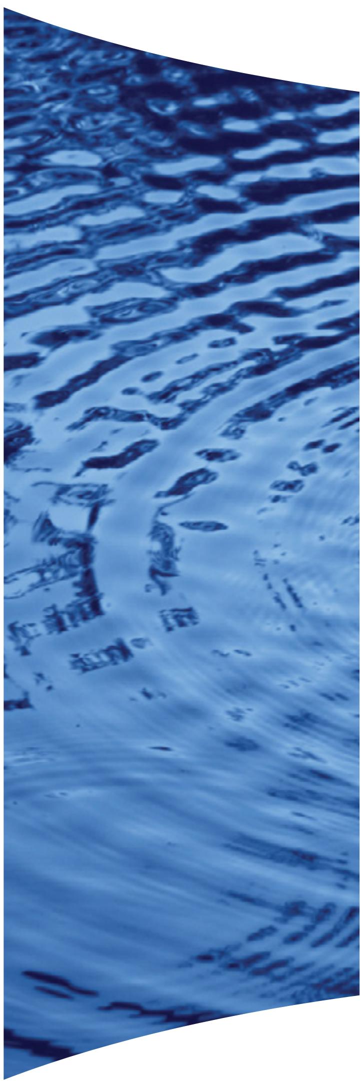
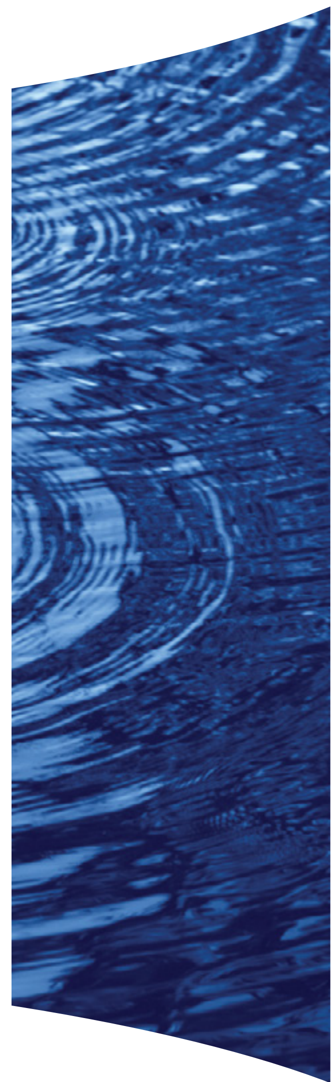
August 2014

Charting New Waters

Optimizing the Structure and Scale of Urban Water Infrastructure:

Integrating Distributed Systems





The Johnson Foundation AT WINGSPREAD

About The Johnson Foundation at Wingspread

The Johnson Foundation at Wingspread, based in Racine, Wisconsin, is dedicated to serving as a catalyst for change by bringing together leading thinkers and inspiring new solutions on major environmental and regional issues. Over the course of 50 years, The Johnson Foundation at Wingspread has inspired consensus and action on a range of public policy issues. Several organizations have roots at Wingspread, including the National Endowment for the Arts, National Public Radio, the International Criminal Court and the Presidential Climate Action Plan. Building on this legacy, The Johnson Foundation at Wingspread has set a new, strategic mission designed to achieve greater, more sustained impact on critical environmental issues. Launched as part of this new direction is Charting New Waters, an alliance of leading organizations calling for action to avert the looming U.S. freshwater crisis.

Report design: Modern Media

Cover image: Michael S. Yamashita/
National Geographic Creative

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Suggested citation:
The Johnson Foundation at Wingspread. *Optimizing the Structure and Scale of Urban Water Infrastructure: Integrating Distributed Systems.* Racine, WI: The Johnson Foundation at Wingspread, 2014.

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Optimizing the Structure and Scale of Urban Water Infrastructure:

Integrating Distributed Systems

Convening Report

Meeting Convened by
The Johnson Foundation at Wingspread
March 2014

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The Johnson Foundation
AT WINGSPREAD

The current phase of Charting New Waters is focused on catalyzing the transformation of U.S. water and wastewater infrastructure to achieve long-term sustainability and resilience of the nation's water resources in the face of climate change, energy constraints, diminishing groundwater supplies, financial challenges and other resource constraints. This phase aims to disseminate information that helps local, state and national leaders set a course for and navigate decisions regarding the construction, management and maintenance of sustainable and resilient water infrastructure of the future. A critical piece of this work is determining the right structure and scale of water systems for optimal long-term sustainability and resilience for water, energy, sanitation, stormwater and other quality-of-life factors.

Partnership in Action

The Water Environment Federation, the Patel College of Global Sustainability at the University of South Florida and The Johnson Foundation worked in partnership to convene a meeting at Wingspread in March 2014 on the topic of optimizing the structure and scale of urban water services and management systems. Meeting participants represented the diverse interests and perspectives The Johnson Foundation sets out to engage through Charting New Waters, including scientists, researchers, engineers, utility managers, federal and state regulators and members of advocacy groups. The partners are working to increase understanding of potential solutions to the nation's urban water system and security challenges and encourage decision makers at the local, regional and national levels to accelerate movement toward sustainable and resilient water infrastructure.

Conferences that Inspire Solutions

Letter from the Director

What type of infrastructure will be up to the task of providing clean water for the cities of tomorrow?

Cities across the United States are experiencing a perfect storm of natural, financial and population pressures that threatens to seriously disrupt how they manage the most fundamental of services: providing clean drinking water and safe wastewater treatment.

The expensive systems of pipes, pumps, deep tunnels and massive centralized treatment facilities on which most urban areas depend for water services can easily require more than a decade to plan and build, and then many more decades to pay for, leaving communities little flexibility as conditions change. Yet conditions are changing. Increasingly variable weather patterns, climate change and declining energy reserves are but some of the challenges that tomorrow's infrastructure must be able to meet.

Fortunately, solutions are at hand. Every week it seems that a new technological innovation is announced, many of which increase our efficiency, reduce input demands, recover a greater percentage of resources that previously were wasted and provide resilient options for water, energy, solid waste or combinations of the three. But how do we transition today's structures to meet tomorrow's needs?

Increasingly, academics, design engineers and water advocates are finding answers in new, small-scale technologies referred to as *decentralized* or *distributed* infrastructure. To those invested in existing systems, distributed can mean disruptive. Distributed systems may disrupt existing business models, maintenance and monitoring protocols, training procedures, financial projections, client–customer relationships and regulatory structures. To others, distributed infrastructure means opportunity: opportunity to live more sustainably, opportunity for innovation and entrepreneurship, and an opportunity to stabilize costs during uncertain times.

In March 2014 we gathered about two dozen leading thinkers and practitioners representing utilities, water-sector manufacturers, academics, consultants, advocates and regulators together to address some of the fundamental questions about the role of distributed infrastructure in addressing the challenges on the horizon.

Though the conversation about the viability of distributed water infrastructure has been ongoing among experts and advocates for some time, it is now rapidly moving into the mainstream. I hope that some of the energy from our conversations at Wingspread comes through in this report. The future will be challenging, but the opportunity is undeniable and the excitement is palpable.

Looking forward to what lies ahead,

Lynn Broaddus
Director, Environment Programs
The Johnson Foundation at Wingspread

Introduction

Large-scale, centralized water infrastructure has provided clean drinking water, wastewater treatment, stormwater management and flood protection for U.S. cities and towns for many decades, protecting public health, safety and environmental quality. To accommodate increasing demands driven by population growth and industrial needs, municipalities and utilities have typically expanded centralized water systems with longer distribution and collection networks. This approach achieves financial and institutional economies of scale and allows for centralized management. It comes with tradeoffs, however, including higher energy demands for long-distance transport; extensive maintenance needs; and disruption of the hydrologic cycle, including the large-scale transfer of freshwater resources to estuarine and saline environments.

Large-scale, centralized water infrastructure has provided clean drinking water, wastewater treatment, stormwater management and flood protection for U.S. cities and towns for many decades.

While smaller-scale distributed water infrastructure has been available for quite some time, it has yet to be widely adopted in urban areas of the United States. However, interest in rethinking how to best meet our water and sanitation needs has been building. Recent technological developments and concerns about sustainability and community resilience have prompted experts to view distributed systems as complementary to centralized infrastructure, and in some situations the preferred alternative.

In March 2014, the Johnson Foundation at Wingspread partnered with the Water Environment Federation and the Patel College of Global Sustainability at the University of South Florida to convene a diverse group of experts to examine the potential for distributed water infrastructure systems to be integrated with or substituted for more traditional water infrastructure, with a focus on right-sizing the structure and scale of systems and services to optimize water, energy and sanitation management while achieving long-term sustainability and resilience.

The diverse participants who gathered at Wingspread in March 2014 – including representatives from utilities, industry, nonprofit organizations, architecture firms, academia and government – noted a growing receptiveness among water and wastewater utilities to consider distributed infrastructure solutions, and agreed that these solutions will play a significant role in the future of U.S. water infrastructure and will bolster efforts to create resilient, sustainable and water-secure urban communities.

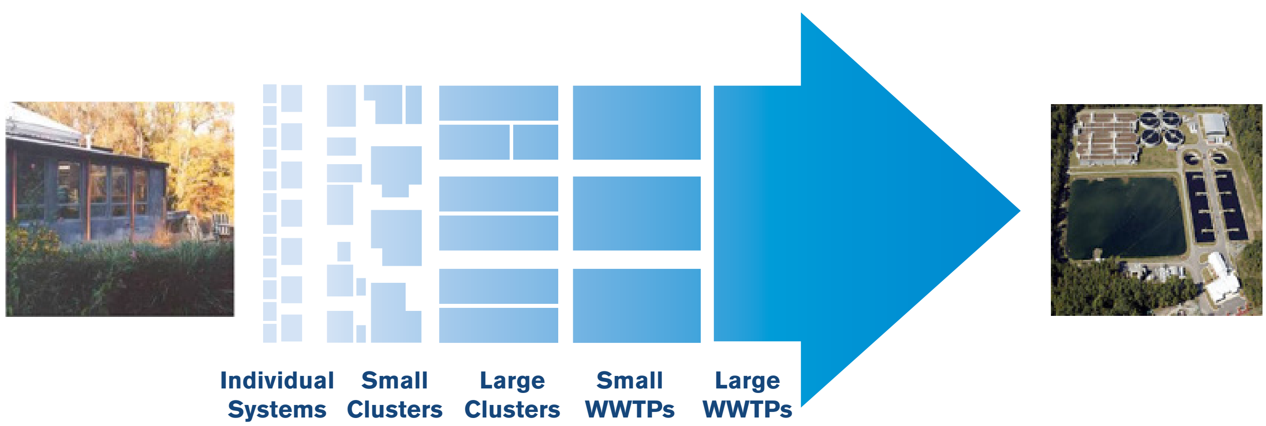
What Is a Distributed System?

In the context of urban water services and systems, the term *distributed* is used to describe dispersed facilities that extend beyond the central infrastructure and are located at or near the point of use. They can service a range of scales, from individual homes to communities; function independently or remain connected to a centralized system; and be located remotely or within city boundaries.

While the terms *decentralized* and *distributed* are sometimes used interchangeably in the context of water infrastructure, participants at the March 2014 meeting stressed the benefits of referring to these systems as *distributed*, suggesting the term aligns better with the benefits and advantages such systems offer, as opposed to *decentralized*, which focuses on what these systems are *not* (i.e., not centralized).

In addition, the group emphasized opportunities to integrate distributed systems with existing centralized systems. Such hybrid systems could be described as *distributed-networked* or *distributed-integrated*, and could provide redundancy that bolsters the overall level of service of urban water systems, as well as flexibility to accommodate new customers and resilience to extreme weather events, natural disasters and other disruptions.

The Wastewater Management Continuum



WWTP = Wastewater Treatment Plant

Images courtesy of Water Environment Research Foundation, *Distributed Water Infrastructure for Sustainable Communities*

Rethinking the Size and Scale of Water Infrastructure: Drivers of Change

Throughout the country, cities and utilities are rethinking traditional approaches to the design, construction and management of urban water infrastructure and the provision of water, wastewater and stormwater management services. The following key drivers are drawing attention to distributed systems as viable and potentially preferable alternatives to conventional water infrastructure:

- Vulnerability to extreme weather, natural disasters and physical security threats
- Water scarcity and security
- Repair backlogs, increasing operational costs and declining revenue

Vulnerability to Extreme Weather, Natural Disasters and Physical Security Threats

Drinking water and wastewater utilities are increasingly looking for more resilient infrastructure and management solutions to prepare for and mitigate the impact of extreme weather events, natural disasters and physical security threats. In water-abundant and water-scarce areas alike, utilities are seeking ways to prevent service interruptions and cascading system failures that adversely affect their customers.

In October 2012, for example, the low-lying Newark Bay wastewater treatment plant operated by New Jersey's Passaic Valley Sewerage Commission – one of the largest centralized wastewater treatment plants in the country, serving 1.4 million residents and 48 municipalities – was severely flooded during Hurricane Sandy and required more than six weeks to fully restore service, with long-term recovery

The Passaic Valley Sewerage Commission's Newark Bay Plant under normal conditions (at left) and inundated in the wake of Hurricane Sandy (at right).

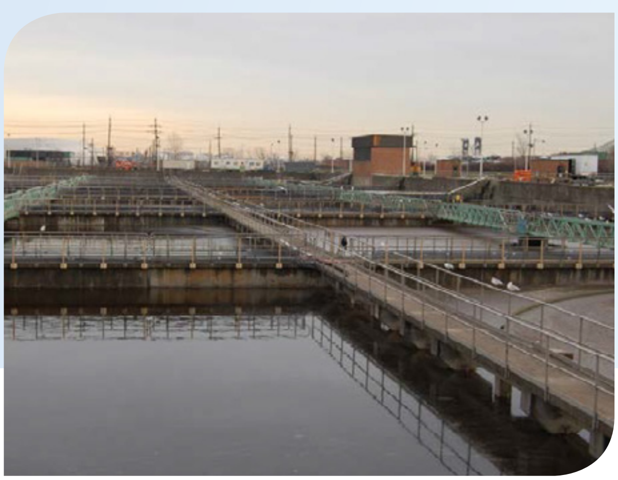


Image courtesy of Matt Ries

Image courtesy of Passaic Valley Sewerage Commission costs of more than $100 million.[1, 2] In the arid Western United States, surface water availability in many areas is expected to decrease by as much as 15 percent, a forecast that is already coming to fruition in California and Texas where extreme drought compounded by increasing population have resulted in some water utilities struggling to meet demand.[3] With climate change predicted to increase the frequency and severity of extreme weather events and natural disasters like these, water and wastewater utilities across the nation need an array of adaptation options from which to choose.

Water Scarcity and Security

Even as per capita water use decreases nationwide, the migration of people into cities is straining water supplies and services. The U.S. urban population increased by 12.1 percent from 2000 to 2010, with 80.7 percent of the nation's population living in urban areas as of 2012.[4] This trend of increasing residential, commercial and industrial urban water demand is beginning to expose the limitations of existing water supplies and infrastructure.[5, 6]

Dwindling water supplies are leading to acute and chronic water shortages in a variety of locales across the country.[7] Demand for freshwater is exceeding natural supplies in nearly one in ten watersheds, an imbalance that is expected to continue and potentially increase as natural supplies decline in some regions. By 2025, cooling towers at thermoelectric power plants are projected to increase water consumption by 165 percent as the electric sector tries to keep pace with energy demand.[8] Trends and projections like these are causing some municipalities and utilities to re-evaluate their dependence on traditional water sources (i.e., surface water and groundwater) and explore options for diversifying their water supply portfolios with more unconventional sources.[9]

Repair Backlogs, Increasing Operational Costs and Declining Revenue

In 2013, the American Society of Civil Engineers gave the nation's drinking water and wastewater infrastructure a grade of "D" in their Report Card for America's Infrastructure, estimating that drinking water systems need more than $1 trillion in repairs and wastewater systems need approximately $300 billion in repairs.[10] In New York State alone, many water systems have been in place for more than 100 years, and the estimated cost of needed infrastructure improvements is $38.7 billion over 20 years.[11]

Even as per capita water use decreases nationwide, the migration of people into cities is straining water supplies and services.

Many water and wastewater utilities are being stretched financially not only by aging infrastructure in need of repair, but by systems that require expansion to serve growing customer bases; increasing operational costs, especially for energy; compliance with more stringent regulations; and (for many) declining revenue driven by water efficiency and conservation trends. In combination, these trends can be financially debilitating.

In the short term, cost considerations tend to reinforce the value of existing, centralized systems that serve a single, discrete function, but small-scale systems are becoming more appealing because they allow utilities more flexibility to respond to demographic and environmental changes. Some utility leaders are already finding incremental investments in distributed technology more financially manageable compared to the large-scale debt required to finance traditional infrastructure.

Principles for Successful Distributed Systems

Participants at the March 2014 meeting identified the following principles for successful implementation of distributed systems, to help utility managers evaluate alternatives for improving, expanding or revamping their infrastructure. With the goals of sustainability and resilience in mind, these principles create space for the successful integration of distributed infrastructure into existing water systems.

Principles for Successful Distributed Systems

- Apply systems thinking to achieve integrated cross-sector management.
- Right-size systems and services to meet situation-specific needs.
- Maximize fit-for-purpose solutions.
- Balance human and ecosystem needs in a watershed context.
- Draw on relevant experience from other sectors.

Apply Systems Thinking to Achieve Integrated Cross-Sector Management: Decision makers should take a systems approach to infrastructure planning that considers and integrates all aspects of the natural and built environment, including the connections between water supply, wastewater and stormwater management, urban flood control, transportation systems, city planning and overall quality of life. Moreover, a holistic, systems approach to management can produce opportunities for multiple uses and benefits, resulting in a more efficient and productive use of water, energy efficiency and greater profitability.

Right-Size Systems and Services to Meet Situation-Specific Needs: Distributed water infrastructure technologies offer opportunities to design systems and services that are sized to meet the needs of customers in a variety of situations and scales (e.g., building, neighborhood, city or region). Right-sized infrastructure solutions can help reduce the costs of capital improvements as well as operations and maintenance, and create greater flexibility to meet demand.

Maximize Fit-for-Purpose Solutions: Fit-for-purpose water management solutions aim to match water of different qualities to specific uses for which they are appropriate. Delivering "tailored" water, particularly for nonpotable uses, reduces the overall volume of water that must be treated to the most stringent quality standards, thus reducing operational costs.

Balance Human and Ecosystem Needs in a Watershed Context: Planning for both centralized and distributed systems should be conducted in a watershed context, to sustain and even revitalize functional, performing landscapes capable of providing for human needs as well as plants, wildlife and ecosystems.

Draw on Relevant Experience from Other Sectors: Many lessons and models may be transferable from other sectors and can provide insight into how to apply and manage distributed technologies. In the energy sector, for example, deregulation, the decoupling of rates and the emergence of small-scale, distributed renewable energy generation systems are disrupting traditional ways of doing business and leading to new solutions.

The Benefits of Distributed Solutions

Distributed water infrastructure offers a number of benefits, including opportunities to create more efficient, effective, restorative and resilient urban water systems. Key opportunities include:

- Water reclamation and reuse
- Resource recovery
- Enhanced resilience
- Flexibility to meet new demand
- Keeping water local
- Corporate sustainability
- Healthier ecosystems

Water Reclamation and Reuse

A variety of technologies and infrastructure systems exist today that enable the capture, treatment and reuse of water at the site, building and community scale. Such systems reduce water demand from centralized systems as well as wastewater flows and utility expenses for owners.

As an example, the Sustainability House at Barrett, the Honors College at Arizona State University, has an on-site graywater treatment and reuse system that captures and treats up to 10,000 gallons of graywater per day for use in campus landscape irrigation.[12] In Compton, California, the 70-unit Casa Dominguez, a multi-family affordable housing development, also captures and uses graywater for irrigation.[13] Water recycling systems have also been used at a larger building scale. The on-site wastewater system at Gillette Stadium in Foxborough, Massachusetts, home of the New England Patriots, can capture an average of 250,000 gallons of wastewater per day; this wastewater is then treated and used in the stadium and surrounding community for toilet flushing, cooling systems and other uses.[14]

While most applications to date have been for nonpotable uses, technology and public acceptance are changing rapidly enough that potable on-site reuse will likely be coming into practice soon.

Resource Recovery

A paradigm shift is underway in the wastewater sector, centered on a move away from treating wastewater by *removing* and discarding nutrients, toward *recovering* nutrients, energy and other useful by-products. The Water Environment Federation has embraced this concept, now referring to wastewater treatment facilities as "water resource recovery facilities" and emphasizing the opportunities associated with nutrient and energy recovery and the creation of new, higher-quality biosolids.[15]

While resource recovery is often achieved more cost-effectively with larger-scale centralized systems, there is growing potential for success using distributed approaches. Opportunities include reduced waste and

The wastewater treatment and reuse system at Gillette Stadium, home to the New England Patriots, eases the strain of the "halftime flush" at the stadium on game days, and also supplies flushing and cooling water for the adjacent Patriot's Place entertainment and shopping complex.

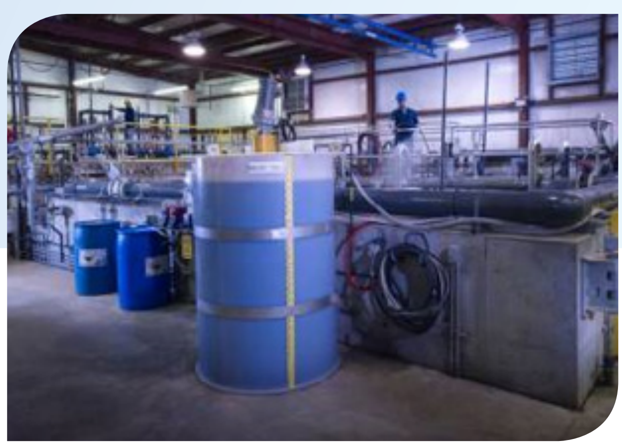


Image courtesy of American Water

treatment costs as well as reduced environmental impact. Some experts apply the term *beneficiation* to describe the opportunities for resource recovery from wastewater, a term borrowed from the mining industry that means gaining as much benefit as possible from a resource.

Energy captured from wastewater can be used within facilities to offset energy costs, with surpluses potentially sold back to the grid, which can translate into lower energy costs or even energy independence, reduced greenhouse gas emissions and reduced rates for customers.[16] For example, while methane recovery is particularly effective in large-scale centralized treatment plants, energy recovery can also occur at a smaller scale through thermal energy capture. In the city of Vancouver, British Columbia, the Southeast False Creek Neighbourhood Energy Utility, which delivers heat and hot water for nearby buildings, captures thermal energy from sewage to offset 70 percent of the area's energy demand.[17]

Energy captured from wastewater can translate into lower energy costs or even energy independence.

Enhanced Resilience

Distributed systems can be more resilient – i.e., better equipped to withstand or bounce back from major disruptions caused by extreme weather, interruptions in energy supplies, long-term drought, chemical spills or terrorist attacks – than centralized systems. Distributed systems are smaller and easier to locate in less flood-prone areas, and they can often be kept online using back-up generators if needed.[18] In addition, wastewater facilities can often generate their own electricity using biogas, combined heat and power systems or other renewable energy technologies.

During Hurricane Sandy, more than 80 distributed systems in the Northeast United States remained operational, while many centralized systems suffered severe damage and operational failures. Ridgewood, New Jersey's water pollution control plant, for example, equipped with an on-site, biogas-fired turbine system, functioned throughout the entire event.[19]

The capacity of some distributed systems to maintain functionality and avoid disruption due to critical interdependencies is referred to as "islanding," and can allow these systems to continue functioning when other infrastructure fails. This characteristic is gaining attention among institutions – such as hospitals and prisons – that have a critical need to continue operations through disasters. Linking or networking distributed systems with centralized water infrastructure produces redundancy that can mitigate the potential for cascading failures and service interruptions. Moreover, if a distributed system does fail, its smaller size makes it easier to identify, isolate and repair the problem.

Flexibility to Manage New Demand

Distributed systems also offer communities and utilities more flexibility to manage new and future demand in a cost-effective manner. In contrast to large-scale, centralized systems that are typically built based on long-term demand projections and optimized at higher population densities, distributed approaches can be designed and implemented in a more incremental or modular manner as demand develops over time, or used to intentionally establish development with lower population densities. Where appropriate, these smaller-scale systems can help reduce or postpone capital investment and financing requirements, and they can be more energy and water efficient.

For example, to prepare for projected population growth in Loudoun County, Virginia, Loudoun Water created the Potomac Water Supply Program, which aims to use distributed infrastructure so that the county will be able to expand the water supply system incrementally consistent with the pace of growth and land-use goals, while ensuring watershed health.[20] The utility uses a combination of site-scale, closed-loop systems and clusters of interconnected distributed systems that are linked to existing centralized infrastructure.

Keeping Water Local

Because distributed systems are dispersed and can be implemented at a variety of scales, they can facilitate more effective management of water at a watershed scale and enhance long-term sustainability and security of local water supplies. Distributed infrastructure can help diversify local supplies and keep water within a watershed in two potential ways: through water-reuse systems and through the capture and use of stormwater as water supply.

The Exxon-Mobil Nitrification Facility – a satellite system for the Edward C. Little Water Recycling Facility (ELWRF) operated by the West Basin Municipal Water District in California – nitrifies recycled water on-site to a quality appropriate for the cooling towers of the Exxon-Mobil Refinery, therefore reducing the significant water demand of the refinery.[21] In Burbank, California, the proposed Rory M. Shaw Wetland Park will convert a 46-acre construction debris landfill into a multipurpose park with a storm drain system, a large retention pond for stormwater capture, a wetlands area for stormwater treatment, and recreational open space. The treated stormwater runoff will be pumped to existing underground infiltration basins at an adjacent park for groundwater recharge.[22]

Systems like these reduce pressure on centralized water systems as well as the ecosystems that provide natural supplies and depend on return flows. They also reduce the need for expensive, energy-intensive transport of water across watersheds. In addition, smaller-scale systems and services make water infrastructure and services more visible and help enhance public understanding and support for such projects at the local level.

Corporate Sustainability

Distributed water infrastructure, including in-situ water recycling and reuse systems, can be used by industries to reduce their water footprints and meet internal sustainability and security goals. Ford Motor Company, for example, has invested in new technologies to reduce its water footprint, including on-site water recycling and reverse-osmosis treatment. Ford has placed particular emphasis on incorporating these technologies in water-scarce regions in the United States and globally, recycling

View of Percy Street in Philadelphia, the first street in the city paved with porous material that allows stormwater runoff to infiltrate the surface and be stored in a stone bed beneath until it is absorbed by the surrounding soil.

Image courtesy of the Philadelphia Water Department an average of 100,000 gallons of water per day at one assembly plant and achieving 100 percent water recycling at another.[23] Water utilities and planners can partner with businesses to ensure that projects are sited appropriately to meet both industry and watershed needs, as well as to identify additional opportunities to implement distributed water management techniques.

Healthier Ecosystems

Green infrastructure is an increasingly common form of distributed water infrastructure being implemented in cities across the United States. Green infrastructure produces multiple benefits, including enhancing or restoring watershed and ecosystem functions and health. Techniques including green roofs, rain gardens, constructed wetlands, porous pavement, trees and bioswales help to capture and infiltrate rainwater where it falls and reduce stormwater runoff and pollution of surface water bodies while simultaneously replenishing groundwater and restoring local water balances. Additional benefits include public green spaces, carbon sequestration, a reduced urban heat island effect and beautified communities. Philadelphia, Washington, DC, Chicago, San Francisco and Portland, Oregon, are among the many cities across the nation working to implement green infrastructure on a citywide scale to address water-quality problems, namely combined sewer overflows, at a reasonable cost and to generate an array of environmental, economic and social benefits for their communities.[24]

Green infrastructure produces multiple benefits, including enhancing or restoring watershed and ecosystem functions and health.

Implementation Challenges

The promise of, and growing interest in, distributed water infrastructure is clear, but several hurdles to widespread adoption still exist. The March 2014 meeting participants identified the following challenges that must be overcome to advance the broader implementation of distributed water infrastructure:

- Altering approaches to management, operations and service integration
- Concern about public health and safety
- Lack of public trust, political will and industry acceptance
- Entrenched financing structures

Altering Approaches to Management, Operations and Service Integration

The implementation of distributed systems poses management, operations and staff capacity challenges for the utilities that own and operate these systems. For example, utility managers must determine strategies to monitor the functionality of dispersed systems and ensure they receive proper maintenance. Supervisory Control and Data Acquisition (SCADA) systems and other information communications (or "smart") technologies make it possible to operate and continuously monitor distributed systems remotely.[25] Nevertheless, utilities need staff skilled in running and servicing these technologies and a wider array of facilities, all of which will require new investment in training and human resources. Utilities will also need to work with property owners to establish agreements regarding responsibility and accountability for the maintenance of privately owned systems.

In addition, current policies associated with the single-service nature of many water agencies can prevent potential partners from coordinating service delivery via distributed infrastructure. In Virginia, for example, the Hampton Roads Sanitation District (HRSD), a regional wastewater treatment agency, is not allowed to construct infrastructure for the conveyance of reclaimed water in right-of-ways within the city of Norfolk's water supply service area without city approval. This effectively eliminates the HRSD's ability to pipe reclaimed water from its smaller satellite treatment plants to prospective industrial customers in the area, because Norfolk is reluctant to relinquish any water supply revenues to the HRSD.

Concern About Public Health and Safety

Concern about whether distributed systems can meet public health and safety standards is a critical challenge. There are real health risks to the public associated with graywater systems and cross-connections with potable water lines, and even small failures have the potential to alarm public officials and undermine public confidence.[26] Due to uncertainty about performance, regulatory agencies may require tighter oversight during installation and more stringent monitoring and inspection schedules during operation to ensure that systems meet water-quality standards and that public health is protected adequately. Fire protection is another important concern, particularly for buildings or neighborhoods using closed-loop systems, as water utilities and other public agencies must ensure adequate water supply and water pressure for firefighting.

Lack of Public Trust, Political Will and Industry Acceptance

To garner the political will and support necessary to implement distributed water infrastructure approaches, public and investor-owned utilities will have to make the case for these new approaches to risk-averse decision makers and ratepayers. Because distributed infrastructure systems are relatively new and unfamiliar, decision makers and the public are likely to be skeptical of proposed projects. The lack of clear and consistent federal, state and local policy and regulations for distributed infrastructure options, such as those for direct potable and nonpotable water reuse, contributes to the reluctance of some leaders to support their implementation.

The general public remains apprehensive about water reuse based on concerns about health, safety, cost and, at times, simply an aversion to the idea of reusing wastewater.

The general public remains apprehensive about water reuse based on concerns about health, safety and cost and, at times, simply an aversion to the idea of reusing wastewater. However, the acceptance of recycled water is dependent on the application of the water. In one study, only 5 percent of respondents were opposed to using graywater on their garden, while another study revealed that 13 percent of respondents were adamantly opposed to direct potable reuse projects.[27, 28]

While members of the water sector increasingly understand the potential of distributed infrastructure, proponents will need to clearly demonstrate water-quality, water-supply and other benefits to develop trust and acceptance of these systems among the public. In addition, utilities, manufacturers and service providers must openly address real and perceived risks regarding the safety and reliability of distributed systems, particularly aspects that could affect public health.

Making the transition to more sustainable and resilient urban water infrastructure systems requires a suite of changes within a water or wastewater utility.

Reluctance within the water sector to embrace distributed systems often stems from business-related concerns, including a lack of confidence in the performance of distributed alternatives; a lack of a clear business case for implementation; a perception of increased monitoring and maintenance responsibilities; and a loss of control if some systems are privately owned. Public awareness and trust, as well as industry acceptance, are all necessary to drive the widespread implementation of distributed water infrastructure.

Entrenched Financing Structures

Unfortunately, it is often difficult for utilities to finance distributed systems using approaches traditionally used for centralized systems. Current policy structures and the uncertainty surrounding distributed systems means that publicly owned distributed infrastructure is often not eligible for financing through revenue bonds or other funds designated for specific purposes.

In addition, the planning horizon for decentralized systems is generally more near-term than that used by utilities for centralized systems. Utilities typically finance centralized infrastructure projects on a 30-year schedule, but those seeking financing for distributed systems may need to negotiate shorter financing schedules that are better aligned with the shorter life cycle of many distributed systems.

Moreover, because drinking water, wastewater and stormwater are typically managed by different entities, there are no financing mechanisms geared toward systems that integrate across these different service functions.

Navigating Toward the Infrastructure of the Future: Integrating Distributed Systems

Making the transition to more sustainable and resilient urban water infrastructure systems requires a suite of changes within a water or wastewater utility – changes that may be technological, managerial, workforce or financial in nature. Yet there is no clear path to follow, and utilities frequently question how best to incorporate distributed technologies within their existing centralized systems.[29] Hence, there is a need to define incremental, achievable phases through which utilities can work over time to demonstrate that it is technically and economically feasible to make the transition.

The Framework for Change presented below reflects a continuum of change for the transformation of U.S. water infrastructure – from optimizing existing systems to completely transforming them – and recognizes that while change often occurs incrementally, it is possible to leapfrog to transformative solutions given the right conditions. The figure shows examples derived from the March 2014 convening, which illustrate a possible path forward for water and wastewater utilities interested in adopting distributed solutions.

Figure 1: Framework for Change: Distributed Urban Water Infrastructure Examples

PHASE 1 Optimize

Image courtesy of Bureau of Environmental Services, City of Portland Oregon

Example: Implement green infrastructure to bolster water management efforts in any watershed. Commonly used in wetter regions to reduce stormwater runoff into sewer systems and to reduce pollution from combined sewer overflows or separate storm sewer systems, green infrastructure can also be used in drier regions to supplement water supply. Some cities are now capturing large quantities of stormwater for managed aquifer recharge projects, which can provide nonpotable water for outdoor irrigation and can augment local drinking water supplies.

PHASE 2 Transition

Image courtesy of Aquapoint, Inc.

Example: Integrate distributed systems into municipal water infrastructure to provide wastewater treatment services for new developments that would otherwise require significant expansion of the existing sanitary sewer system or construction of a new sewer system. Site-scale or “cluster” systems can be designed and built in an incremental, modular fashion as community needs unfold.

PHASE 3 Transform

Image courtesy of Lotus Johnson

Example: Reconfigure wastewater treatment by constructing networks of distributed treatment systems at the site or neighborhood scale that produce water of various quality levels to fulfill different needs, including nonpotable water for irrigation and potable drinking water. Fully distributed systems offer the flexibility to right-size for the number of customers they serve, while reducing energy use and costs for treatment and distribution.

Enabling the Integration of Distributed Systems

Recognizing the many challenges associated with making the transition from centralized water infrastructure systems to hybrid or fully distributed systems, participants in the March 2014 meeting identified a range of activities and actions they believe can facilitate this transition. Some of these actions are already underway in certain parts of the country, while others are novel ideas generated during the convening. In particular, participants identified the following as important enabling actions:

- Advance technological innovation
- Collect and analyze performance data
- Reduce federal regulatory and policy barriers
- Establish state and local policies and incentives
- Develop and disseminate decision support tools
- Explore alternative utility services
- Use creative financing strategies
- Encourage integrated planning and interagency coordination
- Demonstrate and promote distributed solutions

Advance Technological Innovation

An array of distributed water technologies currently exists, and ongoing research and development will improve their efficiency, effectiveness and capabilities. A few key areas in which further innovation could enable broader implementation in the near term include source separation, on-site wastewater treatment, point-of-use drinking water treatment and bio- or hydro-mimicry.

Point-of-use source separation and wastewater treatment technologies have the potential to decrease the costs of water and wastewater transport and treatment associated with centralized systems, while enabling resource recovery. For example, urine-diverting toilets are designed to catch and separate urine from the solids entering plumbing systems. This allows for the recovery of nutrients (nitrogen and phosphorous) from the waste stream and the conversion of these nutrients into commercial products such as fertilizer. Whereas integrating source separation into centralized systems would require installing separate pipes throughout the sewer system to transport different resource streams to treatment or processing facilities, distributed systems offer the value proposition and cost-effectiveness of complementary on-site plumbing and treatment systems.[30]

Existing technologies for treating wastewater on-site to nonpotable quality include up-flow anaerobic sludge blanket reactors, sequencing batch reactors and high-loaded membrane bioreactors.[31] With additional development, water treatment technologies such as reverse osmosis may be able to convert nonpotable water into drinking water at the point of use (e.g., faucet or spigot). In theory, these technologies could be linked to existing distributed water-reuse systems that produce nonpotable water, to achieve direct potable reuse.

While distributed green infrastructure techniques such as green roofs, rain gardens, bioswales and constructed wetlands are being implemented in many places across the nation to manage and treat stormwater, engineers continue to look for innovative ways to mimic natural hydrology and ecosystem functions to increase the sustainability and resilience of built infrastructure.[32] These techniques are often referred to as biomimicry or hydro-mimicry, and they use the biological designs, processes and behaviors of animals, plants and water systems as models for technology and management.[33] For example, more green buildings now include design features that mimic natural ecology, to maximize the capture and reuse of rainwater as well as graywater and condensate from air conditioning units. The advancement of biomimicry concepts and systems could continue to elevate the sustainability and resilience of urban water systems, including restoring local hydrology to a more natural state.

Collect and Analyze Performance Data

Much of the research to date on distributed systems has focused on high-level regulatory and institutional processes or the cost of decommissioning old infrastructure.[34] The body of data on the effectiveness of distributed systems is expanding, and what exists is compelling, but it is not widely available and only addresses a narrow set of circumstances. A concerted effort to collect and compile data from existing distributed systems would enable comparative analyses against conventional options.

Proponents argue, and anecdotal evidence suggests, that distributed systems are more cost effective over the long term than centralized systems, particularly when the costs of emergency response and repair associated with floods, drought and other extreme weather are considered. But research and analyses are needed that compare the capital costs and performance of distributed versus centralized systems, as well as the characteristics of sustainability and resilience. Data collection could be expanded and enhanced through the use of SCADA systems and other smart technologies for remote, real-time monitoring of selected indicators. Making science-based results widely available that validate the real and perceived advantages of distributed infrastructure for certain situations could help build the confidence of utility managers, other decision makers and the public.

Reduce Federal Regulatory and Policy Barriers

Many improvements to water infrastructure could be enabled by federal regulation and policy changes that reduce punitive deterrents and create incentives for distributed systems. Utilities seeking to implement distributed systems often encounter roadblocks because the functionality of the systems cuts across regulatory frameworks. For example, some consider the Sole Source Aquifer Program, under the auspices of the Safe Drinking Water Act, to be a regulatory hurdle for water reuse because it stipulates that areas receiving benefits from the program may not use alternative drinking water sources.[35] The Clean Water Act and Safe Drinking Water Act need to be examined for opportunities to remove regulatory barriers to distributed systems that enable nonpotable and potable water reuse and achieve multiple benefits. While the U.S. Environmental Protection Agency (EPA) provides guidelines for water reuse, the standards vary from state to state, making application across jurisdictions difficult. To help implementers deal with this challenge, the WateReuse Association provides links to state-by-state graywater regulations.[36, 37] In addition, the Association is working with the Water Environment Federation and the American Water Works Association on a project to develop guidance for direct potable reuse standards.

Utilities seeking to implement distributed systems often encounter roadblocks because the functionality of the systems cuts across regulatory frameworks.

The Stafford Disaster Relief and Emergency Assistance Act is another federal law that inhibits the implementation and integration of distributed systems within existing urban water infrastructure systems. The Stafford Act mandates how the Federal Emergency Management Agency can disburse disaster recovery funds, and it currently requires recipients to rebuild to the same specifications of the assets that were lost. This law should be reformed to provide communities more flexibility to rebuild lost or damaged assets with new, more resilient designs rather than perpetuating the risks associated with pre-existing facilities. Such a change in the Stafford Act could facilitate the transition, where appropriate, toward distributed systems when water utilities suffer severe damage that makes them eligible for federal disaster assistance.

Distributed Systems in Action: Building-Scale Nonpotable Reuse

Image courtesy of iStock Photo

Through the Nonpotable Water Program of the San Francisco Public Utilities Commission (SFPUC), new developments have an efficient process for incorporating nonpotable uses into their development designs. Established in 2012 to help reduce pressure on the utility's potable water supply and combined sewer system, the program provides guidelines and water-quality regulations for collection and treatment systems at the building or district scale, including such alternative water sources as graywater, blackwater, rainwater, stormwater and foundation drainage. As of 2013, the program also included a process for sharing water between buildings. In addition to helping expedite the permitting process, the SFPUC offers grant assistance for large alternative water source projects, providing up to $250,000 for an individual building and up to $500,000 for multiple buildings implementing on-site nonpotable water reuse.[38]

Establish State and Local Policies and Incentives

State and local policies that incentivize rather than inhibit the implementation of distributed systems could play an important role in advancing the adoption of these systems. Establishing appropriate standards, codes and clear permitting processes for building- or household-scale water-reuse systems could boost the confidence of developers and property owners to consider distributed systems.

Building-scale systems must be designed to meet applicable local building codes, which may be composed of elements from the Uniform Plumbing Code, the International Plumbing Code and/or the International Green Construction Code. In 2009, California incorporated a residential graywater standard into its state plumbing code, which provides clear guidelines for all graywater systems and allows the implementation of some systems without a construction or building permit.[39] Beginning in July 2014, a group of California state public health officials and utility representatives are initiating a collaborative process to develop a statewide regulatory framework for on-site water treatment systems, which will aim to identify water-quality standards, performance standards and monitoring regimes for on-site systems, to protect public health. The end goal is to create a set of guidelines and standards that local agencies can consult when developing on-site water treatment systems in their communities.

Water utilities can also develop local-level policies that expand the range of water supply sources available for different uses within their service areas, including nonpotable uses. For example, the San Francisco Public Utilities Commission (SFPUC) spearheaded an effort to create the Nonpotable Water Program, a local program for regulating on-site water use that was codified in September 2012 through a city ordinance. Creating this regulatory program required the realignment of existing policies and the creation of a new regulatory framework, which SFPUC accomplished in collaboration the city Departments of Building Inspection and Public Health. Together, the utility and local departments developed a permitting, review and approval process for the installation and operation of on-site nonpotable water-reuse systems. As a result, developers and designers in San Francisco are now incorporating innovative on-site nonpotable water-use systems into their projects, such as using treated graywater for toilet flushing and using rainwater for spray irrigation (see sidebar on p. 16).

In the absence of state or local standards, utilities can draw upon the NSF/ANSI Standards 350 and 350-1, which establish material, design, construction and performance requirements for on-site residential and commercial water-reuse treatment systems.[40]

Develop and Disseminate Decision Support Tools

Because most existing tools for evaluating water infrastructure options generally favor conventional, centralized solutions, decision makers are often not equipped to sufficiently evaluate distributed options. In addition, the loss of "stationarity" driven by climate change means that long-term planning and risk analyses by utilities can no longer assume future climate conditions will be consistent with the past. Unfortunately, there are currently no widely accepted methods for analysis that account for non-stationarity.[41] Therefore, advanced decision support tools that account for future climate projections and use a triple-bottom-line approach are needed to facilitate optimal, context-sensitive water infrastructure decisions that will provide the greatest return on investment.

One such tool is the U.S. EPA's Climate Resilience Evaluation and Awareness Tool (CREAT), which helps water and wastewater utilities assess their risks and use scenario-based planning to devise appropriate adaptation strategies, particularly with respect to climate change impacts. CREAT includes decentralized options such as graywater and reclaimed water systems as part of a menu of options for the repair and/or retrofit of alternatives.[42]

Because most existing tools for evaluating water infrastructure options generally favor conventional, centralized solutions, decision makers are often not equipped to sufficiently evaluate distributed options.

CREAT and other existing decision support tools could be used more broadly within the water sector to help utilities assess the appropriateness of distributed infrastructure options. The Water Environment Research Foundation compiled a toolkit of products available to help utilities assess distributed solutions.[43] The U.S. EPA also offers a variety of scenario planning tools of varying complexity, specifically to examine green infrastructure options, including the National Stormwater Calculator; the U.S. EPA System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) Model; and the U.S. EPA Hydrological Simulation Program.[44]

In the private sector, a company called DynaMind is developing GIS modeling tools that examine water and energy strategies relative to potential climate impacts, including a tool that assesses the layout of urban areas and helps identify opportunities to implement distributed water infrastructure technologies, as well as develop appropriate system performance indicators to evaluate their effectiveness upon implementation.[45]

Explore Alternative Utility Services

Distributed systems can conflict with established utility service areas because they enable water collection, recycling, reuse and treatment close to the source or point of use rather than piping and pumping water to and from large facilities. Therefore, utilities considering the implementation of distributed systems can create new business opportunities by shifting away from the single-purpose service provider model and becoming multi-purpose utilities that provide a variety of services at different scales. This shift could also entail a movement away from comprehensive management by a central entity to a model in which centralized water and wastewater utilities offer new types of services to maintain smaller-scale systems. Or, utilities could have responsibility for some aspects of operations, while maintenance is dispersed among linked entities.

With a broader approach, it may be possible for utilities to generate revenue through tapping new markets.

With a broader approach, it may be possible for utilities to generate revenue through the provision of ancillary services that go beyond the traditional single-service model and tap new markets. For example, utilities could consider providing operations and maintenance (O&M) for private water systems; O&M of customer assets, such as on-site treatment or reuse systems; installation of green roofs and other green infrastructure; customized water products such as carbonated, ionized or ultra-pure water; and consulting on ordinance coordination. In addition, the sale of products produced through distributed resource recovery operations could help to offset some operating expenses.[46] Moreover, the revenues from these types of new services and products could be used specifically to offset the capital costs of utility-owned distributed infrastructure projects or to fund incentive programs to encourage implementation by other parties.

As the engineering and design of urban water infrastructure systems evolves and incorporates more distributed elements, water utilities will need to adapt their business to remain competitive over the long term. The energy sector has evolved in a similar fashion, with the proliferation of site- and community-scale alternative energy systems linked to the main power grid. Traditionally, power utilities were primarily power generators, but they are now gradually playing a larger role in power distribution and grid management as many small-scale independent systems are feeding power into the grid.[47]

Use Creative Financing Strategies

Creative financing strategies are needed to facilitate the implementation of distributed water infrastructure, because mechanisms traditionally used to finance centralized water infrastructure projects often do not align with the economics of distributed systems. Public–private partnerships between developers or other private entities and municipal utilities or governments can be leveraged to garner capital to initiate distributed infrastructure projects. To encourage private investment, water projects ought to be evaluated for merchant risk, similar to how distributed renewable energy projects are evaluated.

Private investors will also need assurances of payments throughout the life cycle of the project. In contrast, public financing assumes a static risk/reward model in which there is greater risk during the early phases of a project, with more reward throughout the lifespan. Private investment can adjust for this by financing the early phases of the project, followed by low-cost public refinancing once the project has reached a level of confidence and stability.

Tax incentives can bolster the ability of a utility or developer to secure financing, because such incentives reduce the financial risk associated with constructing, operating and owning an asset for which the performance is uncertain, by providing a buffer in the initial years following implementation. As the performance of the asset is validated and the risk to the financing entity decreases, tax incentives may be gradually reduced or eliminated. One such tax credit was introduced as part of the Expanding Industrial Energy and Water Efficiency Incentives Act of 2012, which aimed to create investment tax credits for industrial water reuse and recycling. The bill was not ultimately enacted, but it could potentially serve as a model for such incentives.[48]

Encourage Integrated Planning and Interagency Coordination

Water utilities and city planners should seek opportunities to collaborate and integrate water infrastructure considerations into community master plans as well as comprehensive land-use plans and zoning decisions. The integration of key city and regional planning processes with long-term water infrastructure planning (which often occurs on a 30- to 50-year time horizon) can increase awareness of water supply and infrastructure options among elected officials and local decision makers, leading to better land-use and development decisions. At the same time, a greater awareness of future growth targets among water utilities can enhance decision making regarding the optimal size and scale of water system capital improvements. Considering multiple scales and sectors early in the planning and design phases can help to maximize the potential benefits and ensure that water management needs are not only met, but advance broader community and regional development goals.

The California Department of Water Resources, the U.S. Department of the Interior's Bureau of Reclamation and the California Natural Resources Agency – in partnership with other government agencies, water agencies, environmental groups and other stakeholders – developed the Bay Delta Conservation Plan, which seeks to simultaneously address the environmental needs of the state while ensuring a reliable water supply for densely populated urban areas. Through planning that addresses issues beyond cities alone, the plan aims to improve ecosystems and ensure water security for a population of 25 million.[49] In the northwest, the Oregon State Urban Growth Plan established growth boundaries around metropolitan areas, designating lands best suited for development and protecting other areas from development. The creation of such urban and rural reserves make it clear where future growth will occur, therefore enabling the consideration of distributed water infrastructure to meet future service demands.[50] Also with an eye on

> *The integration of key city and regional planning processes with long-term water infrastructure planning can increase awareness of water supply and infrastructure options, leading to better land-use and development decisions.*

the long-term future, Spartanburg Water in South Carolina began adding distributed systems onto its historically centralized system, to reduce the impact of capital costs on ratepayers and increase the flexibility of the system to accommodate future growth with available water supplies.

Interagency coordination can enable historically siloed agencies to leverage each other's resources and technical capacity to meet intersecting objectives. For example, creating mechanisms for coordination between drinking water utilities with stressed supplies and wastewater utilities that can deliver nonpotable water from satellite facilities could reduce pressure on local drinking water supply while expanding markets for recycled water. Coordinating and integrating public works and transportation projects with local stormwater management efforts can facilitate the implementation of integrated infrastructure projects that improve streets for vehicles and pedestrians, while simultaneously meeting stormwater management and ecosystem restoration needs with distributed techniques. Driven by local stormwater regulations, the District Department of Transportation in Washington, DC, is installing green infrastructure as part of new construction and retrofit projects, including through its Green Street and Green Alley initiatives.[52]

Integrated Urban Planning: The Greater New Orleans Urban Water Plan

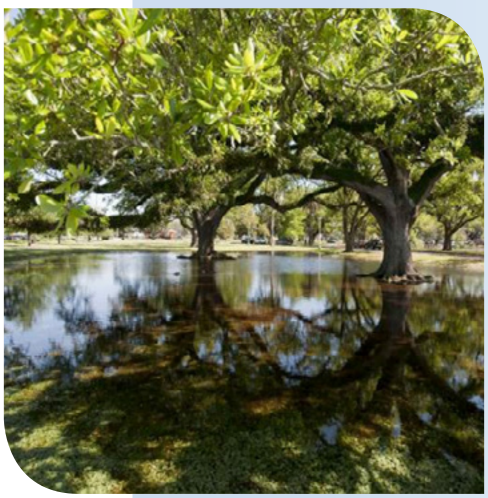


Image courtesy of Andy Sternad/ Waggonner & Ball Architects

Historically, water infrastructure in the city of New Orleans was designed to drain water and mitigate flooding, with the intent of keeping water "out of sight and out of mind." Following the devastation wrought by Hurricane Katrina, the city took a new approach to water management planning, one that brings water to the forefront of urban planning. The planning effort engaged local, national and international water management experts. The resulting Urban Water Plan considers soils, water and biodiversity, in conjunction with existing infrastructure and the built environment. In short, the plan adapts existing infrastructure systems and integrates new distributed elements to create a more resilient city.[51]

Demonstrate and Promote Distributed Solutions

There are a variety of ways in which the skepticism and concerns of risk-averse decision makers and ratepayers may be overcome, including engaging stakeholders in planning processes, highlighting demonstration projects and responding to consumer demand for change. Engaging local stakeholders in the planning and design phases helps them understand the technologies, risks and benefits of different options and can ultimately foster greater support for projects over the long term. For example the SWITCH research project, which focused on developing options for managing water in "the city of the future," engaged community-level stakeholders in cities on four continents to gather information about the perceptions, needs and goals they had with respect to urban water infrastructure, which helped to determine which distributed water infrastructure systems might be most viable for implementation.[53]

Demonstration projects are the most tangible and effective way to illustrate how distributed systems work, convey the multiple benefits they can produce and generate broader acceptance. The U.S. Green Building Council's LEED certification system requires distributed water management systems (e.g., rainwater harvesting, water reuse) and water-efficient plumbing to achieve Gold- or Platinum-level certifications. Although water-related parameters only represent approximately 15 percent of the LEED index, the certification has been an important catalyst for the implementation of projects that can serve as demonstrations. For example, the Bullitt Center in Seattle – touted as the world's most-efficient building – has become a beacon demonstration project. The building's water management system incorporates waterless and composting toilets, graywater treatment, rainwater catchment and constructed wetlands.[54]

To facilitate uptake of the Nonpotable Water Program in San Francisco, the SFPUC has conducted training and education with building code inspectors regarding how building-scale systems meet applicable plumbing codes, which has helped to address concerns about public health. The SFPUC program and a similar program managed by Seattle Public Utilities have had such success that prospective tenants are beginning to specifically seek out buildings served by distributed water infrastructure. Currently, more than 20 new developments in San Francisco are proposing to collect, treat and use alternate water sources for nonpotable applications. Proponents of distributed water infrastructure should continue to leverage the green building movement and other demonstrated successes to raise the visibility of distributed water infrastructure as a viable alternative or complement to centralized water infrastructure.

Conclusion: Seizing the Future

The way that cities think about water is changing. Many of the March 2014 meeting participants remarked on the palpable shift that has occurred in recent years, from distributed infrastructure being a niche topic in which only a small minority was interested, to a concept for which momentum is growing and dialogue is moving into the mainstream. It now seems clear that distributed infrastructure will undoubtedly play a significant role in the future of U.S. water infrastructure, even as elements of our existing centralized water systems remain in use. The group assembled at Wingspread recognized that distributed water systems offer benefits that reach far beyond water and will likely be an integral component of the cities of the future. Using systems thinking and long-term, integrated planning, we have the opportunity to right-size future urban water infrastructure in ways that enhance water and energy efficiency, minimize greenhouse gas emissions, reduce costs, restore ecosystems and enhance the livability of neighborhoods, cities and watersheds.

To seize that future, utilities, decision makers and the public must internalize a different mentality regarding how to address urban water management problems – one in which they are willing to take calculated risks with unconventional and innovative infrastructure systems. With a holistic view of water services, communities can leverage every stage of the water cycle to ensure the most efficient use of water and generate multiple benefits for people and the environment. Vision, creative thinking and strong leadership from within the water sector and beyond will be vital to successfully navigate the transition to urban water infrastructure of optimal structure and scale.

Appendix: Meeting Participants

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