Homeland Security

Office of Cyber and Infrastructure Analysis (OCIA)
National Protection and Programs Directorate
Infrastructure Sector Assessment

Sector Resilience Report: Water and Wastewater Systems

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SCOPE

The Department of Homeland Security Office of Cyber and Infrastructure Analysis (DHS/OCIA)[1] produces Sector Resilience Reports to improve partner understanding of the interdependencies and resilience of certain sectors. Specifically, this report provides a brief overview of water and wastewater systems, and analysis of key dependencies and interdependencies. In addition, this product includes an assessment of, and best practices for, improving community, system, and facility resilience. This SRR was produced to complement other sector-specific guidance, analyses, and scholarly papers on infrastructure resilience by applying data obtained from DHS site visits and assessments analyzing the resilience of critical infrastructure assets and systems.

The resilience issues and best practices identified in this document may be considered by critical infrastructure partners in each sector to improve their resilience at three levels: water and wastewater systems providers and facilities, community risk management organizations (e.g. State or local emergency operations centers or fusion centers), and any critical infrastructure asset or system that depends on water or wastewater service. This product was coordinated with the DHS Office of Infrastructure Protection and the U.S. Environmental Protection Agency (EPA).

KEY FINDINGS

- **Of the 2,661 sites across all 16 critical infrastructure sectors that received DHS assessments (2011–2014), 75 percent depend on external water for operations, and 68 percent depend on external wastewater discharge services for operations.**
- **The majority of facilities assessed by DHS are dependent on water and/or wastewater for domestic uses, cooling, or core operations. Many of these facilities lack an alternate source or on-site backup. The data indicates more attention is needed on contingency or continuity plans for service interruption or priority restoration plans with the water utility service.**

[1] In February 2014, NPPD created the Office of Cyber and Infrastructure Analysis by integrating analytic resources from across NPPD including the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC) and the National Infrastructure Simulation and Analysis Center (NISAC).

- **In the case of an electric power failure (e.g. the outside feed is severed), data show that water treatment and wastewater treatment facilities will lose operational capability by 100 percent if they do not have backup generation capability (e.g. emergency generators).**
- **Most of these facilities assessed have an alternate or backup source of power: 87 percent of water and 88 percent of wastewater facilities. The backup generators typically reduce the impact of primary power loss to 1-33 percent degradation in operations for 7 days without refueling.**
- **One hundred percent of water treatment facilities and 90 percent of wastewater treatment facilities assessed by DHS are dependent upon chemicals for on-site operations.**
- **There is a strong interdependence between the Water Sector and both the Chemical and Energy Sectors. One hundred percent of chemical facilities and 82 percent of electric generation plants surveyed are dependent upon water.**

WATER AND WASTEWATER SYSTEMS OVERVIEW[2]

The U.S. Water and Wastewater Systems Sector is critical to the Nation's public health and welfare, providing access to safe drinking water and proper removal and treatment of wastewater. There are approximately 155,000 public drinking water systems and 16,500 publicly owned wastewater treatment systems in the United States.[3] Approximately 90 percent of the U.S. population receives drinking water from public water systems, and more than 75 percent of the population has its sanitary sewage treated by public wastewater systems.[4,5] The EPA regulates water and wastewater systems under authorities granted by the Safe Drinking Water Act and the Clean Water Act.[6,7]

WATER TREATMENT FACILITIES

Water treatment facilities provide water that is used for drinking and sanitation purposes, safety-related activities such as fire-suppression, and industrial production processes. Water from rivers and reservoirs can contain a variety of organisms, as well as organic and inorganic material that must be removed at a water treatment facility before the water is safe for drinking and other uses. The specific processes used can vary at different treatment facilities, but facilities generally follow the same basic steps.

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2 For more in-depth information about the water and wastewater systems, how they function, and how they are managed, please contact OCIA at OCIA@hq.dhs.gov to request a copy of the *Infrastructure System Overview: Water and Wastewater Systems* (forthcoming).

3 EPA, Public Drinking Water Systems: Facts and Figures, 2012, accessed May 20, 2014, http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm; and DHS and EPA, *National Infrastructure Protection Plan, Sector Specific Plan – Water-2010*; accessed May 9, 2014, www.dhs.gov/xlibrary/assets/nipp-ssp-water-2010.pdf.

4 Ibid.

5 A public water system (PWS) is a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. Public water systems may be publically- or privately-owned. EPA, *Public Drinking Water Systems Programs – Overview, January* 17, 2013, accessed May 19, 2014, http://water.epa.gov/infrastructure/drinkingwater/pws/.

6 EPA, *Safe Drinking Water Act (SDWA)*, March 6, 2012, accessed June 6, 2014, http://water.epa.gov/lawsregs/rulesregs/sdwa/.

7 EPA, *Summary of the Clean Water Act,* March 16, 2014, accessed June 6, 2014, www2.epa.gov/laws-regulations/summary-clean-water-act.

As outlined in Table 1, the treatment of water from surface sources like rivers and lakes typically includes coagulation, sedimentation, filtration, and disinfection. Larger particles such as sand, vegetation, and other materials may be removed first through an initial sedimentation process. Smaller (e.g. microscopic) particles, along with organic and inorganic material, are removed through reactions with coagulants and subsequent sedimentation and filtration. To eliminate disease-causing organisms, unpleasant odors, and tastes in water, disinfecting chemicals are added and the water is stored in a clearwell to allow for adequate contact time with the disinfectants prior to distribution. The final step is to apply chlorine disinfectants that will keep water safe and healthy following treatment during distribution through pipelines to reach homes and businesses.[8] After this step, the treated water enters the distribution system, which often includes smaller storage tanks that typically provide a 2 to 5 day capacity.

TABLE 1.—General Water Treatment Process.[9]

Coagulation	Alum and/or other chemicals are added to the water to form “floc” which attracts particulate and dissolved material suspended in water.
Sedimentation	Heavy particles (floc) settle to the bottom and the clean water moves to filtration.
Filtration	Water passes through filters, which typically include layers of sand, gravel, and charcoal that remove even smaller particles.
Disinfection	Chlorine is added or another disinfection method is applied to kill bacteria or micro-organisms in the water.
Storage	Water is stored in a closed tank or reservoir; water then flows through pipes for delivery.

WASTEWATER TREATMENT FACILITIES

Wastewater treatment systems provide treatment of domestic, commercial, and industrial sewage water through wastewater collection, treatment, and release of treated wastewater into surface water bodies. These systems use a combination of physical and biological processes to remove organic matter and treat the water before its release. The basic function of the wastewater treatment facility is to speed up the natural processes by which water purifies itself.

Historically, the natural processes of streams and lakes were adequate to perform basic wastewater treatment.[10] With the growth of population and industry, increased levels of treatment have become necessary prior to the discharge of domestic wastewater. Table 2 provides an outline of the general wastewater treatment process.

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[8] Clean Water Services, *Wastewater Treatment Process*, 2014, accessed May 9, 2014, www.cleanwaterservices.org/AboutUs/WastewaterAndStormwater/TreatmentProcess.aspx.
[9] EPA, *Drinking Water Treatment*, 2004, accessed May 9, 2014, http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_treatment_web.pdf.
[10] EPA, *Primer for Municipal Wastewater Treatment Systems*, 2004, accessed May 9, 2014, http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf.

TABLE 2.—Wastewater Treatment Process.[11]

Preliminary Treatment	Physical process for screening out debris (e.g., sticks, large food particles, sand, gravel) from wastewater.
Primary Treatment	Chemical process for removing suspended solids and grease from wastewater.
Secondary Treatment	Biological process for removing dissolved organic matter from wastewater.
Final Treatment	Chemical process for killing disease-causing organisms in wastewater before discharge into surface water bodies.
Sludge Treatment	Physical and biological processes for stabilizing, reducing odors, and removing water from the sludge produced during primary and secondary treatments, and reducing sludge volume before its disposal or land application.
Advanced Treatment	Process used for removing nutrients from wastewater.

RESILIENCE

The common themes shared in this report are drawn from data obtained from DHS site visits, including the Enhanced Critical Infrastructure Protection (ECIP) Initiative, analysis produced by the Regional Resiliency Assessment Program (RRAP), and information gleaned from industry reports and academic research.[12,13] This paper summarizes results from numerous infrastructure assessments that examine vulnerabilities, threats, and potential consequences from an all-hazards perspective, leading to the identification of dependencies, interdependencies, cascading effects, and resilience characteristics.[14]

PPD—8, National Preparedness, defines resilience as “the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.”

PPD—21, Critical Infrastructure Security and Resilience, directed the Federal Government to work with critical infrastructure owners and operators and State, local, tribal, and territorial partners to strengthen the security and resilience of its critical infrastructure.

Since 1996, the critical infrastructure community has evolved from a primary focus on protective security to a

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[11] EPA, *Primer for Municipal Wastewater Treatment Systems*, 2004, accessed May 9, 2014, http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf.

[12] The RRAP evaluates critical infrastructure on a regional level to examine vulnerabilities, threats, and potential consequences from an all-hazards perspective, identifying dependencies, interdependencies, cascading effects, resilience characteristics, and gaps. RRAP projects are voluntary and non-regulatory, and rely on engagement and information sharing with Federal agencies, private sector facility owners and operators, law enforcement, emergency response organizations, academic institutions, and other stakeholders. For more information, please email resilience@dhs.gov or visit www.dhs.gov/regional-resiliency-assessment-program.

[13] The ECIP Initiative is a voluntary program where DHS Protective Security Advisors conduct outreach with critical infrastructure facility owners and operators and provide security surveys, training and education, and recommended protective measures. ECIP metrics provide DHS with information on the protective and resilience measures in place at facilities and enable detailed analyses of site and sector vulnerabilities. For more information, please contact PSCDOperations@hq.dhs.gov.

[14] DHS, *Regional Resilience Assessment Program Fact Sheet*, December 2013.

greater emphasis on resilience to disruptive events.[15] National policies, such as Policy Presidential Directives (PPDs) 8 and 21, highlight that collaborative engagement and information sharing with Federal agencies, private sector facility owners and operators, law enforcement, emergency response organizations, academic institutions, and other stakeholders are vital to building a more resilient Nation.

THREATS AND HAZARDS

Water and wastewater systems face a broad range of potential threats and hazards, ranging from a variety of natural hazards to intentional attacks to industrial accidents. Natural events, such as floods, hurricanes, tornadoes, earthquakes, and ice storms, pose significant threats to the Water and Wastewater Systems Sector depending on geographic location.[16] Such events may affect both water quality and quantity, potentially compromising a community's public health and safety. For example, in 2005, Hurricane Katrina disabled or compromised 1,200 drinking water systems and 200 wastewater treatment facilities.[17]

Intentional malicious attacks, by physical and/or cyber means, conducted by insiders (e.g. employees or contractors) or external individuals/groups not associated with the facility can pose a threat to the Water and Wastewater Systems Sector. Potential attack methods include: improvised explosive devices; vehicle-borne improvised explosive devices; hazardous material releases; explosive devices in wastewater collection systems; chemical, biological, or radiological contamination of drinking water distribution systems; assault; sabotage of water treatment systems; radiological dispersal devices; and cyberattacks on supervisory control and data acquisition (SCADA) systems.[18]

Water and wastewater treatment facilities rely on various chemicals throughout the treatment processes. These chemicals pose potential hazards associated with their manipulation, storage, and transportation. Hazards associated with the use of chemicals will vary depending on the volume, form, and concentration of the chemical if released, as well as the size of the on-site and off-site population. For example, chlorine, chloramines, or chlorine dioxide are most often used because of their effectiveness as disinfectants.[19] Chlorine is supplied in three basic forms: sodium hypochlorite (bleach), calcium hypochlorite, and chlorine gas.[20] In gaseous form, chlorine is a respiratory irritant that may be fatal if inhaled or absorbed through skin.[21] It is not

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[15] The Federal Government began to examine potential threats to critical infrastructure in the 1990s as a result of incidents of domestic and international terrorism. President Bill Clinton issued Executive Order 13010 in 1996, which identified the Nation's critical infrastructure sectors and established a Presidential Commission on Critical Infrastructure Protection (PCCIP) whose objective was to recommend a comprehensive national infrastructure protection policy and implementation strategy.

[16] DHS and U.S. Department of Environmental Protection (EPA*), National Infrastructure Protection Plan, Sector Specific Plan – Water-2010*; EPA 817-R-10-001, accessed May 9, 2014, www.dhs.gov/xlibrary/assets/nipp-ssp-water-2010.pdf.

[17] EPA, Understanding Water Sector Interdependencies, August, 2010, accessed May 27, 2014, http://water.epa.gov/infrastructure/watersecurity/communities/upload/CBWRGeneralInterdependenciesFactSheet.pdf.

[18] DHS and U.S. Department of Environmental Protection (EPA), National Infrastructure Protection Plan, Sector Specific Plan – Water-2010; EPA 817-R-10-001, accessed May 9, 2014, www.dhs.gov/xlibrary/assets/nipp-ssp-water-2010.pdf.

[19] EPA, *Drinking Water Treatment Fact Sheet*, 2004, accessed May 21. 2014, www.epa.gov/safewater/sdwa/pdfs/fs_30ann_treatment_web.pdf.

[20] EMC Insurance Companies, *Chlorine Safety for Water Treatment Operators*, accessed February 18, 2014, www.emcins.com/Docs/Risk/TechSheets/Tech_Chlorine_Safety_For_Water_Treatment_Operators_20111025.pdf.

[21] OSHA, *Chlorine*, OSHA Occupational Chemical Database, accessed February 18, 2014, www.osha.gov/chemicaldata/chemResult.html?recNo=650,

flammable but may react explosively when in contact with oil, grease, or organic materials or if it is improperly mixed with acid and acidic materials (e.g., ferric sulfate, aluminum sulfate).[22]

In addition to the threats and hazards mentioned above, the Water and Wastewater Systems Sector faces a variety of challenges that are negatively impacting the Sector, including aging infrastructure, climate change, and population increases. Table 3 outlines several of the current challenges facing water and wastewater treatment facilities.

TABLE 3.—Challenges Facing the Water and Wastewater Systems Sector.[23,24,25,26,27]

Aging Infrastructure	Old and worn water and wastewater treatment, distribution, and collection facilities require repair or replacement to maintain utility service.
Population Growth	New plants are needed to meet the demands of growing populations in some areas, as existing water and wastewater facilities are already taxed.
Population Shift	Pollution not controlled by wastewater treatment results from farm runoff and increasing urbanization. Population migration from metropolitan areas has resulted in increased used of decentralized systems; septic systems serve about 40 percent of new developments in the United States.
Climate Change	According to the 2014 U.S. National Climate Assessment, climate change can intensify stresses on urban environments resulting in a highly variable water cycle. For example, snowpack and streamflow amounts are projected to decline in the Southwest resulting in decreased surface water supply reliability for urban areas, agriculture, and ecosystems.
Cyberdependence	Cyber events could potentially impact water systems in many ways to include interference with treatment processes, resulting in over- or under-dosing of chemicals or disrupting/disabling flow throughout the system. If multiple disruptions take place there may not be adequate staff to help manually mitigate these disruptions.

[22] EMC Insurance Companies, *Chlorine Safety for Water Treatment Operators*, accessed February 18, 2014, www.emcins.com/Docs/Risk/TechSheets/Tech_Chlorine_Safety_For_Water_Treatment_Operators_20111025.pdf.
[23] U.S. Global Change Research Program, *Global Climate Change Impacts in the United States*, 2014, accessed May 21, 2014. http://nca2014.globalchange.gov/report.
[24] Water Sector Coordinating Council Cyber Security Working Group, *Roadmap to Secure Control Systems in the Water Sector*, 2008, accessed May 21, 2014, www.awwa.org/portals/0/files/legreg/security/securityroadmap.pdf.
[25] EPA, *Urbanization and Streams: Studies of Hydrologic Impacts*, 2012, accessed May 21, 2014, http://water.epa.gov/polwaste/nps/urban/report.cfm.
[26] EPA, *Agriculture*, 2014, accessed May 21, 2014, http://water.epa.gov/polwaste/nps/agriculture.cfm.
[27] EPA, *Water: Septic (Onsite/Decentralized) Systems*, 2013, accessed May 21, 2014, http://water.epa.gov/infrastructure/septic/FAQs.cfm.

DEPENDENCIES, INTERDEPENDENCIES, AND POTENTIAL IMPACTS

The resilience of a community or region is a function of the resilience of its subsystems, including its critical infrastructure, economy, civil society, and governance (including emergency services). Resilience can be highly complex due to the dependencies and interdependencies that exist within infrastructure systems and the regions they serve, and the potential for cascading consequences. The loss of water and wastewater treatment facilities can happen at any time as a result of faulty equipment, severe weather, flooding, cyberattack, accident, or sabotage. The loss of readily available treated water is not just an inconvenience for utility customers. Its impacts can quickly cascade to other lifeline systems, including Energy, Healthcare, Communications, Information Technology (IT), and Emergency Services, resulting in the loss of services that are necessary to the community's economy, public health and safety.

Potential impacts caused by a disruption in water service include:[28]

- Loss of water for cooling resulting in impacts to electrical and telecommunications equipment;
- Lack of water for consumption, cooking, bathing, flushing, fire suppression, etc.;
- Loss of water for commercial irrigation, food supply, production of consumer needs;
- Decreased public confidence in water supply;
- Need to access alternate water supplies and/or issue a public notice to boil water; and,
- Adverse economic effects as industry and local government experience water service interruption.

Potential consequences of a wastewater service disruption include:

- Release of hazardous chemicals into treated wastewater, negatively impacting public health and the environment;[29]

Data Collection and Levels of Facility Degradation

The ECIP Initiative collects data through the Infrastructure Survey Tool (IST), a secure web-based tool that provides the ability to collect, process, and analyze survey data in near real time. Data collected during site visits are consolidated in the IST and then valued and weighted, which enables DHS to develop metrics; conduct sector-by-sector and cross-sector vulnerability comparisons; identify security gaps and trends across critical infrastructure sectors and sub-sectors; and establish sector baseline security survey scores.

The term "dependency," as used in the IST and reported here, is defined as the reliance of a facility on an outside/external utility or service to carry out its "core operations."

Degradation addresses how soon a facility will be impacted and to what extent if the source is lost. Data on degradation are gathered in the IST as a mutually exclusive set of answers: 0 percent degradation, 1–33 percent degradation, 34–66 percent degradation, 67–99 percent degradation, or 100 percent degradation.

Data are also collected on the existence of backup generation, duration of backup generation without refueling, and recovery time after external infrastructure service is restored.

[28] EPA, *Understanding Water Sector Interdependencies*, August, 2010, accessed May 9, 2014, http://water.epa.gov/infrastructure/watersecurity/communities/upload/CBWRGeneralInterdependenciesFactSheet.pdf.

- Lack of services posing public health and sanitation consequences;
- Sewage or storm water discharges damaging plants, animals, and aquatic life; and,
- Adverse economic impacts and damaged service provider reputation.

To further highlight these dependencies and interdependencies, the following sections will discuss the dependencies of water and wastewater treatment facilities, followed by the dependencies of other critical infrastructure on the Water and Wastewater Systems Sector. The term "dependency," as collected via the ECIP assessments, is defined as the reliance of a facility on an outside/external utility or service to carry out its core operations (e.g., produce key services/goods). Core operations may include: domestic uses (e.g., potable water), operations (e.g., fire suppression), or cooling (e.g., heating, ventilation, and air conditioning (HVAC)). The degradation in service (i.e., one or more of those core operations) captures how soon a facility will be impacted and to what extent if the source is lost. DHS assessment data from the RRAP and the ECIP Initiative, in which DHS partners with State and local agencies and the private sector to conduct voluntary assessments of a large number of critical infrastructure facilities, was analyzed to determine potential dependencies and resilience of water and wastewater systems.[30]

[29] CDC, *Local Board of Health to On-Site Wastewater Treatment Systems,* 2006, accessed June 11, 2014, www.cdc.gov/nceh/ehs/Docs/Onsite_Wastewater_NALBOH.pdf.

[30] Site assessments under the ECIP and RRAP are voluntary; they may not be representative of the entire sector. The information and data from the RRAP and the Infrastructure Survey Tool (IST, on which the ECIP security survey resides) are often protected as For Official Use Only or as Protected Critical Infrastructure Information; the information provided below has been sanitized to remove any facility, system, or regional references.

WATER TREATMENT FACILITY DEPENDENCIES

Since January 2011, DHS has conducted 134 ECIP surveys of water treatment facilities, collecting data on the facilities' dependencies and resilience. The data show the following dependencies for those water treatment facilities in Figure 1.

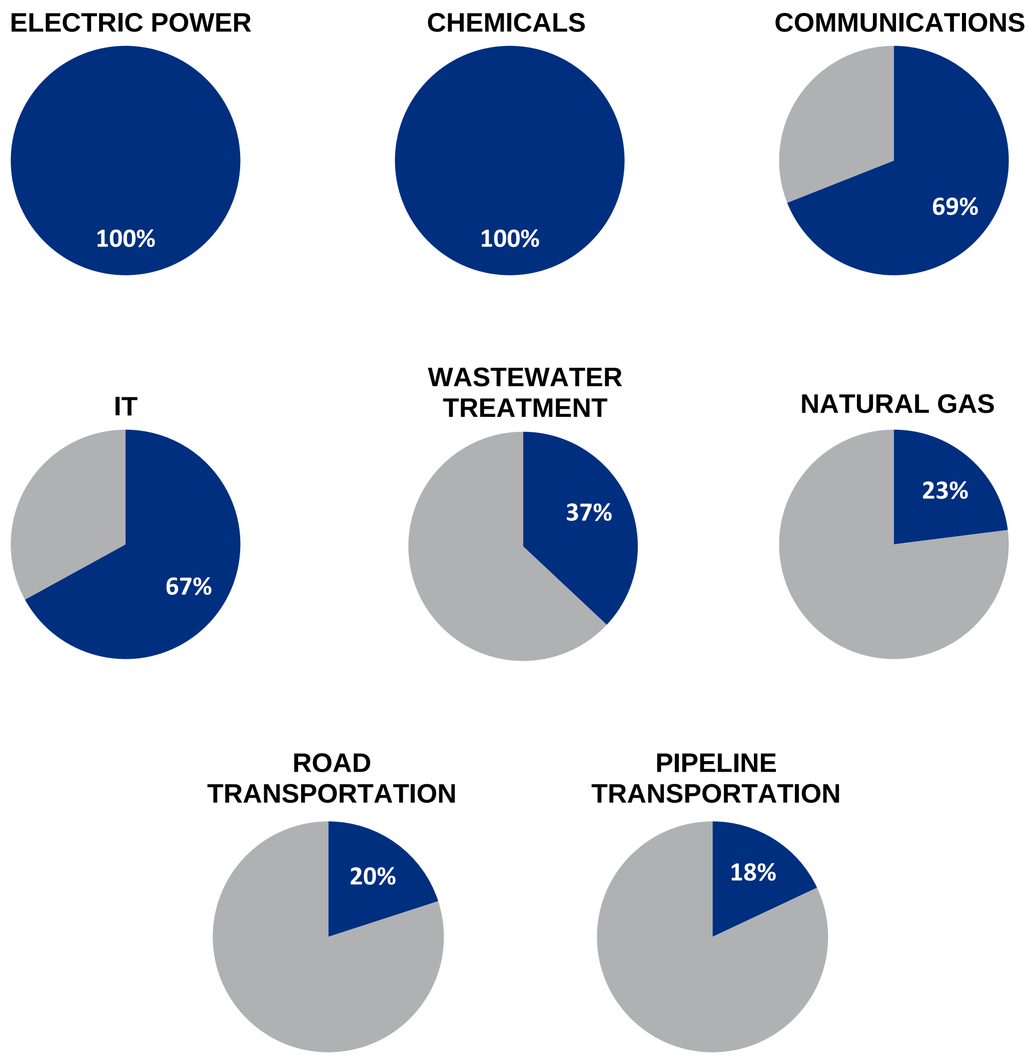


FIGURE 1.—Percent of Assessed Water Treatment Facilities Dependent upon Other Utilities (Courtesy of DHS and Argonne National Laboratory).

WASTEWATER TREATMENT FACILITY DEPENDENCIES

Since January 2011, DHS has conducted 96 ECIP assessments of wastewater treatment facilities, collecting data on the facilities' dependencies and resilience. The data show the following dependencies for those wastewater treatment facilities in Figure 2.

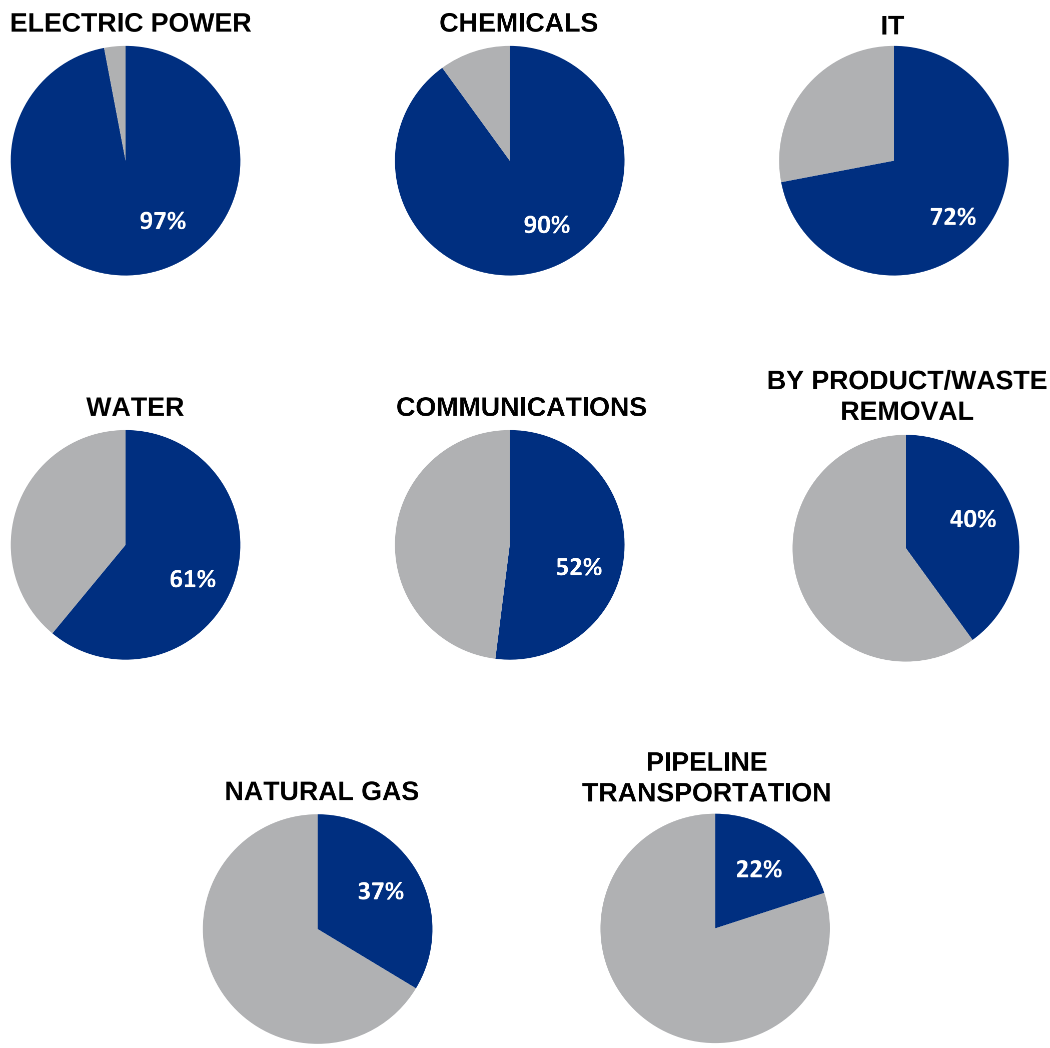


FIGURE 2.—Percent of Assessed Wastewater Treatment Facilities Dependent upon Other Utilities (Courtesy of DHS and Argonne National Laboratory).

THE ENERGY–WATER NEXUS

The energy–water nexus has long been recognized as a critical interdependency; water and wastewater utilities need power to operate pumps and treatment operations, while electric power facilities often depend on water for cooling equipment and processes. It is theorized that people living in the United States may indirectly use as much water to run appliances and lights in their homes as they do taking showers and watering lawns.[31] The increasing U.S. population will drive greater requirements for energy and water (e.g., for food production), thus putting greater strain on this closely tied interdependent system. The data from the DHS assessments indicate that the majority of the Water Sector facilities assessed have made investments in backup electric power generators because a loss of electric power, even temporarily, can have a significant effect on their operations.

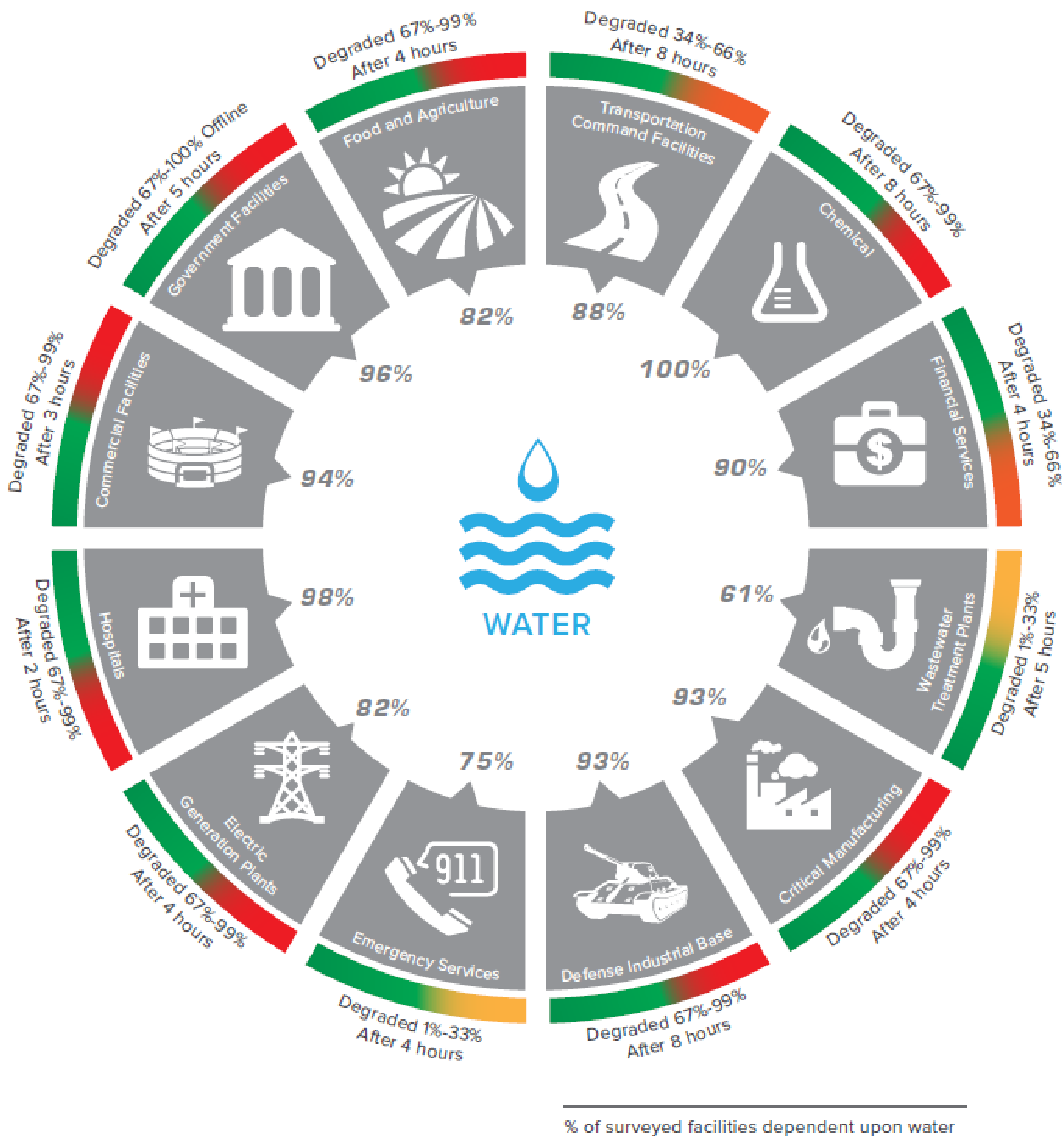
In the case of a total electric power failure (e.g., the outside feed is severed), data show that both water treatment and wastewater treatment facilities will lose operational capability by 100 percent if they do not have backup generation capability. However, most of these facilities have an alternate or backup source of electric power (87 percent of water and 88 percent of wastewater facilities). The backup generators can typically reduce the impact of primary power loss to 1–33 percent degradation in operations for 7 days without refueling.

Within the construct of the ECIP survey, the data on percent degradation is collected via the following question, "Once external electric service is lost (and considering your backup or alternative), what percentage of normal business functions are lost or degraded?"

[31] Sandia National Laboratories, *Energy-Water Nexus Overview*, 2006, accessed May 9, 2014, www.sandia.gov/energy-water/nexus_overview.htm.

IMPACTS TO CRITICAL INFRASTRUCTURE FROM LOSS OF WATER SERVICES

In total, 75 percent of the 2,661 sites that received ECIP assessments depend on external water for operations.[32] To illustrate the possible cross-sector impacts, data regarding degradation of service after loss of water were gathered from select critical infrastructure sectors.[33] The impact data for each asset is based on the average degradation and time to impact for that facility type (Figure 3).



Note: This data represents a majority (60 percent or greater) dependence on water.

FIGURE 3.—Critical Infrastructure Dependent on Water and Potential Functional Degradation Following a Loss of Water Services (Courtesy of DHS and Argonne National Laboratory).

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[32] Between January 2011 and April 2014, 2,661 sites in all 16 DHS Sectors received DHS visits.
[33] Sectors were selected if a majority of the assets had a dependence upon water.

The substantial cascading impacts that result from the loss of water underscore the importance of enhancing the resilience of the water system. In particular, an in-depth knowledge of the resilience capabilities of lifeline system assets is crucial to effectively prioritizing response and recovery activities prior to, during, and after an event. Potential impacts for particular sectors are highlighted below. Table 4 provides detailed statistics on common recovery mechanisms for all sectors in which a majority of the assets assessed by DHS have a high dependency on water.

ENERGY—ELECTRIC GENERATION PLANTS

Electric generation plants depend on water for steam generation, cooling, fire suppression, and domestic water use. Around 35 percent of electric generation plants surveyed stated that they had an alternate or backup supply to replace their primary water source for maintaining core operations. The backup source would permit core operations to continue for a few hours up to a few days. A reduced or limited water supply can affect a facility's fire suppression systems which endangers on-site personnel and critical equipment. Once water service has been restored, it generally takes up to 8 hours for full operations to resume at an electric generating plant.

HEALTHCARE AND PUBLIC HEALTH—HOSPITALS

Hospitals have a significant dependency on water.[34] Water is used for patient care; cooling; hot water; fire suppression; heating, ventilation, and air conditioning (HVAC) utilities; and other core operations. As illustrated in Figure 3, nearly all facility functions could be degraded within 2 hours due to loss of external sources of water. Although approximately half of the hospitals surveyed have a backup source of water (average on-site water storage is 40,000 gallons),[35] which could last up to 14 days in some cases, most of the hospitals surveyed stated that operating with their backup water supply would result in a 34–66 percent degradation of normal core operations. The CDC in conjunction with the American Water Association and the Department for Health and Human Services produced a planning guide for emergency water supply for hospitals. In the event of a main water supply disruption, the guide recommends stopping non-essential services, such as psychiatric services, elective surgeries, and physical therapy. [36]

State and local regulations may require the hospital to shut down if service is significantly degraded over a long period of time. For example, The Joint Commission Emergency Management Standards have a requirement for a 96 hour rule, requiring a hospital to determine if they have sufficient capability to sustain itself (independently through backups or by the local community) for 96 hours (i.e. fuel capacity, water for drinking and patient care, or water for process equipment and sanitation).[37] While the Joint Commissions requirements are focused on obtaining accreditation, the Department of Health and Human Services states in their Hospital Evacuation Decision Guide that "water loss of unknown duration (more than 1 to 2 days) is

[34] Ninety-eight percent of hospitals assessed by DHS reported a dependency on external water.

[35] A quarter of hospitals assessed by DHS stated that they have on-site water storage. Half of those facilities stating they had a backup water source stated they had on-site storage.

[36] U.S. Department of Health and Human Services, Centers for Disease Control and Prevention and American Water Works Association. *Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities*, 2012, accessed June 18, 2014, www.cdc.gov/healthywater/pdf/emergency/emergency-water-supply-planning-guide.pdf,.

[37] The Joint Commission, *Hospital: 2014 National Patient Safety Goals*, 2014, accessed June 18, 2014, www.jointcommission.org/hap_2014_npsgs/.

almost always cause for evacuation." Conversely, the loss of water in support of the fire suppression systems may necessitate a complete shut down much earlier.[38]

EMERGENCY SERVICES

Maintaining emergency services is especially critical during a disaster. Around 75 percent of the facilities surveyed in the Emergency Services Sector (ESS) by DHS stated that they require external water, primarily for domestic purposes (e.g., potable water). Water is also needed for firefighting response. Although emergency service providers are a critical component of community resilience, most do not have contingency plans (79 percent) or provider restoration plans (67 percent) in the event of a loss of water. Fortunately, if there is a loss of primary water, core emergency services operations typically degrade only 1 to 33 percent after 5 hours. Based on the facilities assessed by DHS, once water is restored, a facility could resume full functionality in 15 minutes. Most of the ESS facilities with a water dependency do not have an alternate or backup water source.

TABLE 4.—Percentage of Recovery Mechanisms for Sectors Dependent on Water.

Sector or Facility Type	Percent Dependent upon Water	Percent with Backup or Alternate Water Source	Percent with Contingency Plan	Percent with Priority Restoration Plan for Water
Chemicals and Hazardous Materials	100	25[39]	31	15
Commercial Facilities	94	5	16	16
Defense Industrial Base	93	0	29	21
Electric Generation	82	35	50	39
Emergency Services	75	10	21	33
Financial Services	90	27	18	13
Food and Agriculture	82	43	16	13
Government Facilities	96	7	21	23
Hospitals	98	49	55	65
Manufacturing	93	26	27	20
Transportation[40]	83	0	0	1

[38] U.S. Department of Health and Human Services, *Hospital Evacuation Decision Guide*, 2010, accessed June 18, 2014, http://archive.ahrq.gov/prep/hospevacguide/,.
[39] Due to the small number of facility responses for this data point, the result listed is not statistically significant.
[40] Subset of Transportation facilities: Transit Bus Dispatch or Operations Control Centers, Railroad Operations Center, and Road Transportation Support Facilities

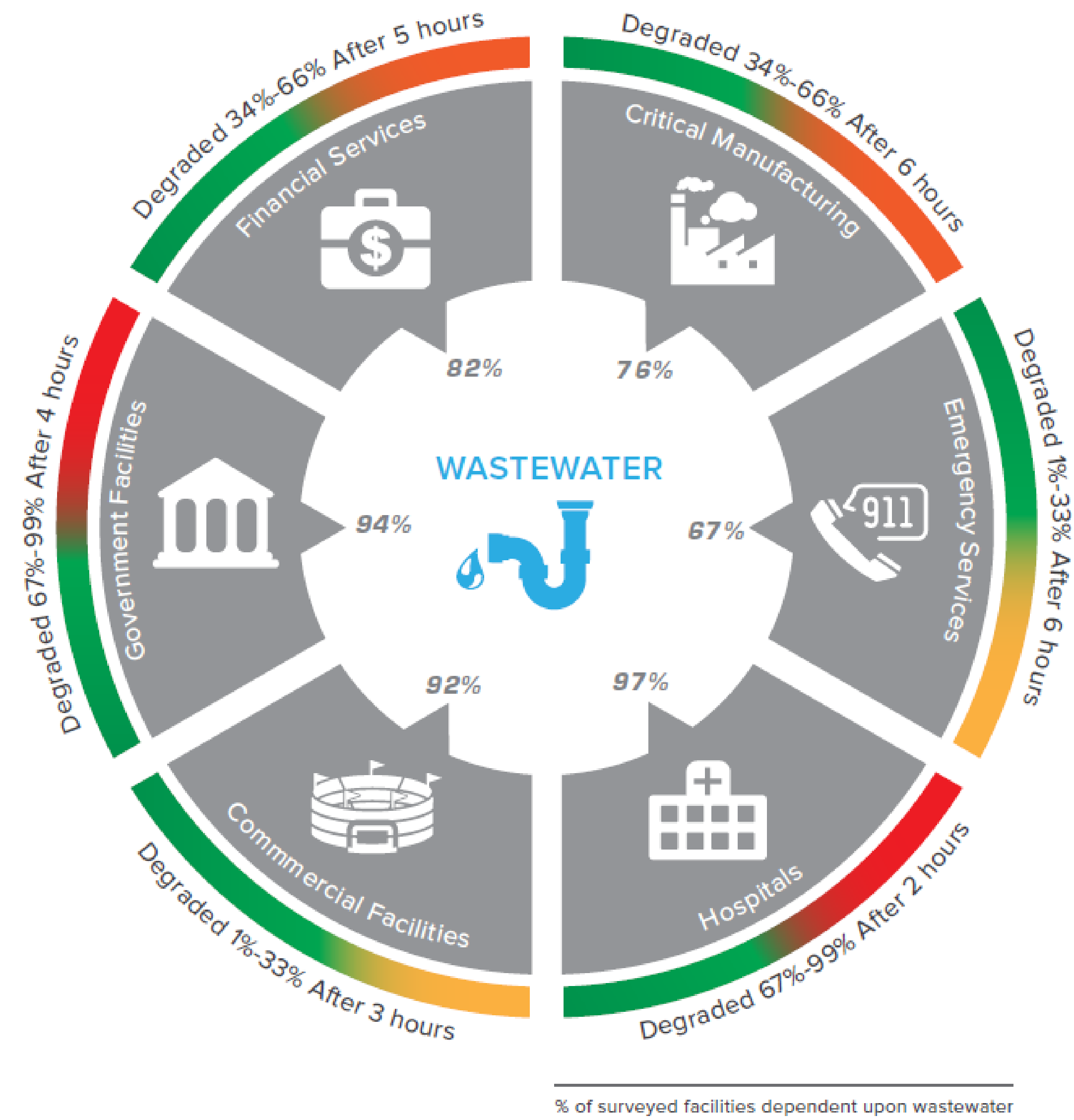
Sector or Facility Type	Percent Dependent upon Water	Percent with Backup or Alternate Water Source	Percent with Contingency Plan	Percent with Priority Restoration Plan for Water
Wastewater	61	20	39	36

As noted in Table 4, a large portion of facilities assessed by DHS that are dependent on water for domestic, cooling, and/or core operations fail to have an alternate source or on-site backup for water. Data indicates inadequate emphasis is placed on contingency or continuity plans for service interruption, or on priority restoration plans with the water utility service. The potential interdependencies between affected critical infrastructure and other critical infrastructure could result in cascading impacts across the region. Loss or contamination of potable water could severely affect the civilian population. The EPA has a number of resources available about the resilience and protection of water infrastructure, planning and exercising for the loss of water, and toolboxes to inform State and local governments about communicating with to the local population.[41]

[41] EPA, *Emergency/Incident Planning, Response and Recovery,* accessed May 9, 2014, http://water.epa.gov/infrastructure/watersecurity/emerplan/index.cfm.

IMPACTS TO CRITICAL INFRASTRUCTURE FROM LOSS OF WASTEWATER SERVICES

In total, 68 percent of the 2,661 sites that received ECIP assessments depend on external wastewater discharge services for operations.[42] The assessments include infrastructure surveys across all sixteen sectors, including roads, bridges, and electric substations, which would not typically rely on wastewater. To illustrate the possible cascading impacts from loss of wastewater services, data was gathered from selected critical infrastructure sectors and facilities (including several lifeline assets.) The dependency data for each asset in Figure 4 were based on the average degradation and time to impact for that facility type.



Note: This data represents a majority (60 percent or greater) dependence on wastewater services.

FIGURE 4.—Critical Infrastructure Dependent on Wastewater and Potential Functional Degradation Following a Loss of Wastewater Services (Courtesy of DHS and Argonne National Laboratory).

[42] Between January 2011 and April 2014, a total of 2,661 sites in all 16 DHS Sectors received DHS visits.

A number of cascading impacts may result from the loss of wastewater service. Understanding the dependencies and the resilience capabilities of lifeline system assets is crucial to effectively prioritizing response and recovery activities prior to, during, and after an event. Potential impacts from the loss of wastewater service for particular sectors are highlighted below. Table 5 summarizes key statistics on common recovery mechanisms of sectors and facilities assessed by DHS that are dependent upon wastewater discharge services.

HEALTHCARE AND PUBLIC HEALTH—HOSPITALS

Hospitals' dependency on wastewater discharge services is very similar to their dependency on water services. As illustrated in Figure 4, nearly all facility functions could be degraded within 2 hours due to loss of external wastewater discharge services, primarily for health and safety considerations. Depending on the nature of the loss, the facility might be forced to evacuate critical patients. Of the 193 hospitals that have been assessed by DHS, only 9 percent have a backup or alternate to their primary wastewater discharge services.[43] Once wastewater discharge is restored, hospitals would generally resume full operations within an hour.

COMMERCIAL FACILITIES

Most commercial and government facilities assessed by DHS depend on external wastewater discharge services. However, outdoor facilities such as horse and dog tracks, motor racetracks, and community parks and fairgrounds have a slightly lower dependency on wastewater discharge, because portable restrooms are often utilized at these facilities.[44] Because wastewater for these facilities comes primarily from domestic uses, there is little emphasis on contingency plans or priority restoration services. However, facilities with large numbers of customers (i.e., arenas, stadiums, and office buildings) are required by external regulations to shut down after prolonged loss of wastewater services.[45]

TABLE 5.—Percentage of Recovery Mechanisms for Sectors Dependent on Wastewater.

Sector or Facility Type	Percent Dependent upon Wastewater	Percent with Backup or Alternate for Wastewater	Percent with Contingency Plan	Percent with Priority Restoration Plan for Wastewater
Commercial	92	6	13	14
Emergency Services	67	6	21	24
Financial Services	82	10	17	20
Government Facilities	94	3	20	20

[43] The 193 hospitals addressed here do not include Critical Access Hospitals (CAHs). The addition of CAHs (29) results in 222 total hospital facilities that have received assessments, with only 10 percent having a backup or alternate to their primary wastewater discharge services.

[44] Around 70 percent of these types of facilities responded they required external wastewater discharge services, versus 90 percent for all other commercial facilities. 92 percent of office buildings responded they required external wastewater discharge services.

[45] Twenty-six percent of facilities surveyed in the commercial sector are required to shut down after an average time of 5 hours.

Sector or Facility Type	Percent Dependent upon Wastewater	Percent with Backup or Alternate for Wastewater	Percent with Contingency Plan	Percent with Priority Restoration Plan for Wastewater
Hospitals	97	9	46	51
Manufacturing	76	28	21	17

One of the greatest hazards related to the loss of wastewater discharge is plumbing-related backups or breaks in the lines, which could cause sewage to leak into the environment. The resulting sanitation and environmental hazards can have escalating consequences. The Centers for Disease Control and Prevention maintains an informational Website addressing on-site wastewater issues that could have public health impacts.[46] Many case studies have been published looking at industrial waste discharge into the local environment and its effects on the local flora and fauna, as well as the public that comes in contact with the polluted waters. Conducting wastewater contingency plan training and exercises with local governments and emergency response organizations will increase resilience of the local area and limit the potential for cascading consequences; restoration agreements between critical infrastructures and wastewater utilities can also help in this regard.

[46] Center for Disease Control (CDC), Environmental Health Services, *Onsite Wastewater*, accessed May 9, 2014, www.cdc.gov/nceh/ehs/topics/wastewater.htm.

RESILIENCE ISSUES AND BEST PRACTICES

Table 6 presents commonly observed resilience issues and best practices summarized for three categories of users: water or wastewater provider systems and facilities, community risk management organizations (i.e. State or local emergency operation centers or fusion centers), and any critical infrastructure asset or system that depends on water or wastewater services (i.e., water customers). The issues and best practices listed in Table 6 were identified in RRAPs and from among the results of the ECIP assessments, as well as general literature reviews.[47] The information is meant for general application across water and wastewater systems and impacted sectors and customers; the issues and best practices identified may apply to other regions or other facilities or types of facilities. See the Appendix for supporting resources and references.

TABLE 6.—Resilience Issues and Best Practices

FOR WATER/WASTEWATER PROVIDER SYSTEMS OR FACILITIES

Many surveyed water facilities lack business continuity and/or emergency response plans

- Develop, train, and test a business continuity plan to enable personnel to respond quickly to potential disasters, increasing the likelihood of quicker restoration of core operations.
  - DHS and the Federal Emergency Management Agency (FEMA) provide resources for business continuity planning at www.ready.gov/business.
  - All community water systems serving a population of greater than 3,300 are mandated by Title IV of the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 to prepare or modify Emergency Response Plans to address potential terrorist actions against those systems
- Communicate plans to all personnel, as well as frequent training and exercise (especially with first responders).
- Exercise plans with local first responders to ensure familiarity with the facility and their emergency procedures in the event of an actual incident.

Water utilities generally lack written priority restoration plans with other utilities in the event service is lost

- Establish contingency plans for the loss of utilities critical to core operations (electricity, communications, etc.).
- Establish priority restoration agreements with critical utilities and suppliers to ensure minimal disruption to services during manmade or natural disasters.
- Work with local government officials and other critical infrastructure asset owners to establish regional restoration plans that will take effect upon interruption of service.

Critical utility lines are either co-located with other utility lines, or are unprotected from both manmade and natural disasters

- Harden or relocate at-risk critical equipment to prepare for region-specific common natural disasters such as flooding or tornadoes.
- Consider geographically separating utility lines to provide less chance of losing all dependent services in the event of an incident.

[47] Resilience information gathered via the RRAP and the ECIP assessments are often protected as For Official Use Only or as Protected Critical Infrastructure Information; the information in Table 6 has been sanitized to remove any specific facility, system, or regional references.

- Install protective measures, such as bollards, fencing, or electronic security measures, around equipment that is at risk of sabotage or accidents and, if necessary, install fire/blast walls to protect adjacent equipment.

Facilities typically lack a robust cybersecurity plan

- Establish a written cybersecurity policy that encompasses critical items such as privacy, data security, network security, email policies, employee responsibilities, incident response and reporting, and policy development and management guidelines.
- Consider utilizing resources provided through the Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) to support plan development and organizational cybersecurity training. Review guides to assist in the development of cybersecurity plans (i.e., www.transition.fcc.gov/cyber/cyberplanner.pdf).
- Tailor cybersecurity policies and configurations for the SCADA network in accordance with guidelines established in formal cybersecurity guidance such as NIST Special Publications 800-series, ISO/IEC 27001, CoBIT, ITIL (http://csrc.nist.gov/publications/PubsSPs.html).
- Arrange a cybersecurity assessment, many of which are available from Government sources or with a third−party private provider at no cost to the facility.

FOR COMMUNITY RISK-MANAGEMENT ENTITIES

There exists a lack of water restoration prioritization for critical governmental emergency response agencies and for privately owned critical infrastructure facilities that are dependent on water to support other critical infrastructure or emergency responders

- Governmental agencies should ensure that emergency operation centers have identified critical equipment and determined the emergency generation capabilities, including fuel needs.
- State and local emergency plans should include provisions for the distribution of potable water to priority government and privately owned critical infrastructure and lifeline sector customers following a disaster.

Citizens may not be aware of what steps to take to help ensure personal resilience and preparedness for prolonged water outages

- Conduct outreach to inform citizens of steps they can take to prepare for loss of water and other critical utilities; such outreach will aid local utilities by reducing calls for information and damage or distress calls.
- Prepare a community plan for potable water distribution centers that will take effect after a disaster, and socialize information to community citizens to maximize resilience of the local population.

Aesthetic concerns often preclude water and wastewater facilities from installing adequate security measures to protect critical equipment

- Consider adding protective fencing that includes outriggers and barbed wire to deter individuals that wish to harm or sabotage critical pieces of equipment.
- Install adequate lighting to deter individuals who wish to infiltrate critical areas within the facilities; local regulations often prohibit this lighting due to proximity to residential neighborhoods and “light pollution” complaints.
- State and local governments can work with water and wastewater utility providers to determine alternative measures to protect critical equipment from both manmade and natural disasters.
- State and city officials should develop an urban design and critical infrastructure security policy plan; consult the FEMA Security Risk Management Series publications to assist with development of a plan (https://www.fema.gov/what-mitigation/security-risk-management-series-publications).

Functions, vulnerabilities, and impacts of the loss of water and/or wastewater on other critical infrastructures need to be internalized at the community level

- The EPA developed the Community-Based Water Resiliency (CBWR) Initiative, which focuses on identifying and developing a suite of tools and resources that can be successfully implemented by water utility owners and operators and the local communities they serve; CBWR tools can be implemented at the local level, by local officials, with only a minimal financial investment (http://water.epa.gov/infrastructure/watersecurity/communities/).
  - Potential funding sources for resilience enhancements at water utilities may include hazard mitigation grants from FEMA, State homeland security grants, and Urban Areas Security Initiative funds; more information is available from the American Water Works Association, which has summarized funding opportunities applicable to the water sector (www.waterworld.com/articles/print/volume-24/issue-1/editorial-feature/awwa-issues-guide-to-water-security-funding.html).

FOR WATER CUSTOMERS

Critical water supply equipment (i.e., fire suppression lines, main water line, shut-off valves) are located above ground and are unprotected, making the water line susceptible to accidental damage or vandalism

- Install enclosures, barriers, locks, and/or electronic security measures around equipment that is at risk of sabotage or accidents.
- Establish and implement a written contingency and continuity plan for loss of water; ensure employees responsible for implementation of the plan are informed and trained on the plan.
- Develop a solid working relationship with the water service provider; good working relationships with utility providers can potentially speed up the restoration process in the event of an outage.

Facilities often lack backup for domestic water supply, which could jeopardize the function of the fire suppression system, among other critical operations

- Conduct a feasibility study to determine water needs, as well as costs for multiple backup options (i.e., onsite water storage, contract with third party to provide), or develop a contract with a local provider to provide water in the event of a loss of service.
- Develop a priority plan for restoration with the local water provider to enable minimal disruption after an event.
- Work with local government officials and other critical infrastructure asset owners to establish regional restoration priorities in the event of an interruption of service.

Many facilities lack business continuity plans in the event that water service is lost

- Develop, train, and test of a business continuity plan to enable personnel to respond quickly to potential disasters, increasing the likelihood of quicker restoration of core operations.
- Communicate continuity plans to all personnel.
- Frequently train and exercise plans with employees and, when possible, with local first responders to ensure familiarity with the facility and their emergency procedures in the event of an actual incident.
- DHS and FEMA provide resources for business continuity planning at www.ready.gov/business.

FOR WASTEWATER CUSTOMERS

Customers often have only one wastewater line leaving their facilities and have not considered how to address waste backup

- Prepare and stock adequate supplies of standalone sanitary units, alternative waste disposal units, and/or “waterless bathrooms” that can be deployed in case of reduction or loss of wastewater service.
- Establish and implement a written contingency and continuity plan for loss of domestic wastewater; ensure inclusion of employees responsible for implementation of the plan are informed and those trained on the plan.
- Develop a solid working relationship with the wastewater service provider; good working relationships with utility providers can potentially speed up the restoration process in the event of an outage.

Pumps used to transfer wastewater from the facility to the sewer/septic system often have no backup in the event of failure

- Conduct a cost-benefit study to determine ejector pump electrical needs, as well as cost to support a facility in the event electricity is lost; backup generation must have sufficient capacity to support core operations until service can be restored or safe shutdown procedures can be implemented.
- Determine the amount of fuel that would need to be stored onsite to allow continued operation of emergency generation equipment in the event of fuel supply disruptions.

APPENDIX

RESILIENCE ISSUES AND BEST PRACTICES: REFERENCES AND RESOURCES

The following references provide the reader with more in-depth information on the Water and Wastewater Systems Sector, including vulnerabilities, gaps, resilience technology, and other sector-specific guidance.

American Water Works Association

- *Process Control System Security Guidance for the Water Sector*, 2014, available at www.awwa.org/Portals/0/files/legreg/documents/AWWACybersecurityguide.pdf
- *Wastewater Resource Community*, 2014, available at www.awwa.org/resources-tools/water-knowledge/wastewater.aspx
- *Security and Preparedness – Tapping All Resources for Recovery and Disaster Funding*, 2013, available at www.awwa.org/publications/journal-awwa/abstract/articleid/35096444.aspx
- *How Water Works*, 2006, available at www.awwa.org/Portals/0/files/resources/water%20knowledge/how%20water%20works/ConventionalWaterTreatmentProcessesPart1.pdf

Argonne National Laboratory

- *Resilience: Theory and Applications*, January 2012, available at www.dis.anl.gov/pubs/72218.pdf

Center for Disease Control and Prevention

- *Water Treatment*, December 2012, available at www.cdc.gov/healthywater/drinking/public/water_treatment.html

Critical Infrastructure Partnership Advisory Council Water Sector Working Group

- *Roadmap to a Secure and Resilient Water Sector*, October 2009, available at www.nawc.org/uploads/documents-and-publications/documents/document_5582326a-7a35-4f67-923b-279c642b5129.pdf

Department of Homeland Security (DHS)

- *Water and Wastewater Systems Sector Overview*, 2014, available at www.dhs.gov/water-and-wastewater-systems-sector

- *National Infrastructure Protection Plan 2013, Partnering for Critical Infrastructure Security and Resilience*, 2013, available at www.dhs.gov/national-infrastructure-protection-plan

- *Water Sector-Specific Plan, An Annex to the National Infrastructure Protection Plan*, 2010, available at www.dhs.gov/xlibrary/assets/nipp-ssp-water-2010.pdf

- *Critical Infrastructure Cyber Community (C^3) Voluntary Program* helps critical infrastructure sectors and organizations reduce and manage their cyber risk by connecting them to existing cyber risk management capabilities provided by DHS, other U.S. Government organizations, and the private sector. At the time of launch in February 2014, available resources primarily consisted of DHS programs, which will grow to include cross-sector, industry, and State and local resources. Available at www.us-cert.gov/ccubedvp.

Environmental Protection Agency (EPA)

- *2006 Community Water System Survey*, February 2009, available at http://water.epa.gov/infrastructure/drinkingwater/pws/upload/cwssreportvolumeI2006.pdf

- *Adaptation Strategic Guide for Water Utilities*, March 2013, available at http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817k11003.pdf

- *A Water Security Handbook: Planning for and Responding to Drinking Water Contamination Threats and Incidents*, 2006, available at www.epa.gov/watersecurity/pubs/water_security_handbook_rptb.pdf

- *Drinking Water Treatment,* 2004, available at http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_treatment_web.pdf

- *Primer for Municipal Wastewater Treatment Systems*, September 2004, available at http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf

- *Public Drinking Water Systems: Facts and Figures*, April 2012, available at http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm

- *Public Drinking Water Systems Programs*, 2013, available at http://water.epa.gov/infrastructure/drinkingwater/pws/index.cfm

- *Understanding Water Sector Interdependencies*, August 2010, available at http://water.epa.gov/infrastructure/watersecurity/communities/upload/CBWRGeneralInterdependenciesFactSheet.pdf

- *Community-Based Water Resiliency*, 2014, available at http://water.epa.gov/infrastructure/watersecurity/communities

- *FACTOIDS: Drinking Water and Groundwater Statistics for 2009*, 2009, available at www.epa.gov/ogwdw/databases/pdfs/data_factoids_2009.pdf

Federal Emergency Management Agency

- *Security Risk Management Publications*, 2013, available at www.fema.gov/what-mitigation/security-risk-management-series-publications.

United States Congress

- *Public Health Security and Bioterrorism Preparedness and Response Act of 2002*, Public Law 107-188, June 12, 2002, available at http://www.gpo.gov/fdsys/pkg/PLAW-107publ188/pdf/PLAW-107publ188.pdf

U.S. Fire Administration

- *Water Supply Systems and Evaluation, Volume I: Water Supply System Concepts*, 2008, available at www.usfa.fema.gov/downloads/pdf/publications/Water_Supply_Systems_Volume_I.pdf

- *Water Supply Systems and Evaluation, Volume II: Water Supply Evaluation Methods*, 2008, available at www.usfa.fema.gov/downloads/pdf/publications/Water_Supply_Systems_Volume_II.pdf

Water Sector Coordinating Council Cyber Security Working Group

- *Roadmap to Secure Control Systems in the Water Sector*, 2008, available at www.awwa.org/portals/0/files/legreg/security/securityroadmap.pdf

- *Cybersecurity Guidance and Tool*, 2014, available at www.awwa.org/resources-tools/water-utility-management/cybersecurity-guidance.aspx