessarily led to new urban centers to be developed further away from water, where infrastructure is also less developed.

One such area is New Cairo, expected to grow from a population of 550 000 to over 3 million by 2026. However, the existing infrastructure could not keep up with the pace of development, and untreated wastewater was being discharged directly into the river. Due to a lack of funding and the potential risk to the public sector, the government wanted to consider a public-private partnership (PPP) as solution, but there was no legal or regulatory structure to handle PPPs at the time.

In collaboration with the International Finance Corporation (IFC) and the World Bank Group's Public Private Infrastructure Advisory Facility (PPIAF), the Government of Egypt created a conceptual framework and transaction model, so the process to construct the New Cairo Wastewater Treatment Plant could also be used to design a model for future PPPs in Egypt. The PPP law was consequently approved in 2010.

The wastewater treatment plant has been hailed as a success, for more than just the contractual setup behind its construction. The plant can process up to 250 000 cubic metres of wastewater per day, serving the satellite cities of New Cairo, Madinaty and El Mostakbal. The treated water is directed to agricultural operations, reducing the demand for freshwater from farmers, and allowing that supply to be diverted for use by the city.

Though small, the consortium at the helm of the project can generate an extra revenue stream from the sale of compost from the wastewater sludge. Used as fuel, instead of the traditional coal, the sludge is being supplied to the cement industry. This also circumvents considerable sludge transport costs for the consortium.

The biological treatment process used in the treatment plant is conventional and did not require any major renovations. Rather, the novelty of the project is the process behind its development. The success is put down to sound governance strategies in the early stages through completion as well as strong stakeholder participation and coordination on the part of the government of Egypt and the Ministry of Finance. Furthermore, a PPP Central Unit was established for coordination within the government. The stakeholder participation was enabled by a transparent procurement process, and the use of external advising from PPIAF and the IFC contributed to success.

**Source:**

- *Wastewater: From waste to resource, - the case of New Cairo, Egypt, published by the World Bank*

## CAN GREEN INFRASTRUCTURE BE USED TO SOLVE GREYWATER PROBLEMS IN SOUTH AFRICA'S INFORMAL SETTLEMENTS?

Petro Kotzé

*Langrug community leader, Solomon Sonxi, says the Genius of SPACE project has resulted in vast improvements to the settlement.*

Western Cape Government

*Before the pilot project, greywater posed a real risk to the health of the people, and the environment of Langrug.*

"Meza2Meza – neighbour to neighbour; let's keep it safe and clean for all of us." That's the campaign that we ran to get people involved in the project, says Langrug community leader, Solomon Sonxi.

Petro Kotzé

*One of the tree pits is looking worse for wear a couple of months after project completion.*

Langrug is an informal settlement located on a mountain slope in scenic Franschoek, outside of Stellenbosch, South Africa. A novel project to pilot a different sort of wastewater treatment system driven by the forces of nature, was recently successfully completed at the settlement. However, the project showed that the challenges of applying new solutions to old problems go beyond any technical aspects. Rather, more so than technology, community support is the key to a successful outcome.

### THE PROBLEMS WITH WATER AT LANGRUG

Langrug was established in the 1990s, when migrants from the Eastern Cape flocked to the area for job opportunities in the surrounding wine industry. Though originally established illegally, the municipality provided basic sanitation services, such as toilets and taps. Still, provision of basic services did not offer a clear-cut pathway to a better quality of life. Some of the infrastructure has fallen victim to vandalism, and though the toilets and taps were there, the necessary infrastructure to collect and manage the resulting wastewater was not.

This has resulted in a situation all too common in many informal settlements. Highly concentrated greywater flows down a matrix of unsanitary channels, delivering the untreated wastewater, in the case of Langrug, to the bottom of the hill and ultimately into the Berg River via the Stiebeuel and Franschoek rivers, from where it is abstracted to irrigate orchards and vineyards. Over and above the health concerns to the local market, some of the agricultural produce irrigated with this water is meant for export.

The potential economic impacts, the declining state of the river and the social circumstances at Langrug made the settlement ideal to pilot a sustainable and ecological wastewater treatment system, as part of the broader Berg River Improvement Plan (BRIP). Developed by the Western Cape Government, the BRIP aims to address water quality concerns in the Berg River. The programme's vision is to improve the water of the Berg River to an acceptable quality and quantity for sustainable farming, industrial development, human consumption and recreation, as well as ecological health.

## CLEANING WASTEWATER WITH NATURE'S HELPING HAND

The biomimicry-inspired project is called the Genius of Systems for People's Access to a Clean Environment or, in short, the Genius of SPACE project. It makes use of natural elements to treat wastewater before linking into the main sewer network. As such, the project aims to demonstrate how alternative systems can be used to deal with waste flows in an informal settlement.

**To learn more about the Langrug Genius of SPACE project, visit www.flow.org.za/all-causes/genius-of-space-langrug/**

There are multiple benefits to a system such as this, especially in comparison with conventional (or grey) treatment systems. It requires minimal energy, and does not need mechanical parts to function. Any maintenance can thus take place quickly, is usually straightforward and not too difficult. At Langrug, the maintenance could be done by the community members. Another benefit of systems such as these is that they do not require the space necessary for conventional treatment plants. They can be built to fit the available space in the settlement, which can often be very limited.

The pilot project serves 115 households in two blocks of the settlement. Greywater disposal points – each serving about five households – have been constructed. Each one is topped with a filter to remove solids like tissue paper and food scraps, before the water is led through a narrow, flexible pipe, allowing it to curve around the bends and turns of the surrounding erratic infrastructure. Along the way, small gardens (micro-wetlands) act as living filters. The water is then led to a series of tree gardens, overflowing into the next as each tree bed becomes saturated. The deep pit tree wells act as treatment mechanisms for the greywater through absorption and decomposition of contaminants by micro-organisms and fungal communities. Nutrients and organic material are removed from the greywater and converted to humus, allowing better quality effluent to infiltrate back into the ground.

In the process, the tree wells and small gardens feed off the water and nutrients, creating a sustainable green corridor through the settlement. Over time, the system can leave behind a network of deep planted tree wells with rich, high-carbon soils.

The final step is a biomimicry-based water treatment system called an 'Eco-machine'. This relies on natural processes to create mechanically simple but biologically complex systems to treat contaminants and human waste streams. In a nutshell, nature is employed to clean wastewater. The system consists of multiple cells. Within each of the cells, all five kingdoms of life aim to be represented, from microbes, bacteria and fungi to higher life forms such as snails and fish. Combined, these organisms work together to metabolise, degrade and sequester organics, pathogens and heavy metals from the wastewater. The series of cells through which effluent is treated mimics natural water purification within wetland ecosystems.

## THE ELEMENTS OF SUCCESS ARE NOT NECESSARILY TECHNICAL

Initial observation and water quality tests confirmed that highly-polluted greywater was effectively being separated from stormwater. Furthermore, the completed system could treat water to an acceptable standard to be discharged back into the river.

However, though the project enjoyed hard-won support from community members, only months after the conclusion of the pilot project in 2018 some of the infrastructure has fallen into disrepair.

"When the payment stopped, the cleaning stopped," says Sonxi. The intention was to get the community to clean their own disposal points, he says, but because some are used by the general public people don't want to clean it, especially since the disposal points are sometimes soiled during the night. Now that the system has blockages, it causes a lot of headache, he explains, though disposal points inside private properties, among the cluster of houses, are being maintained.

Western Cape government project manager, Jason Mingo, says that their experience with the Genius of SPACE project taught them that while the implementation of a technological solution is not necessarily difficult, the key is rather to obtain the community's buy-in to sustain and maintain it over the long-term.

This is integral not only after completion of the project, but from the very first stages. "The involvement of the community in the decision-making process is key," says Mingo. "They need to be integrated throughout the entire process." You can't design and develop the project, and then present your solution for them to the community, he says.

According to Mingo, lessons that they have learned from the project are much more about the social and community perspective than the engineering side of the project. "A big focus for us was the impact of surface runoff on water quality in the river," he says. However, they later learned that for the community, the solid waste was a bigger problem. "Had we placed greater emphasis on working within the community structure there would have been greater support for implementing the solid waste system first, instead of greywater disposal, and then we would have had greater community commitment. If you clean the community up first, then the aesthetic elements, such as tree gardens, could become a possibility."

However, the project was also a learning curve for the community members. According to Sonxi, he originally thought they could make a change in his community without relying on somebody else, but he has since realised they need municipal support. The technology works, but you need both government and community support in future. Sonxi further points out that boundaries between the community and the municipality does not help. Members of the municipality are also members of the community, he says. "They are part of us, and should consult with us so we can create a better community together." Last, a follow-up plan is of big importance, he says. "Now that the project is complete what do we do, and how do we do it?"

Still, Sonxi would recommend the system for any other settlement. He points out that though there are challenges, the project still resulted in "vast improvements". Before the project, the areas where it has been applied could barely be accessed without wearing safety boots, while the street is now paved and the alleys dry. Using green instead of grey infrastructure here makes sense, he says.

Furthermore, though the initial pilot project is complete, international funding has been secured for the Langrug Community Project Committee to initiate training linked to the development of an eco-precinct – a concept part of the Genius of SPACE project that broadly entails using recycled water for small-scale agricultural purposes. "This further demonstrates the value of investing in the people of a community, and empowering them to partner in making change," says Mingo.

The project was initiated by the Western Cape Government with the appointment of Biomimicry South Africa, John Todd Ecological Design (JTED), Greenhouse Systems Development, Maluti GSM and Isidima Design and Development. The system constructed at Langrug is a flagship of the Western Cape 110% Green Initiative, funded by the Western Cape Government.

**Sources:**

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## SAN FRANCISCO EMPLOYS RIGHT OF LAW TO EMBRACE WASTEWATER FOR A MORE RESILIENT FUTURE

In San Francisco (United States of America), all water is seen to be of value, and they strive to waste as little as possible. A big step in this direction was made in 2012, when San Francisco became the first municipality in the country to adopt groundbreaking legislation to allow onsite non-potable water systems. The Non-potable Water Ordinance established a local oversight and management programme allowing for the use of alternate water sources like rainwater, greywater, stormwater, foundation drainage, and blackwater in buildings.

Subsequently, San Francisco's Non-potable Water Programme was developed, providing the design and development community with a streamlined permitting process for onsite non-potable water projects. The San Francisco Public Utilities Commission (SFPUC) collaborates with city partners including the San Francisco Department of Public Health, Department of Building Inspection, and Public Works Department to provide oversight and management of the use of treated non-potable water to ensure systems are protective of public health.

"These onsite non-potable water systems are transforming the way we live and do business in San Francisco", says Steven R. Ritchie, SFPUC Assistant General Manager, Water. Ritchie says they are pioneering new ways to collect and treat water for reuse within buildings and neighborhoods in San Francisco. "We recognise the opportunity to build upon our centralised water infrastructure by integrating smaller, onsite water treatment systems to produce water fit for toilet flushing and irrigation that not only matches the right resource to the right use, but also helps us stretch our drinking water supplies," he says.

Since 2012, the programme has expanded to allow for district-scale projects, where two or more parcels can share treated alternate water sources, and in 2015, the programme became a mandatory requirement for new commercial, mixed-use, and multi-family development projects over 23 225 $m^2$ (250 000 square feet).

Today, recycling water is seen as integral to reliable long-term water supply to the city. Together with water infrastructure, water supply diversification, water transfers and water conservation, wastewater has become an essential water resource as part of the mix to ensure that the city meets a water resilient future, in a more livable space to all residents.

# CHAPTER 08

# OUT OF SIGHT, BUT TOP OF MIND: TAPPING INTO GROUNDWATER'S POTENTIAL FOR WATER RESILIENT CITIES

*Once known as the Cinderella of the South African water industry, waiting for its true potential to be recognised, groundwater has actually long been a staple of resilient water provision in dry countries. Often, sinking a well to tap the blue gold below the surface has been the first action to signal the start of a settlement and subsequently, as the world has become more urbanised, groundwater has been the basis upon which major growth has been built worldwide.*

Many countries, from across the European Union and the United States to Brazil, China, India, Nigeria, Pakistan, Peru and Vietnam are highly dependent on groundwater, especially in smaller towns, though it's not uncommon as part of the water supply mix of large cities either. It's also common for people and businesses to drill boreholes for private use. In some Brazilian cities this private self-supply from groundwater reaches 20% of total water use in drought, and even more in Indian cities. In South Africa, this is common too, especially in low-density high-income areas. Earlier research in Pretoria (in 1990) estimated that as much as 38% of properties in the study area had private access to groundwater.

Estimates in 2003/04 suggested that about 30% of residential properties over 1 000 $m^2$ in the Western Cape enjoyed the same privilege, though the numbers are likely to have increased exponentially as a result of the recent water crisis.

This widespread dependency on groundwater for development has resulted in vast modifications to the groundwater cycle. On the one hand, less water filters into the ground to replenish aquifers due to the large amount of impermeable surfaces. On the other, a lot of water (some would say more than enough to compensate for the first aspect) is fed into the ground again through leaks in water provision pipe systems, wastewater that seeps into the earth, constructed stormwater soakaways and from watering gardens.

Still, the nature of this water is obviously different to that of the rain that would originally have replenished groundwater sources. Leaking sewage systems, inadequate sanitation, improper handling of chemicals by people and industries and other soluble contaminants can all filter into groundwater and impact on its quality. Then, irresponsible abstraction of groundwater can potentially place the infrastructure built on the ground above at risk. However, if the risks are understood, the benefits of using groundwater still makes it a preferential source above other options.

## GROUNDWATER AS A RESILIENT WATER SOURCE

Provided it is managed well, the environmental impact of harvesting groundwater is much lower than for sources such as large-scale desalination and even surface water systems. The latter, in particular, requires large infrastructure for storage (dams and reservoirs) while the impact on the surface of using the groundwater below is comparatively small. Plus, if water is stored underground, less is lost to evaporation.

During drought, tapping into groundwater is particularly appealing. It's much faster to put into practice than constructing water transfer schemes or large desalination plants, and often much cheaper too. Studies in South Africa have placed the cost of desalination as much as 6.5 times more expensive than the development of groundwater resources (including linking boreholes to the reticulation infrastructure). Furthermore, desalination also has significant energy and carbon implications.

The benefits of groundwater have led to its reputation as a sustainable resource that can increase the resilience of a city and settlement, especially against the impacts of drought. Often, when a water crisis looms on the horizon, drilling boreholes is one of the first responses. Yet, the benefits of its use should also include it as a valuable and permanent element of a strategy to adapt to long-term climate change. In comparison to water above the surface, groundwater will be impacted less directly and more slowly. Droughts and floods are quickly reflected in dam and river levels, but it's mostly only after prolonged drought that groundwater levels show decline.

Still, just like surface water, groundwater will eventually show the impact of the development that it supports. Groundwater resources can and do decline over time, necessitating municipalities to look for more water, sometimes further afield to secure long-term water supply. In this situation groundwater has a particularly attractive trump card to play – suitable aquifers can be replenished. And of even more relevance, it can be replenished with water from other systems, such as stormwater and wastewater. Potentially, this then allows for over-extraction from the aquifer during times of water scarcity, as it can be replenished again during times of plenty.

## BANKING ON WATER SECURITY UNDERGROUND

Artificial recharge is the process whereby surface water is transferred underground to be stored in an aquifer. The most common methods used is to inject water into boreholes and transferring water into spreading basins where it infiltrates the subsurface. The case for artificially replenishing groundwater, and using this to secure the long-term water supply of a settlement was first made in places that had seemingly no other alternatives left. It started in dry places, where innovation was bred by necessity (see insert, ***How Windhoek banks on water security underground***).

South Africa's first major water recharge scheme is located at arid Atlantis in the Western Cape (see insert on the ***Atlantis Water Resource Management Scheme***). Other famous examples include Leiduin in Amsterdam (the Netherlands), the Orange County Groundwater Basin in California (USA) and the Floreat Scheme in Perth, Australia among others. But the practice is becoming increasingly common. In 2015, the International Groundwater Resource Assessment Centre (IGRAC) compiled an inventory of managed aquifer recharge schemes listing about 1 200 case studies from over 50 countries in Europe, Asia, Africa, North and South America and Oceania.

The benefits are multiple. Water can be stored for use during dry seasons or even longer, for use during times of drought. This also guarantees an emergency store of water for when transmission pipelines are interrupted, for example. Certain recharge schemes also improve water quality, as nitrates, iron and manganese, to name a few, can be treated as the water filtrates through soil. Storage in suitable limestone chambers, again, can be used to treat water needing calcium carbonate. Over and above that, groundwater levels are restored, saltwater intrusion prevented, and the production of wells improved. At the same time, less water needs to be extracted from rivers, helping to maintain the environmental integrity of waterbodies and all the varieties of biodiversity dependent on these waterbodies.

In line with international best practice thinking, more South African cities are now including groundwater in the suite of water resources to tap from to work towards a water secure future, especially since surface water resources are already stretched to the limit.

## GROUNDWATER USE POTENTIAL IN SOUTH AFRICA

Already, a large number of South Africans depend on groundwater for their daily domestic needs. The source is essential to the water supplies of many towns, including Beaufort West, Prince Albert, Graaff Reinet, Vryburg and Musina. Even large cities such as Pretoria and Johannesburg are partly dependent on groundwater. Despite this important role and the potential it holds, it remains an underutilised resource.

According to South Africa's most recent National Water Resources Strategy (second edition, published in 2013) estimates of sustainable potential yield of groundwater resources at high assurance in the country is 7.5 km$^3$ per year. Current groundwater use is estimated at around 2 km$^3$ per year. Allowing for an underestimation on groundwater use, about 3.5 km$^3$ could be available annually for further development.

Ashraf Hendrikcs/Groundup

*The City of Cape Town drilled additional boreholes into the Cape Flats Aquifer during recent droughts.*

Lani van Vuuren

*Pretoria's water is supplemented with various groundwater sources, including the Sterkfontein spring.*

Despite the figures and its increasingly raised profile on paper, many municipalities only turn to groundwater as a last resort, but there are signs that the tide is slowly turning. The City of Johannesburg, for one, recognises groundwater as a potential source to supplement potable water supply. The city has embarked on a feasibility study to determine the areas with the biggest potential for groundwater use, and to identify what purposes, such as irrigation or cooling, it can be used for.

According to the City of Cape Town's ***Water Outlook*** (2018) groundwater is part of the diversified sources of water supply under consideration to contribute to the city's resilience. Three aquifers have been identified as potential sources, including the described Atlantis aquifer, where planning for additional yield is underway as well as the Cape Flats and Table Mountain Group aquifers. The ability to extract more from aquifers during droughts and to re-charge with other water sources during wet periods is seen to be a significant contribution to a more water resilient Cape Town.

For a city and settlement with access to suitable groundwater resources, the journey towards a resilient future should be taken in consideration of the potential that lies underground. Groundwater has long shed its Cinderella shoes to take a worthy stand among the role players that can help settlements live happily, and water secure, ever after.

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## HOW WINDHOEK BANKS ON WATER SECURITY UNDERGROUND

If you've been to Namibia, its strained relationship with water supply is obvious. The parched landscape makes for an impressive sight. Dunes that undulate from glaringly white to copper red attract visitors from afar. At places, a lone aloe might break the otherwise bare horizon. The bitterly cold Atlantic that runs along its coast jealously contains moisture, rarely letting enough go to form clouds sufficiently heavy for rain. It is the most arid country south of the Sahara Desert.

The capital is placed at the centre of the country, but far from life-sustaining sources of water. The closest perennial river to Windhoek, the Okavango River, lies along the northern border 700 km away. Windhoek itself receives only about 360 mm rain per year, with annual evaporation rates as much as 2 170 mm.

Water to the city is supplied by NamWater, which is the national supplier of bulk water in the country. Windhoek's water supply is mostly from the so-called "three dam system" through which water is transferred to the Von Bach Water Treatment Plant near the town of Okahandja. This is supplemented by the Windhoek reclamation scheme (also read about the Goreangab Water Reclamation plant elsewhere in this publication) and groundwater in the Windhoek and northern aquifers.

Large-scale abstraction from the complex Windhoek Aquifer started in the 1950s and is a vital part of the supply to keep the largest urban and industrial development in the country going. However, the aquifer was being tapped dry to feed growing numbers of people and industry. In 2018, the population of the city was 326 000, projected to grow to 790 000 by 2050. Concurrently, water demand is set to almost double in the same time, from 27 million $m^3$ per year to over 50 million $m^3$.

Already by the late 1990s water levels in the Windhoek aquifer had dropped by about 40 m in the main wellfield areas, and were steadily declining in other areas too. The resources from the aquifer were being mined beyond what it could sustain. Experts said the aquifer would need up to a decade of rest to recover fully, and authorities started investigating different options for water supply to the city. They settled on managed aquifer recharge (MAR), among other reasons because it was the most cost-effective alternative. The idea was to use the Windhoek Aquifer as a water bank. Treated surface water would be transferred to the aquifer for safe storage, to be used when water was scarce.

Starting in 1997, the project became the first major MAR scheme in the world to be constructed in a complex, fractured, hard-rock aquifer. The aquifer is injected with treated, potable-quality water that has to adhere to strict quality guidelines in order to prevent the deterioration of groundwater quality and minimize the clogging of boreholes. The water is a blend of three-parts dam water, and one-part treated, reclaimed water.

After seven years of recharge, parts of the aquifer were filled to their highest levels since the 1950s when large scale abstraction began. The overall aim of the ongoing project is to use as much of the aquifer's storage as practically possible, and after the initial success, the scheme was expanded in 2011 with ten more injection and abstraction boreholes each.

When Namibia experienced extreme drought in 2016, a major crisis loomed for the bigger towns in the central area of the country, including Windhoek. Part of the emergency response was the installation of 12 more large, deep-well boreholes in the Windhoek area to link to the Windhoek water supply network, and the establishment of new bulk conveyance infrastructure from the dedicated well fields. This project allowed for three times the previously available capacity from the Windhoek aquifer to be abstracted, which could cater for about two-thirds of the 2016 suppressed water demand of the city. As a result, not a single tap in Windhoek was closed during the crisis, and the benefits remain available to the city's residents for similar emergency situations in future.

Water supply in arid Namibia and Windhoek remains a major challenge. With inland water sources already tapped to capacity, the city has repeatedly stated that they are very mindful of the challenges of the fragile environment that they make a living in. The Windhoek aquifer is key to this process. When fully developed, it is expected that the city can bank enough water there to sustain them for three years during drought, allowing the city the opportunity to continue, and even flourish, long beyond what other cities in a similar situation would have been able to.

**Sources:**


- *Transformational Strategic Plan for the City of Windhoek 2017 – 2022*
- *Water Management Plan for the City of Windhoek (version 2/2017)*
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# CHAPTER 09

# A WATER RESILIENT AND LIVABLE PLACE IS A JOURNEY UNIQUE TO EACH SETTLEMENT

*Try and picture a city of the future where you can live your ideal life. There would, of course, be clean air and water. Perhaps there are many green areas, like parks and rivers in-between high-rise buildings with walls covered in vertical hanging gardens. There could be the noise of birds and insects. Maybe in your best city, the fresh morning air is marked with the smell of bread from sidewalk cafes or grilled chicken from a myriad of informal traders, dishing up delicacies to people as they rush by on their way to schools and churches, or offices and businesses. Maybe you see sky-trains and on your way to the station, you have a sip from a waterpoint fed from a well below.*

In this city, you could see yourself enjoying a life that is safe, in an environment that keeps you healthy. Maybe you see yourself as part of the management structures that help make that happen; a resident committed to live in this space until you grow old or, perhaps you are just passing through, harnessing one of the many opportunities it has to offer. In this place, life happens easily and systems work.

Different than the examples of where development has gone wrong, the perfect example of a water wise, resilient and livable city does net yet exist. It might never. The goal of what each settlement can work towards is probably best made up of elements borrowed from cities everywhere – from Cape Town to Cairo, Toronto to Singapore to Johannesburg, Atlantis, Durban or Windhoek. In the process, each settlement and city will move along its own road to resilience, becoming a unique place shaped by its location, the local climate, the available resources, the people that live there and what they are willing to fight for, and compromise on.

However, there are common traits to the cities that now stand as examples of the places that urban areas can strive towards. Perhaps more than anything, they are embracing change. In all of their cases, tried and tested solutions could not be applied to emerging problems. New answers are being sought to face challenges and even more so, different questions regarding what the real problems are, are being posed.

Then, they collaborate. In these places, resilience is something that is worked towards in partnership between governing bodies, residents and businesses, and across areas of different expertise. Everybody pays the price when cities and settlements become unlivable, and there is increasing recognition that everybody has to work towards changing the development trajectory in a better direction. One management authority or stakeholder simply does not contain the expertise, resources and clout that all the role-players together can leverage.

To achieve this, stakeholders are informed and have input on the decisions made. In places like these, learning is a constant process, and systems are adapted as new lessons and knowledge emerges. The outcome of an action or new technology is not always known or guaranteed, but at the same time, the benefits can ripple far beyond the intended purposes of the action. In these circumstances, innovation and imagination count, and are given space in traditional systems where strict rules and guidelines were often used to measure success.

This entails collaboration across the traditional borders of water management. Engineers, who traditionally focused on channeling stormwater out of a city to keep roads safe, now have to partner with environmental managers, for example. Outside of a municipality, engineers, architects and property developers need work together to achieve the co-benefits encapsulated in new methods of development mentioned throughout the publication.

Much of these demand the embrace of nature-based systems. All of the cities and settlements used as examples have turned their attention to some form of green infrastructure, whether it is an aquifer, green roofs, wetlands or the harvesting of rainwater, and foresee a larger reliance on such systems in future.

To do this, knowledge and skills on various levels are integral, to correctly apply and develop innovative, integrated solutions. Pilot sites to test and demonstrate effective application of concepts are necessary, and champions to keep on fighting for the cause are vital. These actions entail risk on multiple levels, and carries potential financial, legal, political and personal repercussions.

Yet, examples of places where it is happening are ample, throughout the world and in South Africa. During the research for this publication it has become clear that we have, within our municipalities and government structures, as well as research institutions, renowned champions that have taken up the baton and are running with it.

We too, have become a hub of prominent experts in the arenas of water-wise and resilient urban development, which many other countries are looking towards for a new range of solutions, as an uncertain future beckons. Furthermore, South African themselves have proven beyond doubt that they can rally to the cause when called upon. Though the recent drop in water use by Capetonians are a prime example, we already had a long legacy of insisting on, and embracing change when necessary.

Though there is still large scope for improvement in many arenas related to water management in South Africa, change is clearly on the cards. To embrace a future in which water insecurity might become more common than it already is, we need to approach this limited resource from different angles. This includes the prospect of tapping our future supplies from the array of 'new' sources available to us; including the water we already have (through WC/WDM), stormwater, wastewater, and groundwater. It also includes recognition that we are dependent on healthy basins, and that we must protect our natural water sources in their broader environment, in order to keep using them.

If we progress along this way, as international examples elsewhere have shown, South Africa's looming water crisis could perhaps even be seen as an opportunity, to take us forward into a more sustainable future; one that we might not have had the urge to approach, had water still been perceived to be running from a tap that could never run dry.

# ABBREVIATIONS

| | |
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| AWRMS | Atlantis Water Recharge Management Scheme |
| BRIP | Berg River Improvement Plan |
| CRCWSC | Cooperative Research Centre for Water Sensitive Cities |
| IFC | International Finance Corporation |
| IPCC | Intergovernmental Panel on Climate Change |
| IWA | International Water Association |
| MAR | Managed aquifer recharge |
| NBS | Nature-based solutions |
| NWRS-2 | National Water Resources Strategy Second Edition |
| PPIAF | Public Private Infrastructure Advisory Facility |
| PPP | Public-private partnership |
| PUB | Public Utilities Board [Singapore] |
| UCT | University of Cape Town |
| SFPUC | San Francisco Public Utilities Commission |
| SuDS | Sustainable drainage systems |
| UN | United Nations |
| WC/WDM | Water conservation and water demand management |
| WRC | Water Research Commission |
| WSD | Water sensitive design |
| WSUD | Water sensitive urban design |

WATER
RESEARCH
COMMISSION