Leadership in Sustainable Infrastructure

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CONTRIBUTING FACTORS TO REDUCED RESILIENCY IN WATER AND WASTEWATER INFRASTRUCTURE

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Abstract: A lack of resiliency in our infrastructure is a problem throughout the United States. Compounding this problem is the current condition of much of this infrastructure, especially in older cities. The American Society of Civil Engineers, in its infrastructure report card, gives both water and wastewater infrastructure a grade of D (poor). When water or wastewater systems face outside stressors, such as weather events, fires, or earthquakes, the state of the infrastructure is a major factor contributing to the infrastructures' resilience to these events. This study examines factors contributing to this lack of infrastructure resiliency, focusing on water and wastewater systems. The contributing factors are then ranked and evaluated for recommended improvement. Communities analyzed in this report were previously selected for participation in a U.S. Environmental Protection Agency (EPA) funded program titled Water Community Assistance for Resiliency and Excellence in Drinking Water and Wastewater (WaterCARE). Communities selected for WaterCARE face issues related to their continuing ability to provide for, manage, or fund drinking water, wastewater, or stormwater infrastructure.

1 Introduction

The condition of infrastructure in the United States, especially in older cities, has been declining steadily. This trend is exacerbated when the infrastructure is primarily located underground, which is the case in water and wastewater infrastructure. Both water and wastewater infrastructure were given a grade of D (poor) by the American Society of Civil Engineers in their most recent infrastructure report card ("2013 Report Card for America's Infrastructure" 2013). When infrastructure is already in poor condition, outside stressors (severe weather events, fire, etc.) have a major impact on its resilience. Current funding levels are not keeping up with this problem and the housing crisis of 2008 further reduced funding options and strategies for local utilities. The intent of this analysis is to identify factors contributing to this lack of resiliency in water and wastewater systems, rank them, and assemble recommendations for improvement. Communities analyzed in this report were previously selected for participation in an U.S. Environmental Protection Agency (EPA) funded program titled Water Community Assistance for Resiliency and Excellence in Drinking Water and Wastewater (WaterCARE). WaterCARE is jointly managed by the University of North Carolina Environmental Finance Center and the University of New Mexico Southwest Environmental Finance Center. Communities selected for WaterCARE face issues related to their continuing ability to provide for, manage, or fund drinking water, wastewater, or stormwater infrastructure. Those selected for the program have a combination of some or all the following criteria: a community population of less than 100,000; existing public health challenges to be addressed; a below-average median household income; and a "shovel-ready" project relating to water infrastructure.

2 Background

The definition of resiliency varies widely depending on its context. For the purposes of this study, resiliency is defined as a measure of infrastructure's ability to handle hazards, either by resisting or adapting, while continuing to provide acceptable levels of service to its customers. While the WaterCARE program is primarily focused on water and wastewater resiliency, stormwater systems both directly and indirectly impact water and wastewater systems and will be included peripherally in this report. Often, the public has little knowledge regarding what it takes to keep water and wastewater systems operating. However, public awareness of this issue is on the rise. Since the U.S. terrorist attacks of 2001, emergency management has received more attention from the public. Hurricanes Rita and Katrina in 2005 increased the public's cognizance of just how critical water systems are to a functioning community and how easily a natural disaster can disturb these systems. More recently, the ongoing water quality crisis in Flint, Michigan, has highlighted the risks to resiliency associated with aging infrastructure and lack of local funding.

Resiliency of underground infrastructure, especially water and wastewater infrastructure, has not been researched as extensively as above-ground infrastructure, such as the electrical grid system. A recent study of resiliency in water and wastewater infrastructure identifies four primary aspects of resiliency: water distribution redundancy; wastewater storage capacity; structural integrity of collection systems; and backup power/structural integrity of pumping facilities. Redundancy of distribution systems is important during typical utility operation, but becomes integral in emergencies to ensure continued service. Wastewater storage provides a space for safe storage of wastewater when the system is overloaded. An overload can occur during flooding, power outages, or during blockages of the system. If the system is overloaded and has no storage capacity for the wastewater an overflow of the sewer flow into surface waters can occur. This overflow into surface waters introduces contaminants into the local waters, threatening the local ecosystem and potentially blocking the sewer lines with debris. The structural integrity of water and wastewater collection systems will be put to the test during disasters; increased internal and external flows will test the system, which must be able to resist these hazards while continuing to provide acceptable levels of service. Providing backup power and ensuring structural integrity of the pumping systems ensures that flows are directed to appropriate locations and operations stay on track. One method of evaluating resilience of a system is to assigned resilience parameters to the primary aspects of resiliency. Numerical scores are given on a scale of one (low) to three (high) levels of resilience. It is recommended that communities design their utility systems at a level two resilience level to ensure a cost-effective level of resiliency (Matthews 2016).

Threats to water systems fall under three major categories: natural disasters; human-caused incidents; and workforce/infrastructure threats. Natural disasters, such as flooding, earthquakes, hurricanes, tornados, etc., can interrupt infrastructure systems, thereby interfering with emergency response and recovery efforts. For example, hurricanes Katrina and Rita disrupted services in portions of Louisiana and Mississippi in 2005. This disruption included over one hundred water systems and dozens of wastewater systems. These disruptions slowed down disaster response and caused difficulties in setting priorities. Restoring all systems to normal operations took years. Human-caused incidents can come from either internal or external forces. Internal threats often come from former and/or disgruntled employees of the utility. Damage could be small (theft of materials), large (introduction of contaminants into the system), or severe (threats or violence against personnel, destruction of facilities). Internal threats are a major problem for utilities; employees have detailed knowledge of the system and can easily identify weakness while covering their tracks. Water and wastewater infrastructure facilities are critical to a community's function, and as such can be targeted by external agencies. These external threats can be direct, such as destruction of specific facilities, or indirect, such as cyber attacks. Many utilities have upgraded their systems to utilize supervisory control and data acquisition (SCADA) networks. SCADA networks increase a systems' efficiency by permitting operators to analyze and operate their equipment remotely. However, this introduces a security risk. SCADA systems were not designed with security in mind and are susceptible to hacking. Workforce/infrastructure threats are primarily attributed to our aging workforce and our aging infrastructure. Employees within the utility industry are primarily baby boomers of between 45 and 54 years of age. These employees hold significant knowledge of the system; when this portion of the workforce retires, the system loses this knowledge base. As our workforce has aged, so have our infrastructure assets. Our infrastructure is past its design lifespan with no immediate plans for replacement. This leads to larger failures within the system, leading to critical failures (Van Leuven 2011).

Public health and safety relies on clean water systems. This raises the question: what happens to our water and wastewater systems during emergencies? Even a short break in these services can impact safety. Extreme events can cause significant damage. For example, hurricanes can cause wind damage to above ground components. If hurricane-force winds uproot trees, their root systems can pull utility lines out of the ground as they fall. Severe flooding can flush away soil that is covering pipelines or even disjoint pipes, especially at manhole or inlet connections. Disjointed water pipes may no longer maintain pressure, leading to boil water requirements or even a stoppage in service. This can lead to localized above or below-ground contamination. Debris entering the stormwater system can block drainage ways, increasing flooding in the area and leading to debris entering the wastewater system. Coastal flooding can cause corrosion issues, leading to decreased service life. If corrosion impacts manhole covers and frames, additional water can infiltrate the wastewater system, taking the treatment plant over its capacity. If these events are not addressed in a timely manner, long-term damage may result. Collapsing pipes can cause voids within the soil, leading to unstable foundations and sinkholes. Leaking wastewater pipelines can contaminate the groundwater and nearby networks. Mitigation strategies to address this problem include removing debris from stormwater systems; developing and updating a disaster mitigation plan; clearing root intrusion from infrastructure systems; assessing the vulnerability of the local infrastructure systems; and constructing redundant systems (power supply, pump stations, etc.) into the infrastructure system. Implementation of these mitigation items can help reduce damage during emergency events, as well as reduce the time needed to address damage (Matthews 2013).

Recognition of the threats to the system is a significant step in addressing resiliency concerns. Recent analysis of resilience measures for water infrastructure have resulted in the following key aspects: redundancy in the water distribution system; storage capacity of the wastewater collection system; structural integrity of the distribution and collection systems; and backup power and stability of treatment and pumping facilities. Analysis of these aspects give a community an idea of their current resilience levels (Matthews 2016). Next steps include intensive analysis of systems and plans to address critical areas.

The Engineering industry is used to separating all aspects of water (drinking water, stormwater, wastewater) into their individual components. Water does not leave the Earth; it is continuously recycled through the natural water cycle. Water, stormwater, and wastewater systems are not separate; they directly and indirectly impact each other. Treating water, stormwater, and wastewater systems as parts of a larger system is referred to as a ‘one water’ analysis (Dyson 2016). ‘One water’ analyses are gaining traction in the Engineering industry. To address this concept within this study, stormwater management issues will be included in this analysis.

Long-range planning for resiliency utilizes modeling techniques to forecast future needs based on previous experiences. However, modeling cannot necessarily predict new needs as they develop over time. There are multiple barriers in utilizing modeling methods into resiliency planning: short political cycles; infrastructure owner/operator emphasis on immediate investment returns; unpredictable infrastructure change; absence of government faith in resilience planning; and lack of tools and methods to address resiliency issues (Sage et al. 2015). These barriers are interconnected; some are more difficult to address than others. Developing appropriate tools to address resiliency issues is a goal of the research community and will have a positive effect on government opinions regarding resiliency.

3 Methodology

3.1 Aim

This paper presents qualitative findings correlated to infrastructure resiliency, with an emphasis on water and wastewater systems.

3.2 Data Collection

Communities who have provided data for this report are currently participating in the EPA WaterCARE project and are listed in Table 1. As such, these communities have needs relating to their ability to provide safe and clean water over the long term.

Table 1. WaterCARE Communities

	Population (2015)	Growth Rate (2010 to 2015)	Median Household Income	Drinking Water	Source Water	Wastewater
Gatesville, TX	15,724	-0.1%	$40,480	Public Utilities District	Surface Water	Public Utilities District
Haines Borough, AK	2,534	1.0%	$57,551	Public Utilities District	Surface Water	Public Utilities District
Hoopa Valley Tribe, CA	3,163 (2013)	17.1 % (2010 to 2013)	unknown	Public Utilities District	Surface Water	Decentralized Septic Systems
Johnston, IA	20,871	20.9%	$94,821	Regional Service Agreement	Surface Water	Regional Service Agreement
Lawrence, MA	80,231	5.0%	$34,496	Public Utilities District	Surface Water	Regional Service Agreement
Youngstown, OH	64,628	-3.5%	$24,361	Public Utilities District	Surface Water	Public Utilities District
Buchanan County, Virginia	22,776	-5.5%	$29,698	Public Utilities District	Surface Water	Public Utilities District

A multi-step process was developed and implemented to analyze the needs of each community. This process began with the initial identification of the affected communities by the EPA. Once these communities were identified, they were researched intensively. In addition to their water and wastewater programs, stormwater management, demographics, primary industries, tourism, long range plans, and local politics were also defined. These data were assembled prior to speaking with local staff. After assembling each community's background information, meetings were scheduled with local representatives to further identify issues and develop potential mitigations. During these meetings with community leaders (managers, elected leaders, operators, finance, planners, legal), additional issues and concerns were identified that were specific to each community. This data was collated to a list of "needs/wants" (approximately 15 items) to focus on. This "needs/wants" list was prioritized, and the prioritization list of identified issues was presented to each community for review and modification. After this last prioritization, a final summary detailing reports, analyses and information matrices for each community based on their specific concerns was tabulated.

4 Results

The data collected from the communities were reviewed for commonalities that affect resilience. Each community was given a unique identifier to ensure privacy. Due to the small sample size, a direct analysis was performed on the qualitative data received thus far. Quantitative analyses will be done in future research. These factors are summarized in Table 2; resilience factors defined as a priority for the community are defined with an X.

Table 2. Priority Resiliency Factors in WaterCARE Communities

Community Identifier	Asset Management	Community Support	Financial Needs	Infrastructure Adequacy	Leadership	Staffing
A	X		X			
B	X		X			X
C	X	X	X	X		
D	X		X			
E	X		X			
F	X	X	X		X	
G	X		X			

As shown in Table 2, factors affecting a community's ability to be resilient to outside stressors were categorized into the following groups:

1. Asset Management: the process of maintaining and tracking a system's infrastructure. This system focuses on maintenance, rehabilitation, and replacement scheduling. For example, multiple communities have difficulty defining the amount of water they have lost during routine operation. This leads to extra costs and waste within the system.

2. Community Support: local user support and cooperation is integral to a successful utility program. If a local utility's public outreach / engagement is inadequate, it is difficult to educate the public of its needs. An adversarial relationship between the community and their utility provider can lead to a lack of cooperation and a refusal to consider necessary rate increases.

3. Financial Needs: utilities are funded by a combination of utility rates, capital funds, and outside funding (e.g. grants, loans, etc.). Multiple communities have reached or are near their debt ceiling and are unable to take out any more loans.

4. Infrastructure Adequacy: ensuring a utility's infrastructure population provides service to the community and is adequate for the local users. One community has had a population drop of over fifty percent since the 1950's; their infrastructure is severely oversized for their current population.

5. Leadership: parties responsible for sponsoring utility rate increases and ensuring operator training / certification. Leaders need an understanding of the role a utility plays in the community. Lack of understanding can lead to disputes and a refusal to consider financial necessities.

6. Staffing: maintaining necessary staff and keeping them adequately trained. One community has expressed issues with transferring knowledge from their more experienced staff prior to attrition.

While multiple communities need assistance with community support, infrastructure, leadership, and staffing, every community considered asset management and financial needs a priority. This indicates that, while many factors may be important, recommendations for these communities should include addressing asset management and financial needs.

5 Conclusions / Recommendations

Resiliency in water and wastewater systems can be increased with factors contributing to reduced resiliency are plainly identified. The aim of this paper was to present qualitative findings found to correlate to water and wastewater infrastructure resiliency. A literature review and interviews with participants in the EPA WaterCARE program led to the identification of six resiliency factors. Based on an analysis of the community-defined priority factors, recommendations were made for each community. As each community considered asset management and financial needs a priority, recommendations for these resiliency factors will be summarized below. These recommendations are based on specific problems and issues experienced by one or more community.

5.1 Asset Management

Asset management is a broad term with a relatively simple definition. Any system used to track and maintain a system's infrastructure falls under the category of asset management. A frequent issue with community infrastructure is a lack of specific knowledge about their infrastructure. For instance, communities may lack a centralized reference; instead, they will rely on "as-built" drawings, design drawings that were certified after construction. These "as-builts" are valuable information, but finding the specific drawing required can delay action in an emergency and hinder long-range planning efforts. To address this issue, a mapping and asset inventory system is recommended. Keeping one centralized map of all assets will reduce confusion during emergencies and assist in long-range planning. In addition, maintaining a detailed inventory of all infrastructure information (type, age, remaining lifetime, size, material, etc.) into a database makes the process of maintaining, rehabilitating, and replacing outdated infrastructure simpler, as all needed information is available in one location. Another issue related to this lack of specific knowledge is water loss. Any water system will experience some water loss, but it is important for a community to be aware of the quantity of loss occurring and the location where these losses occur. Many communities interviewed for this report have no way to quantify the water loss they experience. Undergoing a water loss audit, where background information such as flow data and master meter readings are gathered and used to determine how much water is lost within the system, can assist in determining which areas within the system are most in need of repair. Implementing these methods reduces costs and overall waste within the system.

Another issue with community infrastructure is knowledge loss. This loss of knowledge can be attributed to two primary factors. Local politics can mean that leadership changes every few years, meaning the decision-maker of today may not be the decision-maker of tomorrow. While local utility managers and operators will likely remain longer, an employee can leave at any time. Without specific plans in place to ensure a community's needs are appropriately defined and explained to the local leaders, major maintenance needs can go unaddressed. Ensuring local managers and operators have the information they need can be addressed by knowledge management. Information is gathered from management, designers, and operators of the system and stored for future reference. Without management of this knowledge, it will be lost during employee turnover. Keeping local political leadership knowledgeable is a more challenging task, as they often have no background in public works and no way of identifying a utility's needs. Leadership education can be achieved by demonstrating a "day in the life of an operator," via a document or video. This gives leadership a better idea of what it takes to provide water and wastewater services to a community and how funding is expended. Another method to inform the entire community about a utility's needs is capital planning, where the major needs of the community are defined on a long-term plan (typically 20 to 50 years). Analyzed accurately, this information could prevent future budget shortfalls and assist elected officials in fiscal planning.

5.2 Financial Needs

Unsurprisingly, every community identified financial needs as a major contributing factor to their resiliency efforts. As the United States continues to recover from a recession, communities are attempting to provide essential services with fewer financial resources. As employees leave, they are not replaced; instead, others are expected to pick up their tasks. Falling tax revenues ensure budget cuts across the board, including utility operations. Maintenance tasks are delayed, leading to more line breaks and emergency repairs. Completing a through analysis of a utility's finances can help ensure needs are addressed. An initial financial analysis calculates the monies available to the community for services (including the contributions of rate payers) and compares it to the community's needs. Now that a community can identify their financial needs, a rate and affordability analysis is undertaken. The amount of money paid in by system users is compared to the system's overall needs to determine whether current rate payments are sufficient. In addition, the rates paid by users are compared to users in nearby communities with similar median household incomes. This comparison will help determine whether future rate increases will cause a hardship to local users and whether a sliding-scale rate should be implemented. It is important to ensure the community is aware of the value of a utility's assets. To ensure this, a valuation of assets can be done. A valuation determines an approximate value of a community's existing infrastructure as well as its replacement value. Valuation of assets helps put water and wastewater operating budgets in context and assists in communicating the complexity of the facilities to governing bodies and decision makers.

5.1 Future Research

A questionnaire is in development to further clarify and assess each communities' perceptions regarding the relative importance of various factors on their water and wastewater resiliency. Respondents will be asked to indicate their response, on a scale of one (strongly disagree) to five (strongly agree), on different resiliency factors.

6 References

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