Our cities' water systems are becoming obsolete. What will replace them?

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Most of us in the United States don't give much thought to our drinking water. When we turn on our faucets, clean drinking water comes out. When we flush our toilets, the waste goes away. Simple, right?

"Urban water systems evolved in response to three major crises — now we're facing a fourth "

But as David Sedlak explains in his fascinating book, *Water 4.0: The Past, Present, and Future of the World's Most Vital Resource*, nothing about water has ever been simple. The urban water systems we rely on so heavily were developed in response to three major crises stretching back centuries — from water shortages in the Roman Empire to cholera outbreaks in the Industrial Revolution to polluted lakes in the United States in the 1970s.

And now, Sedlak writes, we're about to face a fourth major water crisis — "as continued population growth and climate change stretch the ability of urban water systems to meet our needs."

During past crises, engineers came up with ingenious technical fixes. The Romans perfected systems for bringing freshwater from faraway sources to crowded cities. In the 19th and 20th centuries, Europe and the United States developed water-treatment methods — sand filtration and chlorination — to clean up drinking water so that it didn't make people sick. And, in the 1970s, the US enacted the Clean Water Act to fund waste-treatment plants, so that we were no longer choking our lakes, rivers, and streams with raw sewage.

Those fixes worked well. But now cities are facing a fresh round of problems — in need of further, drastic fixes. Many of the pipes and sewage-treatment plants we've built will soon reach the end of their lifespans and require big, costly upgrades. In the Northeast, cities have grown so large that sewage systems are struggling to rein in overflow during big storms. And in the Southwest, cities like Phoenix and Las Vegas are grappling with a lack of water — a problem that will become more dire if global warming makes drought more common.

I talked to Sedlak in October about his book and how our water systems will have to change in the future. There's no one single technology that will fix all of our water woes, he says. Some cities will simply have to plunk down billions to update their aging pipes and plants — although many will try to postpone fixes for as long as possible. "Historically, we've always been reluctant to spend money on water systems until a real crisis comes along," Sedlak says. "And we're starting to enter one of those periods."

Meanwhile, better conservation can help water-stressed cities — but only up to a point. Many cities in the Southwest may have to look to new technologies, such as water recycling, desalination, or even radically decentralized water systems. Some of these technologies have drawbacks (desalination uses an enormous amount of energy, for one), but they could become more common in the years ahead.

Sedlak is the co-director of the Berkeley Water Center, and the director of the Institute for Environmental and Science and Engineering at the University of California, Berkeley. A lightly edited transcript of our interview is below.

How water systems evolved: from the Romans to the 1970s

The Pont du Gard, an ancient Roman acqueduct bridge in southern France (Dmitry Shakin/Flickr)

To understand why our current water systems are entering a new crisis era, it's worth going back and understanding how we got here. "I like to describe the history of urban water systems as a series of three big revolutions," Sedlak says. "Water systems tend to remain static for long periods of time, and it's only when the system is under stress that people decide to allocate the resources necessary to bring about a change."

"The Romans laid the ground for the next 1,900 years or urban water systems"

Water 1.0 — bringing drinking water to cities. "The first of these water revolutions, I credit to the Romans and call it 'Water 1.0,'" he begins. "Rome was a very large city, anywhere from 500,000 to 1 million people at its height, and it was impossible to provide everyone there drinking water from the Tiber River and local groundwater sources alone.

So the Romans brought in water from the nearby countryside — the system that included those famous Roman aqueducts. And because the Romans were so wealthy and had such sophisticated engineering, they were able to provide their citizens something like 100 gallons per person per day — which is comparable to what we provide in modern cities."

"That system of bringing in imported water via a gravity-fed system, distributing it around the city, and then ultimately disposing of it through an underground sewer network, really laid the ground for the next 1,900 years of urban water."

Water 2.0 — water treatment. "Water 1.0 was a great idea, and made it possible for people to have large quantities of inexpensive water come into their homes. But it then led to a new problem in the modern age. Steam engines and water wheels allowed us to pressurize water and deliver it to the home, which led to inventions like the toilet and shower. We were using so much water that it had to go somewhere."

"Before, human waste could go into night-soil buckets and it would get taken to the countryside [for use as fertilizer]. But now we were putting human waste into water and putting it in the sewer, and if you lived downstream from a city that was doing this, this was contaminating your drinking water supply. So in the 19th century and early 20th century, it was commonplace to have waterborne disease outbreaks like cholera and typhoid fever."

"Many cities dealt with this problem by bringing in water from places that weren't contaminated. But there was one city that couldn't do this — Lawrence, Massachusetts, which was downstream from the textile manufacturing city of Lowell. Wastewater from Lowell was contaminating the Merrimack, but Lawrence had no other alternative. So [in the 1880s] they turned to engineers at MIT, who came up with the simple idea of filtering water through sand as a way of removing typhoid fever bacteria. That was later coupled with chlorination of water and basically solved the problem of waterborne disease outbreaks."

"I call that Water 2.0, because it really was a revolution. That technology extended the lifespan of the average American by something like 15 years. The National Academy of Engineering ranked drinking-water treatment right up there with electricity and air travel as the biggest innovations of the 20th century."

Water 3.0 — paying for sewage treatment. "But there was still a problem. We were still putting more sewage into our rivers and lakes. And even though we could still pull out clean drinking water from those polluted sources, that sewage was causing ecological damage. Between the 1920s and the 1970s, our rivers and lakes and estuaries really got degraded — there were discussions of the Great Lakes dying, the waterfronts of big cities reeked from sewage going directly into the river. You had fish kills, algae blooms."

"Now, we actually had the technology to treat sewage — this was perfected between the 1920s and 1940s. But cities didn't want to pay for them. It wasn't until the late 1960s and early 1970s that the public got concerned about environmental problems and Congress passed the Clean Water Act, which created a federal system for underwriting the cost of sewage-treatment plants. For a 20-year period, starting in 1972, the federal government paid up to 75 percent of the cost of building sewage treatment plants. And we largely made these polluted rivers and lakes, once again fishable, swimmable, and in many cases drinkable. That was water 3.0."

Now our urban water systems are starting to break down

Harlem River Park in New York City. Combined sewer overflows (CSOs) can occur in wet weather when wastewater treatment plants and/or parts of the sewer system fill to capacity with rain or snow. To relieve pressure on the already filled to capacity wastewater treatment system, the excess flow is forced into the open waters of a river, bay or inlet. (j-NO/Flickr)

So what are the biggest problems facing water systems today? "I would categorize the stresses on our modern water infrastructure into three groups," says Sedlak.

"'When we built all this water infrastructure, we didn't think hard enough about creating a system to fund its upkeep' "

1) Our water infrastructure needs costly upgrades: "First, when we built all this water infrastructure, we didn't think hard enough about creating a system to fund its upkeep, maintenance, and replacement. We had a federal grant system to build these treatment plants, but needed to set aside money to rebuild them."

"So now we're entering a period where many of the water pipes and treatment plants built throughout the 20th century are falling apart and need to be replaced at almost the exact same time. This puts a tremendous financial strain on our water utilities, and they're really limited on how much they can raise our water rates, because no one likes their water bill going up."

2) Many sewer systems are becoming overloaded: "The second strain I see on our urban water systems is particularly relevant in places with a lot of rain and snow — the Northeast and the Midwest and even the Pacific Northwest. Many of these cities built what are known as 'combined sewer systems,' where all of the storm runoff gets routed through the sewage treatment plant."

"But as cities have grown and we haven't kept up with increasing the size of pipe network, there's a tremendous need to upgrade our systems to handle that large volume of water that comes in every time it rains. Cities like Indianapolis and Philadelphia and Seattle are struggling to spend hundreds of millions of dollars or billions to upgrade their systems to prevent raw sewage from leaking out of the treatment plants during large storms."

3) Water scarcity in drought-prone areas: "The third stress on urban water systems is more relevant in places where we don't have enough water. That would be the West and Southwest and increasingly the Southeast of the United States."

"In these areas we see tremendous population growth. Ten of the country's 20 largest metropolitan areas are located in the South or West in areas where there's just not enough water supply. And our conservation efforts are starting to reach their limits. We're also realizing that some of these regions are most prone to climate change. So we see drought in California, drought in Texas, until recently the drought in the Colorado River basin, and that has sparked real concerns about providing cities in this region with enough water in the future."

Climate change will make this all harder. "The most recent global climate models suggest that the wet places will get wetter and the dry places will get drier. And that's exactly the wrong thing for the water infrastructure that we have. Cities in the North and Northeast that are struggling with combined sewer overflows can expect more big storms and stress on their systems. And cities in the South and Southwest can expect longer drought periods and higher water demand as temperature gets higher."

Cities are already struggling to deal with these crises

(Marcy Leigh/Flickr)

"The situation that many utilities find themselves in could be described as 'muddle on in the best way possible,'" Sedlak says.

"Conserving water only works up to a point "

"So, for example, in the case of cities that struggle to dispose of all the storm water that overwhelm their sewage treatment plants, many cities are building gigantic pipe networks to intercept rainwater and hold it underground temporarily so it doesn't overwhelm the treatment plants when it rains. In those cities you see increases in people's water bills. But it's difficult to do this — people tend to notice anytime their water bill goes up faster than inflation."

Meanwhile, in the Southwest, many cities have been pushing for conservation measures to save water — but even those have limits. "When you look at where water goes in the western United States," Sedlak says, "almost half of the water that comes to our cities that are grappling with water-supply problems goes outdoors to lawns. So the logical thing is to try to discourage people who live in arid climates from having green lawns — or at least encourage more appropriate landscaping."

But this is easier said than done. "Simply raising someone's water rates is hard because there are poor people in the community who struggle to pay their water bills. So you can try to come up with system that penalizes people for high water use. But it takes more than a $50 or $100 month water bill to get someone with a lush green lawn to change their behavior."

"The other strategy available to utilities is more of a carrot approach — that is, to provide people with incentives for replacing their lawns with desert-friendly plants. But that requires a fair amount of effort and community outreach to do."

Possible fixes: Water recycling, desalination, decentralization

This file picture taken on April 22, 2008 shows fresh water pumped into a reservoir after being treated at a desalination plant in Carboneras, near Almeria, southern Spain. (Jose Luis Roca/AFP/Getty Images)

In his book, Sedlak makes clear that we still don't know exactly how cities will deal with all of the water crises they're now facing — from overflows in the Northeast to drought in the Southwest. But he explores a number of nascent technologies that might play a much bigger role:

"'We now have the ability to recycle water within cities' "

Water recycling: "We now have the ability to recycle water within cities," Sedlak says. "And that idea of taking our wastewater and using it again in a centralized fashion is really revolutionary. It extends our water supply with a source of water that is largely resistant to drought."

"The first generation of water reuse focused on taking wastewater effluent for industrial purposes — like water for cooling towers or oil refineries or using the water for landscape irrigation and agriculture. Those approaches are well established. But the forefront of water reuse is today is treating that water to a point where it can introduced back into the drinking water supply."

This isn't *quite* as novel as it sounds. "When we look at southern California, there are a number of cities that have engaged in this practice for decades," Sedlak says. "They take the wastewater effluent, they subject it to reverse osmosis, then treat it with another oxidation process. And that water is so clean that it's hard to distinguish it from a distilled water that you would buy at the store. They then put it back in the aquifer."

"The real direction this is going is a practice called direct potable reuse — where people take wastewater and treat it and put it *directly* into a drinking water treatment plant. And that's already starting to happen. We have a couple of projects in Texas starting to deliver water this way, in Odessa and Midland. There's one in a town called Big Spring."

Desalination: Many people still think of desalinating sewater as something that's too costly to work. Not so, explains Sedlak. "Seawater desalination has undergone tremendous technological advances just in the past decade. When Australia struggled with their millennial drought or when Israel and Spain have grappled with their water supply needs, seawater desalination was a major part of solution."

Unfortunately, this solution also comes with drawbacks. "There are lots of concerns over energy consumption and greenhouse-gas emissions and the possible damage that desalination plants can cause to the aquatic environment. I think the ecological damage from desalination has largely been addressed through projects in Australia. But it's really this concern about energy consumption that is slowing down desalination's movement in the western United States."

"Still, there's a big desalination plant, a 50-million-gallon a day plant being built in Carlsbad, just north of San Diego and there's a large seawater desalination operating in Tampa. So there are examples, and the jury's out on whether it will become more widespread."

Decentralization: Many cities currently have centralized water systems — all the water comes from one big water treatment plant, and all the waste goes to one big sewage-treatment plant. But as water becomes scarce in areas and older systems come under strain, more places may decide to decentralize their systems.

"In North America, remember, most people live in suburbs," Sedlak says. "So we have the potential to build our water infrastructure in a distributed fashion. We might build a small wastewater treatment plant for a small neighborhood, and use that water for local landscape irrigation — or even recycle it for drinking water — instead of sending that water all the way back to a centralized treatment plant many miles away and then pumping it back to the community.That would give us tremendous potential for saving energy and avoiding the need to maintain and operate a large underground networks of pipes.

So what's standing in the way of "Water 4.0"?

"The first obstacle is that people don't want to spend the money until there's a crisis," Sedlak says. "It's only o nce crises occur, people to start investing money very quickly. We see that with respect to flood control infrastructure in New Orleans and New York City. People had issued warnings that those cities were susceptible to major hurricanes, but we had to wait for those hurricanes to hit."

"Similarly when you look at the questions of drought, or combined sewer overflows or decaying pipes — prior to an emergency, the public's hesitant to make the investment. So the challenge for water engineers is to try to have the right technologies available, so that when society decides it's time for a change, these are the shovel-ready projects that we build. Because if we don't do the demonstration-scale projects and learn about the pros and cons of different approaches, we'll just continue to build more of the same."

I asked Sedlak whether climate change might be more difficult to plan future water systems — since we don't know for sure how future rainfall patterns will change. "I think there's a fair amount of uncertainty in terms of no longer being able to use the historic record to predict rainfall patterns in the future," he says.

"But I also don't think the increased uncertainty should push us to try to make our water systems more robust than they are now. So that if the worst comes to pass, we'll be ready for it. Unlike our cellphones or computers that we replace every four or five years, investments in water infrastructure take decades to plan and are intended to last 40 or 50 or 100 years. So when we make those investments it's important to get it right."