

## NEWS FEATURE:

## The next water cycle

Lisa Palmer

Adaptation of water resources management will help communities adjust to changes in the water cycle expected with climate change, but it can't be fixed by innovations alone.

Something is drying up the Pangani River. Maybe it is the Tanzania Electric Supply Company, which manages three hydropower plants located on the river, providing up to 17% of the country's electricity. Maybe it is the thousands of farmers and herders, whose traditional furrow irrigation methods deplete the river. Or maybe, as scientists say, drought is to blame for the recent problems. Under climate change and changes in population dynamics, this problem of unpredictable fresh water will only get worse in the Pangani Basin, because more people are depending on the water, and the water sources for the Pangani River — rainfall and glacial meltwater flowing from Mounts Meru, Pare and Kilimanjaro — are rapidly diminishing<sup>1,2</sup>.

Climate change is affecting the global water cycle like never before. The changing pace of precipitation, droughts and extremes of the two is altering the way farmers, pastoralists and Tanzania's energy company, for example, manage water — with implications for agricultural irrigation and hydropower energy that affect the people they feed and supply energy to<sup>3</sup>. But it's not just the developing world that is adjusting to new uncertainties around freshwater management. All around the world, water managers are finding new ways to work towards adaptation. New techniques and planning for an uncertain future means that both urban and rural development plans are moving away from large, static projects that were once pillars of engineering to solve water problems.

Instead, water managers are looking for long-term sustainability solutions by combining historically antagonistic approaches — engineering and ecology. The result is a joint focus where water management is a multifaceted science and part of everyone's job, including policymakers, economists, energy companies, city planners and water-treatment agencies.



Historically antagonistic fields, engineering and ecology, are seeking multifaceted solutions to water management under climate change.

In the Pangani Basin, for example, climate change means a rise in temperatures, changes in rainfall patterns and reduced surface flows of the river<sup>1</sup>. But around the world, climate change broadly means water change. It is projected to increase droughts, storms, floods and ice melt, and to raise sea level, which will alter the flow of water into river basins worldwide. Nearly all countries expect increasing water risks due to climate change. According to the Organisation for Economic Co-operation and Development (OECD), extreme events such as floods and droughts are a primary concern of 32 countries, and water shortage is

a key issue for 23 countries, including the European Commission<sup>4</sup>. Add to that changes in human systems, and it becomes obvious why water management practices need to change. Water managers are now seeking an integrated systems approach, furling into the mix both social and environmental dimensions — such as governance and ecosystems — and different disciplines, including economics and hydrological engineering.

“People working on adaptation for water management realize the past is no longer a sufficiently reliable guide to the future,” says Kathleen Dominique, an environmental economist at OECD. “While we can't predict with precision the exact pace and magnitude of change, there is a clear recognition that flexible approaches are necessary to adjust to changing conditions at least cost.” One example, she says, is simply periodically updating standards for flood protections; another is finding more flexible ways to allow water to be allocated where it is most needed, instead of locked into historical uses.

For the Pangani River, leaders adjusted water allocation policies with the changing needs of the communities. Still, they made water availability for ecosystems a main priority by maintaining at least a minimum flow of water to wetlands, riparian forests and mangroves to provide water for wildlife including fish, plants for medicinal use, timber and fruits, for example<sup>5</sup>. Then, as the region's population swelled, water uses for urban city centres were balanced with the needs of subsistence farmers, pastoralists and the Tanzanian energy company. That same kind of flexibility is the hallmark of the new thinking on water management. Rather than relying on large, long-lived concrete infrastructure, often built all at once and designed based on historical climatic conditions, the OECD advises a more flexible system, Dominique says. In a similar way, the European Union's water directive, developed in 2000, manages the rivers of Europe<sup>6</sup>. It is adjusted every six

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years, taking into account all changes and uses, not only climate change.

Mark Fletcher, a water engineer by training, is the global water business leader at UK-based Arup, a global company of consulting engineers with 14,000 employees. He has become a global leader in sustainable water management by rethinking ways to manage fresh water. Modular is one way to describe sustainable water work, he says.

“We had assumed that the world was static. We knew that the climate was predictable. Due to climate change or due to a changing climate, it is harder to predict things. So rather than build overly conservative monolithic solutions, we now design systems that can be tweaked and twiddled,” he says. A good example is osmosis desalination. “You literally stack desalination units, much like you would batteries, until you solve your problem.”

Fletcher favours natural solutions. In New York City, for example, new plans for city orchards and 9,000 grassed bio-swales, which resemble marshy depressions in the land, will slow the flow of storm water from sidewalks to water catchment basins. “Think of them as green sponges all over the city. The water gets soaked up and you avoid pumping every time it rains,” he says. “It’s the gift that keeps on giving.” Furthermore, rather than design water treatment plants that can accommodate extreme rainfall, he favours multiple local responses that can be changed and adapted, much in the way that a Lego building block is removed and added.

Fletcher suggests that the solution to water management under climate change is beyond engineering. That’s why ecologists John Matthews, coordinator of the Alliance for Global Water Adaptation, and LeRoy Poff, a professor at Colorado State University, have been leading a team of 27 researchers at the US National Socio-Environmental Synthesis Center in Maryland. The team includes economists, hydrologists, policymakers and engineers. Climate change, they say, has prompted the researchers to work together on an integrated approach to freshwater adaptation. Rather than isolating water management issues within a single field, such as engineering or hydrology, the team’s multifaceted work is developing solutions for decision-makers. Think of their combined work as a chemical reaction. Instead of one element, such as engineering, working in seclusion on a freshwater adaptation project, their form of synthesis science means suddenly more ingredients are added to the beaker.

Matthews says that a model for integrating systems in a sustainable way is the Dujiangyan network in the Sichuan

Province of Xing Du, on the Minjiang River, in China. Built in 256 BC, it is a large water-diversion system still in operation today. It pulls some of the water from the Minjiang River and diverts it through a series of canals, and now supplies fresh water for roughly 20 million people. Water ecologists ideally want systems that work in the same way — on a timescale of hundreds of years. But that hardly seems possible given the uncertainties associated with a changing climate, says Matthews, unless social sciences and ecological thinking are included in water projects.

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Since the original construction, the Dujiangyan water network has had few changes, and is essentially intact. One of the keys to its sustainability is that it didn’t cause irreparable harm through the construction or operation of the irrigation system. “The basic design was good from the beginning, and it could be modified over time to make it better and to match shifting conditions,” Matthews says. The main facility has been repaired several times, and the operations have been flexible to adapt to a greater number of water users. Matthews adds that another key to its environmental sustainability is the governance system in place among local farmers that is based on age-old mnemonic phrases, used to signal the timing of actions to keep the water flowing and cleaned out, or certain water conservation strategies during periods of low flow, methods that are still used today.

To put other water management systems on a similar path, Matthews and Poff’s team are identifying markers of resilience of both infrastructure and ecosystems in basins and using the analysis to help incorporate ecological principles into the project from the very beginning.

Dams are the particular focus of their synthesis research. For a dam to be environmentally sustainable, the downstream rivers also need to remain healthy, even under climate change and changes in human systems. Poff says the design and operation of dams need improvement from the ecological side to allow downstream rivers to remain more dynamic and to have varying flows that provide a range of habitat for diversity of species.

“They could design downstream floodplain areas that can naturally store flood waters, meaning the dams can be smaller,” he says. This would allow for a connection between the river channel and floodplain, which is critical for many fish species whose young are reared in off-channel backwaters. Furthermore, he says that such a design can allow species to move through the river basins and find suitable habitats to complete their life cycles and share genes among populations.

By identifying such resilience markers, in this case features that make a river a river, the project can allow the river to remain diverse and productive in the longer term. For example, dynamic flow variation, seasonal changes in water flow and temperature, and connection to floodplains are all resilience markers. When these features are diminished, resilience is reduced. The specific ecological indicators for such markers vary from river to river, but the general principles hold, Poff says.

Perhaps the most recognizable example of using strategies that are flexible to shifting hydrological realities is the United Kingdom’s Thames Estuary 2100 project. It is a strategy for the tidal flood risk management of the estuary, which would protect 1.25 million people, £200 billion of property value, and major infrastructure, including the London Underground, 16 hospitals and eight power stations<sup>4</sup>. The plan has a flexible approach to make small incremental changes first and leave the big, irreversible infrastructure decisions far into the future.

By incorporating ecological principles into the building of water infrastructure and dams, Matthews says that both natural capital and ecosystem services can be preserved while also providing sources of energy and water security where they are most needed. □

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