URBAN WATER MANAGEMENT

Study explores stormwater's potential as an alternative water supply

Can stormwater harvesting provide a viable source of water for municipal supply? A project funded by the Water Research Commission (WRC) used an urban catchment in Cape Town to explore the possibilities. Article by Sue Matthews.

Sue Matthews

The increasingly harsh water restrictions in Cape Town over the year-and-a-half before early winter rains broke the three-year drought in 2018 raised the ire of local residents. Accusations of incompetence and some rather pie-in-the-sky solutions littered the comments section of online articles. Some of these bemoaned the fact that any little rain that did fall in the city was allowed to flow down stormwater channels and out to sea, rather than being captured by the municipal authority.

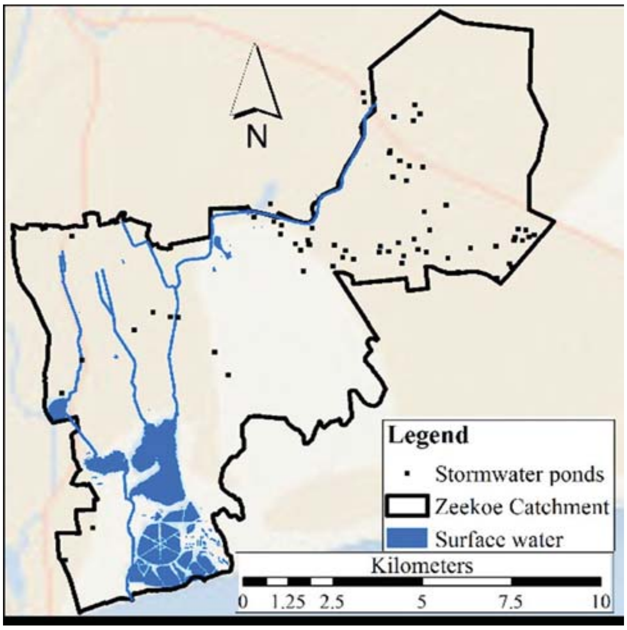
By then, scientists and engineers from the Future Water Institute at the University of Cape Town (UCT) had already been investigating the potential of stormwater harvesting for a few years. One such study was Dr John Okedi's WRC-funded research project, titled 'The viability of stormwater ponds in the Zeekoe catchment as water resources for Cape Town', South Africa, for which he was awarded his PhD in 2019. The catchment has more than 60 stormwater ponds within its 89 km^2 area, as well as three large but shallow lakes – Zeekoevlei, Rondevlei and Princess Vlei.

Through desktop research and a modelling approach, Okedi initially assessed the extent to which water from stormwater ponds could meet the demand for non-potable uses in the form of irrigation and toilet flushing. Given that Cape Town lies in a winter rainfall area and water for irrigation is mainly needed in the dry summer months, creating a mismatch between supply and demand, some means of storing stormwater would be required. Land is at a premium in most urban environments and there is limited space to build new storage facilities, but real-time control – commonly referred to as RTC – offers a way of optimising storage in the existing stormwater ponds.

First implemented in the USA in the 1960s, RTC allows water levels in urban drainage systems to be dynamically controlled. At its simplest, it might entail somebody being on site to monitor incoming flow and water levels at particular ponds, and then open or close sluice gates according to operational rules. Advanced RTC would rely on a network of automatic rain, flow and water-level gauges, and even radar-based rain forecasts, with data fed into predictive models that issue alarms and instructions for remote control through a SCADA (Supervisory Control and Data Acquisition) system. Regardless of the complexity, the aim would be to manage the drainage system so that it fulfils its flood-prevention role while also ensuring the maximum amount of stormwater is captured and stored instead of being lost to the sea, known as spillage.

The total capacity of the stormwater ponds in the Zeekoe catchment represents about 5.5% of the catchment's modelled mean annual volume of stormwater, estimated at 18 Mm^3, or 18 000 Megalitres. Okedi assessed three demand options for non-potable water – Sc1 for agricultural irrigation, Sc2 for residential garden irrigation and toilet flushing, and Sc3 for residential garden irrigation, toilet flushing and irrigation of public open spaces. He found that even with the use of RTC, the storage in the ponds was only able to supply 40%, 60% and 58% of the demands of Sc1, Sc2 and Sc3, respectively. Much of the mean annual stormwater volume would still overflow the ponds and be lost as spillage.

Next, Okedi considered making use of the vleis for additional storage. This would allow 22% of the modelled mean annual



The project focused on the Zeekoe catchment, which contains more than 60 stormwater ponds. The main drainage channel is the Great Lotus, which rises in the precinct of the Cape Town International Airport and flows into Zeekoeivlei, as does the Little Lotus. The Southfield Canal discharges into Princess Vlei and then Rondevlei. Discharge to the sea is via the Zeekoe Canal, which receives treated effluent from the Cape Flats wastewater treatment works oxidation ponds just upstream of the outlet.

stormwater volume to be stored, with 70%, 79% and 76% of the Sc1, Sc2 and Sc3 demands being met.

"If you converted the vleis to reservoirs, they would provide a significant amount of storage, but the issue is practicality," says Okedi. "They are used for recreation and have ecological value, so not many people would be happy if their existing function was taken away!" Both Rondevlei and Zeekoevlei form part of the False Bay Nature Reserve, which was declared a Ramsar wetland site of international importance in 2015, while Princess Vlei forms the core of the Greater Princess Vlei Conservation Area and was designated a provincial heritage site in September 2020.

Thus, the water levels in these permanent waterbodies should not be overly manipulated on a frequent basis – currently, periodic 'drawdowns' are done for ecological purposes and to lower water levels enough for mechanical removal of accumulated sediment and encroaching reeds. But what if water was simply abstracted from the vleis, pre-treated and then pumped approximately 30 km to the Faure water treatment plant, where it could be fully treated to potable standard and then piped through the existing water distribution network? Because while stormwater harvesting for non-potable uses such as irrigation and toilet flushing would theoretically reduce pressure on the six dams of the Western Cape Water Supply System, which currently provides 98% of Cape Town's potable water, it would necessitate installing a dual reticulation system. Laying all those extra pipes to transport the non-potable water would be extremely expensive, not to mention disruptive to all.

The study found that it would indeed be more cost-effective to harvest stormwater for potable water, which is needed throughout the year, unlike irrigation water (toilet flushing, although year-round, makes up a very minor portion of total demand). Besides, there are health risks associated with consuming fruit and vegetables irrigated with untreated stormwater, which is typically highly polluted, not only through faecal contamination – as evidenced by the excessively high ***E. coli*** counts – but also by heavy metals and hydrocarbons. The findings showed, however, that it would be difficult to abstract water from the vleis, treat it and supply it at a rate that would minimise spillage.

A better option would be to take advantage of the underground storage potential of the Cape Flats Aquifer, through managed aquifer recharge (MAR). The predominantly unconfined aquifer is close to the surface here, occurring in sandy sediments that were once windblown coastal dunes. The aquifer is already the main source of water for the Philippi Horticultural Area, where farming of vegetables and livestock takes place on approximately 2 000 hectares (roughly 20 km^2) of farmland, most of it falling within the Zeekoe catchment.

Okedi investigated the MAR that could be achieved if the stormwater ponds were adapted to promote infiltration into the aquifer. About 70% of the stormwater ponds in Cape Town are detention ponds – unlined earth basins constructed to hold stormwater for short periods during rainstorm events, after which the water flows away slowly, evaporates or infiltrates into the ground. The modelling study assumed that the detention ponds could be converted to bio-retention cells, typically

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Most of the stormwater ponds in Cape Town are detention ponds that hold water for short periods during rainstorms but are dry for most of the year. Many are used as play-arks or informal sport grounds.

composed of a vegetated surface layer, a middle soil layer with organic matter or fly ash mixed with a filter media, and a deeper storage layer consisting of crushed stone or gravel, with a drain at the bottom.

Groundwater flow and abstraction were also modelled, and water quality considerations assessed. The results indicated that the proposed MAR would allow the Zeekoe catchment to support 140 boreholes, each pumped at 3.5–8.1 litres per second to ensure that the flow fields were drawn largely from the areas around the stormwater ponds. This would provide a combined mean annual groundwater yield of 29–33 Mm^3, of which approximately 30% would be attributable to stormwater infiltration. Water quality would improve somewhat during the time in storage, with natural die-off of pathogens, although disinfection treatment would still be needed for potable uses.

Okedi had planned to follow up this theoretical research, which drew upon available data from previous studies for the modelling, with a postdoctoral project to do experimental work and ground-truthing. But soon after completing his PhD he was appointed to an academic position in UCT's Civil Engineering Department, so a PhD student has recently been recruited to conduct this research. He will be working on a specific stormwater pond, measuring rainfall and incoming flow, monitoring groundwater levels, modelling it all and calibrating the model with his data.

Okedi is excited to see whether this research will show that the concept is practically possible. His own economic analysis on the viability of stormwater harvesting – comparing surface water and groundwater sources for potable and non-potable supply and including capital, operation and maintenance costs – indicated that the most cost-effective option would be MAR for potable water supply using the existing water reticulation system.

However, although the City of Cape Town committed in its water strategy, approved in mid-2019, to make "optimal use of stormwater and urban waterways for the purposes of flood control, aquifer recharge, water reuse and recreation", it has since revealed the intention to use treated wastewater effluent, rather than stormwater, for MAR of the Cape Flats Aquifer. For more than 40 years, it has used both stormwater and treated wastewater to recharge a similar sandy aquifer on the west coast through a series of infiltration ponds and recharge basins that form part of the Atlantis Water Resource Management Scheme.

In the case of the Cape Flats Aquifer, the potential of using treated wastewater effluent for MAR was thoroughly investigated in a long-running WRC-funded project during the

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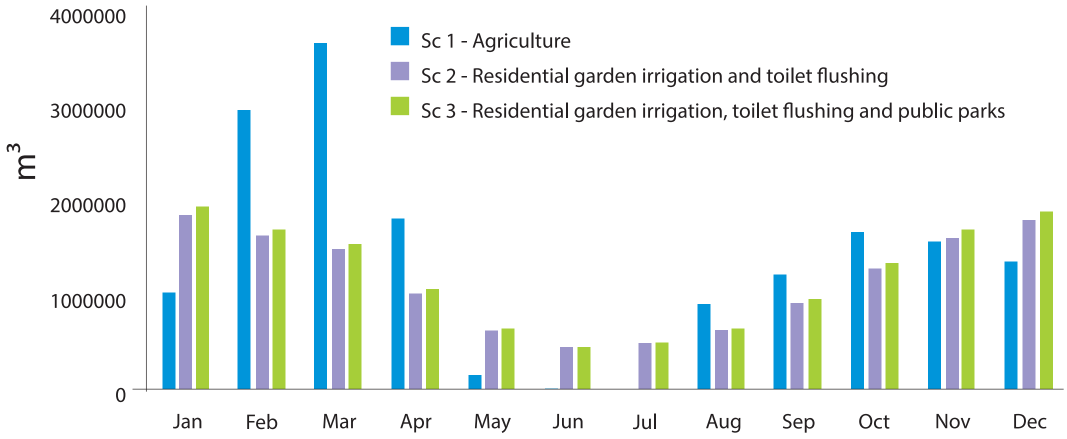
Zeekoevlei is a popular recreational area and forms part of the False Bay Nature Reserve, which must be taken into consideration if used for stormwater harvesting.



The estimated mean monthly demand values for the three water demand options assessed in the project.

1970s, 'The reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula', led by the CSIR. But the aquifer was not developed as a municipal water resource, and over the years additional research indicated that it was under increasing threat of pollution from wastewater treatment works (WWTW), leaking sewers, informal settlements, solid waste sites, cemeteries, as well as industrial and agricultural areas.

The 'Day Zero Drought' provided the incentive that was needed to refocus on the Cape Flats Aquifer, which now features strongly in the City of Cape Town's New Water Programme, designed to fulfil the commitment made in the 2019 water strategy to develop 300 Megalitres per day of additional water supply capacity by 2030. The first wellfield, Strandfontein West, is almost complete and will start contributing to the municipal supply by mid-year. The abstracted groundwater will be treated on site in a package plant with a capacity of five Megalitres per day before being introduced directly to the potable distribution network. The MAR component of the Cape Flats Aquifer Project is only planned to be operational by 2026/7, although construction of the pre-treatment plant for treating wastewater effluent to a high standard before it is injected into the aquifer is expected to be completed in 2024.

Other projects within the New Water Programme, which will require an investment from the City of Cape Town totalling some R4.7 billion, include the Table Mountain Group Aquifer Project, the refurbishment and expansion of the Atlantis Aquifer scheme, the Berg-Voelvlei River Augmentation Scheme, the Faure New Water Scheme – a water reuse scheme that will treat effluent from the upgraded Zandvliet WWTW for potable supply – and desalination.

Okedi says that City of Cape Town water staff had explained that the reason for choosing treated wastewater effluent over stormwater for the Cape Flats Aquifer MAR was due to variability in both quality and quantity. "They would rather work with wastewater because they are sure of the water quality – it's not very variable compared to stormwater, and with their testing regime they don't have a good handle on what's in stormwater, in terms of heavy metals and emerging contaminants. But I would argue that with wastewater we don't know what people are doing in their homes, like taking drugs or discarding substances down drains, and those things are not tested for in the existing regime. Wastewater is not just sewage and grey water, but what you don't test you don't know, and what you don't know won't scare you!" he quips.

"The other issue is reliability, which I do agree with, because stormwater is only really available in the winter rainy season in Cape Town, while wastewater flow is quite consistent year-round." What's more, the variability in stormwater flows is likely to increase in future, as climate change is predicted to cause more extreme events, such as droughts and floods.

Okedi assessed the impact of climate change on demand and stormwater yield in the Zeekoe catchment using modelled data provided by UCT's Climate Systems Analysis Group. The data suggested an annual mean reduction in rainfall of 40–200 mm by the year 2100, along with a 3–5°C rise in mean daily temperature, which will increase evapotranspiration. This will likely result in a 15–50% decrease in stormwater yield in the catchment, but it will be more than offset by the increase in hard, impervious surfaces that can be expected with land-use change. Should the mean imperviousness of the entire study area increase from the current estimate of 45% to 75% as developments replace agricultural land and other open spaces, a 91% increase in stormwater yield is predicted.

"If we are able to capture that water, it would make a significant contribution to future water security and be very useful for sustainability," says Okedi. "Sustainability is not about going many kilometres away to the mountains to get water and then whatever falls on our city is drained off to the sea. We could augment the city to become a giant catchment so that any rain that falls here is infiltrated into the ground and stored there for later use. So it's vital that we protect our greenbelts and ponds, as these will be our access to the unconfined aquifer to preserve water for the future."

To download the final report, ***The viability of stormwater ponds in the Zeekoe catchment as water resources for Cape Town, South Africa*** (**WRC report no. 2526/1/22**) Visit: https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/2526.pdf