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January 2020

WATER INFRASTRUCTURE

Technical Assistance and Climate Resilience Planning Could Help Utilities Prepare for Potential Climate Change Impacts

GAO-20-24

GAO Highlights

Highlights of GAO-20-24, a report to congressional requesters

January 2020

WATER INFRASTRUCTURE

Technical Assistance and Climate Resilience Planning Could Help Utilities Prepare for Potential Climate Change Impacts

Why GAO Did This Study

Human health and well-being require clean and safe water, according to the Water Research Foundation. The Fourth National Climate Assessment states that the potential impacts of extreme weather events from climate change will vary in severity and type and can have a negative effect on drinking water and wastewater utilities. GAO's previous work on climate change and resilience to extreme weather and disasters has shown how the federal government can provide information and technical and financial assistance to promote and enhance climate resilience. In 2015, GAO reported that enhancing climate resilience means taking action to reduce potential future losses by planning and preparing for climate-related impacts, such as extreme rainfall.

This report examines federal technical and financial assistance to utilities for enhancing climate resilience, and options experts identified for providing additional assistance, among other things. GAO reviewed relevant federal laws, regulations, and guidance from four federal agencies—EPA, FEMA, HUD, and USDA—and interviewed federal officials, representatives from 15 water utilities selected for diversity of size and geography, and 10 experts selected to represent different views.

What GAO Recommends

GAO recommends that EPA identify technical assistance providers and engage them in a network to help water utilities incorporate climate resilience into infrastructure projects. Also, Congress should consider requiring that climate resilience be considered in planning for federally funded water infrastructure projects. EPA neither agreed nor disagreed. GAO believes the recommendation is still warranted.

View GAO-20-24. For more information, contact J. Alfredo Gómez at (202) 512-3841 or gomezj@gao.gov.

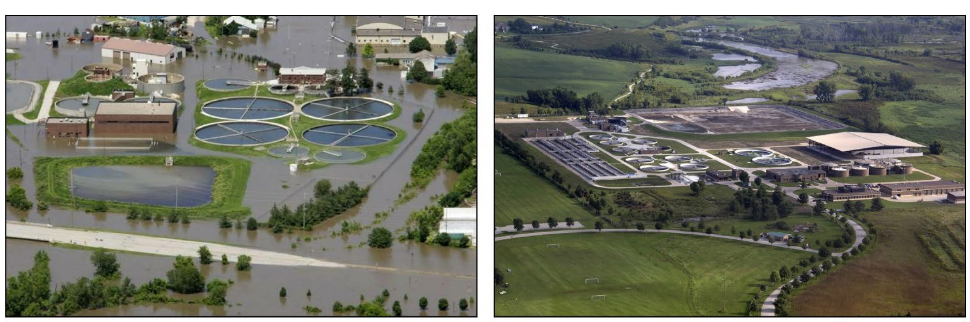
What GAO Found

Four federal agencies—the Environmental Protection Agency (EPA), the Federal Emergency Management Agency (FEMA), and the Departments of Housing and Urban Development (HUD) and Agriculture (USDA)—provide technical and financial assistance (e.g., loans and grants), to drinking and wastewater utilities.

Technical assistance. EPA provides technical assistance to drinking water and wastewater utilities to enhance their infrastructure's resilience to climate change. However, according to EPA officials, EPA's program is small and cannot assist utilities nationwide. All of the selected experts GAO interviewed stated that utilities need additional technical assistance on an ongoing basis to manage climate risks, and most experts said that organizing a network of existing technical assistance providers, including federal and state agencies, universities, and industry groups, would be needed to provide such assistance. Under a presidential policy directive, EPA is to work to enable efficient information exchanges among federal agencies and to help inform planning and operational decisions for water and wastewater infrastructure. By identifying existing technical assistance providers and engaging them in a network to help utilities incorporate climate resilience into their infrastructure projects on an ongoing basis, EPA would have better assurance that climate information was effectively exchanged among federal agencies and utilities.

Financial assistance. Federal agencies have taken some actions to promote climate resilience when providing financial assistance for water infrastructure projects, but agencies do not consistently include the consideration of climate resilience when funding such projects. Most selected experts suggested that federal agencies should require that climate information be considered in the planning of water infrastructure projects as a condition of providing financial assistance. Moreover, representatives from several utilities said that such a requirement could be an effective and feasible way to help enhance utilities' climate resilience. A requirement would ensure that utilities consider climate resilience in planning for water infrastructure projects and potentially limit future fiscal exposures. For example, from fiscal years 2011 through 2018, the federal government provided at least $3.6 billion in disaster recovery financial assistance for drinking water and wastewater infrastructure related projects (see figure).

Relocation of Iowa City's North Wastewater Treatment Facility Because of 2008 Flooding



Source: Iowa City Public Works. | GAO-20-24

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Abbreviations

CREAT	Climate Resilience Evaluation and Assessment Tool
CRWU	Creating Resilient Water Utilities
DHS	Department of Homeland Security
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Administration
HUD	Department of Housing and Urban Development
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
RISA	Regional Integrated Science Assessments
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
WIFIA	Water Infrastructure Finance and Innovation Act

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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January 16, 2019

The Honorable Benjamin L. Cardin
Ranking Member, Subcommittee on Transportation and Infrastructure
Committee on Environment and Public Works
United States Senate

The Honorable Sheldon Whitehouse
Ranking Member, Subcommittee on Clean Air and Nuclear Safety
Committee on Environment and Public Works
United States Senate

Human health and well-being require clean and safe water, and the lack of access to such water is a significant threat to human health, according to a 2014 study by the Water Research Foundation.[1] In addition, a 2017 drinking water and wastewater sector work group report cochaired by the Environmental Protection Agency (EPA) found that natural disasters are among the most significant risks to our nation's drinking water and wastewater infrastructure. Significant risks from natural disasters can result from acute disasters related to extreme weather events, such as floods and hurricanes, and chronic hazards related to climate change, such as drought and sea level rise.[2]

Moreover, the U.S. Global Change Research Program's (USGCRP) *Fourth National Climate Assessment* reported that the impacts of climate change are projected to intensify in the future, including increases in the incidence of extreme high temperatures and heavy precipitation as well

[1]The Water Research Foundation is a nonprofit, educational organization that funds, manages, and publishes research on the technology, operation, and management of drinking water, wastewater, reuse, and stormwater systems—all in pursuit of ensuring water quality and improving water services to the public. See the Water Research Foundation, *Water/Wastewater Utilities and Extreme Climate and Weather Events: Case Studies on Community Response, Lessons Learned, Adaptation, and Planning Needs for the Future* (Alexandria, Va: 2014).

[2]Water and Wastewater Sector Strategic Roadmap Work Group, *Roadmap to a Secure and Resilient Water and Wastewater Sector* (May 2017).

as high-tide flooding events along the coastline.[3] Climate change impacts have the potential to negatively affect drinking water supplies, water and wastewater conveyance, and treatment infrastructure, as well as stormwater management systems. A 2009 study by a global engineering company reported that failure to plan for the potential impacts of climate change may lead to loss of water and wastewater treatment services for homes, municipalities, and industry with consequences to human health and the economy.[4]

As evident from Hurricanes Harvey, Irma, and Maria in 2017, individual extreme weather events can cause tens of billions of dollars in damages, including damages to critical infrastructure.[5] For example, flooding from Hurricane Harvey in 2017 submerged 18 of Houston's 39 wastewater treatment facilities rendering them inoperable during and in the immediate aftermath of the storm. In Harris County, where Houston is located, over 23 million gallons of untreated wastewater were released from treatment facilities into surrounding water bodies as a result of flooding from Harvey.[6]

Drinking and wastewater infrastructure are typically designed to withstand and continue to operate under risks associated with historical climate patterns. However, as we reported in April 2013, historical climate patterns may no longer be reliable for predicting future climate risks to

[3]Under the Global Change Research Act of 1990, the Federal Coordinating Council on Science, Engineering, and Technology, through the Committee on Earth and Environmental Sciences, is to periodically prepare a scientific assessment—known as the National Climate Assessment—which is an important resource for understanding and communicating climate change science and impacts in the United States. *See* Pub. L. No. 101-606, §§ 103, 106, 104 Stat. 3096, 3098, 3101 (1990). The USGCRP coordinates and integrates the activities of its 13 participating federal departments and agencies that carry out research and support the nation's response to global climate change. See the U.S. Global Change Research Program, *Climate Science Special Report, Fourth National Climate Assessment, Volume I* (Washington, D.C.: 2017).

[4]CH2M Hill, Inc., *Confronting Climate Change: An Early Analysis of Water and Wastewater Adaptation Costs* (October 2009).

[5]According to the National Oceanic and Atmospheric Administration Hurricanes Harvey, Irma, and Maria had total costs of $125 billion, $50 billion, and $90 billion, respectively Hurricane Harvey ranks as the nation's second costliest weather disaster on record; Irma ranks fifth, and Maria ranks third.

[6]Texas Commission on Environmental Quality. *Hurricane Harvey Related Sanitary Sewer Overflows and Other Wastewater Discharge* (Dec. 28, 2017).

infrastructure.[7] According to the National Research Council, as the climate changes and historical patterns—in particular, those related to extreme weather events—no longer provide reliable predictions of the future, infrastructure designs may underestimate the climate-related impacts to infrastructure over its design life, which can range as long as 50 to 100 years. Moreover, as more climate events occur, utilities must reexamine the design and operational assumptions associated with their water supplies, infrastructure performance and limitations, and user demands to avoid disruptions in service to the communities they serve.[8]

To better prepare for extreme weather events and the potential effects of climate change, these utilities will need to take steps to enhance the resilience of water and wastewater infrastructure, according to the 2014 Water Research Foundation study.[9] The National Academies of Sciences, Engineering, and Medicine (National Academies) have defined resilience as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events.[10] These adverse events include, for example, natural disasters and the potential impacts of climate change. Enhancing climate resilience means being able to plan and prepare for, absorb, recover from and more successfully adapt to climate-related impacts.[11] The Association of Metropolitan Water Agencies estimated that it would cost from $448 billion to $944 billion for

[7]GAO, *Climate Change: Future Federal Adaptation Efforts Could Better Support Local Infrastructure Decision Makers*, GAO-13-242 (Washington, D.C.: Apr. 12, 2013).

[8]Water Research Foundation, *Water/Wastewater Utilities and Extreme Climate and Weather Events*.

[9]Water Research Foundation, *Water/Wastewater Utilities and Extreme Climate and Weather Events*.

[10]The National Academies of Sciences, Engineering and Medicine, Committee on Increasing National Resilience to Hazards and Disasters and Committee on Science, Engineering, and Public Policy, *Disaster Resilience: A National Imperative* (Washington, D.C.: 2012).

[11]We reported in May 2016 that two related sets of actions can enhance climate resilience by reducing risk. These are climate change adaptation and predisaster hazard mitigation. Adaptation is defined as adjustments to natural or human systems in response to actual or expected climate change. Predisaster hazard mitigation refers to actions taken to reduce the loss of life and property by lessening the impacts of adverse events and applies to all hazards, including terrorism and natural hazards, such as health pandemics or weather-related disasters. In this report, we use “climate resilience” for consistency and to encompass both sets of actions as they relate to addressing climate risks. See GAO, *Climate Change: Selected Governments Have Approached Adaptation through Laws and Long-Term Plans*. GAO-16-454 (Washington, D.C.: May 12, 2016).

drinking water and wastewater infrastructure to become resilient to climate impacts through 2050.[12]

As we reported in November 2015, decisions made by state, local, and private sector entities can affect the federal government's fiscal exposure to the impacts of climate-related change, as those entities are responsible for planning, constructing, and maintaining certain types of vulnerable infrastructure that are paid for partly with federal funds, insured by federal programs, or eligible for federal disaster assistance.[13] EPA estimates that drinking water and wastewater utilities need to invest almost $744 billion to repair and replace their existing infrastructure over the next 20 years.[14] Further, in 2017 alone, it cost the federal government over $300 billion to repair damage resulting from climate- and weather-related events, including damage to drinking water and wastewater infrastructure, according to the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA).[15] The risk of these events will likely

[12]The Association of Metropolitan Water Agencies is an organization of the largest publicly owned drinking water systems in the United States that works with Congress and federal agencies to ensure that federal laws and regulations protect public health and are cost-effective, according to the association's website. The Association of Metropolitan Water Agencies provides programs, publications and services to help water suppliers be more effective, efficient, and successful. Climate change adaptation costs do not include the costs for extreme storm events and drought, or the costs associated with uncertain future regulatory controls. See CH2M Hill, Inc., *Confronting Climate Change: An Early Analysis of Water and Wastewater Adaptation Costs* (October 2009).

[13]GAO, *Climate Information: A National System Could Help Federal, State, Local, and Private Sector Decision Makers Use Climate Information*, GAO-16-37 (Washington, D.C.: Nov. 23, 2015).

[14]EPA's most recent estimates indicated that drinking water infrastructure funding needs totaled $473 billion (as of 2015), and wastewater infrastructure needs totaled $271 billion (as of 2012). EPA conducts a separate needs survey and cost assessment for drinking water and wastewater infrastructure on separate 4-year schedules. These cost estimates reflect the 20-year projected drinking water and wastewater infrastructure costs, starting with the year in which each survey was conducted. See Environmental Protection Agency, *Drinking Water Infrastructure Needs Survey and Assessment: Sixth Report to Congress*, EPA 816-K-17-002 (Washington, D.C.: March 2018), and *Clean Watersheds Needs Survey 2012: Report to Congress*, EPA-832-R-15005 (Washington, D.C.: January 2016).

[15]National Oceanic and Atmospheric Administration, National Centers for Environmental Information, *Billion-Dollar Weather and Climate Disasters* (2019).

increase over time as the U.S. climate continues to change, according to the *Fourth National Climate Assessment*.[16]

In February 2013, we placed *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* on our list of agencies and program areas that are at high risk because of their vulnerabilities to fraud, waste, abuse, and mismanagement or because they are in need of transformation.[17] Our work over the last decade has identified key federal roles in recognizing and managing risks in order to limit the federal government's fiscal exposure to the potential impacts of climate change.[18] In addition, our previous work on disaster funding and management identified federal actions and opportunities to enhance disaster resilience nationwide, focusing on how the federal government can provide information, integrate programs, and incentivize decisions.[19]

You asked us to review what federal actions may be taken to reduce the potential impacts of climate change and related effects on drinking water and wastewater infrastructure. This report examines (1) the potential impacts of climate change and the effects of these impacts on drinking water and wastewater infrastructure; (2) technical assistance selected federal agencies provided to selected utilities to help make drinking water and wastewater infrastructure more resilient to the impacts of climate change, and options experts identified for providing additional technical assistance to utilities; and (3) financial assistance selected federal agencies provided to selected utilities to help make drinking water and wastewater infrastructure more resilient to the impacts of climate change,

[16]U. Lall, T. Johnson, P. Colohan, A. Aghakouchak, C. Brown, G. McCabe, R. Pulwarty, and A. Sankarasubramanian, "Water," ch. 3 in *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* (Washington, D.C.: U.S. Global Change Research Program, 2018).

[17]GAO, *High-Risk Series: An Update,* GAO-13-283 (Washington, D.C.: February 2013).

[18]For example, see GAO, *Climate Change Adaptation: Strategic Federal Planning Could Help Government Officials Make More Informed Decisions*, GAO-10-113 (Washington, D.C.: Oct. 7, 2009); GAO-13-242; and GAO-16-37.

[19]For example, see GAO, *Hurricane Sandy: An Investment Strategy Could Help the Federal Government Enhance National Resilience for Future Disasters*, GAO-15-515 (Washington, D.C.: July 30, 2015); *Flood Insurance: Comprehensive Reform Could Improve Solvency and Enhance Resilience*, GAO-17-425 (Washington, D.C.: Apr. 27, 2017); and *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, GAO-20-100SP (Washington, D.C.: October 2019).

and options experts identified for providing additional financial assistance to utilities.

For the first objective, to examine the potential impacts of climate change and the effects of these impacts on drinking water and wastewater infrastructure, we reviewed the *Fourth National Climate Assessment*,[20] and EPA's *Climate Ready Water Utilities Adaptation Strategies Guide*,[21] *Climate Resilience Evaluation and Awareness Tool Methodology Guide*,[22] and Climate Scenarios Projection Map,[23] and the U.S. Climate Resilience Toolkit.[24] Based on our review of these sources, we identified different categories of potential climate change impacts and how those impacts may vary in the different climate regions identified in the *Fourth National Climate Assessment.*[25]

For both the second and third objectives, we reviewed the efforts of and interviewed officials from five federal agencies and 15 drinking water and wastewater utilities. We selected five federal agencies by reviewing our previous reports to identify key agencies that provide financial or technical assistance, or both, to drinking water and wastewater utilities. The five agencies are EPA, NOAA, the Department of Housing and Urban Development (HUD), the Department of Homeland Security's (DHS) Federal Emergency Management Agency (FEMA), and the U.S. Department of Agriculture's (USDA) Rural Utilities Service. We used a stratified purposeful sampling approach to select a nongeneralizable sample of 15 drinking water and wastewater utilities for interviews with

[20]Lall et al., *Fourth National Climate Assessment*, ch. 3.

[21]Environmental Protection Agency, *Climate Ready Water Utilities Adaptation Strategies Guide,* (Washington, D.C.: 2015)

[22]Environmental Protection Agency, *Climate Resilience Evaluation and Awareness Tool, Version 3.0 Methodology Guide*, (Washington, D.C.: 2016).

[23]EPA, *Climate Resilience Evaluation and Awareness Tool Climate Scenarios Projection Map*, accessed July 09, 2019, https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=3805293158d54846a29f750d63c6890e .

[24]National Oceanic and Atmospheric Administration, *U.S. Climate Resilience Toolkit*, accessed July 9, 2019, https://toolkit.climate.gov/topics/built-environment/water-and-wastewater .

[25]The Fourth National Climate Assessment identifies 10 climate regions for the United States and its territories: Northeast, Southeast, Midwest, Northern Great Plains, Southern Great Plains, Southwest, Northwest, Alaska, Hawaii and Pacific Islands, and Caribbean.

officials.[26] We selected utilities based on their size and climate region in order to capture both commonalities and variations among utilities of different sizes and locations. We defined small utilities as serving a population of 10,000 or less, medium utilities as serving a population of 10,001 to 999,999, and large utilities as serving a population of 1 million or more.[27] Findings from our interviews with the 15 utilities cannot be generalized to all drinking water and wastewater utilities but provide illustrative examples and detailed insights into how these utilities used federal technical assistance and financial assistance.[28]

For the second and third objectives, we also selected 10 experts in the climate change and disaster fields to interview about options for providing additional technical and financial assistance to drinking water and wastewater utilities. We used a quantitative analysis to select a range of authors whose work was frequently cited by other authors within the relevant literature we reviewed. We selected 15 experts who were frequently cited, based in North America, and still active in the fields and whose research was topically relevant. Eight of the 15 agreed to participate in our work; we supplemented this list with two experts who worked on the Fourth National Climate Assessment and who agreed to participate. Findings related to the 10 experts cannot be generalized to all experts but provide a wide range of views from highly-cited experts.

To examine the first parts of the second and third objectives, the technical and financial assistance selected federal agencies provided to selected utilities, we reviewed relevant laws, regulations, and planning guidance about programs that provide technical or financial assistance to drinking water and wastewater utilities to help enhance climate resilience. We also interviewed federal officials at each agency. We then provided a short

[26]A stratified purposeful sampling approach selects cases from within major subgroups, or strata, of the population.

[27]The five small utilities we selected were: Cottage Grove, Oregon; Estes Park, Colorado; Fredericktown, Missouri; Hillsboro, Kansas; and Keene, New Hampshire. The five medium utilities we selected were Anacortes, Washington; Bozeman, Montana; Charleston, South Carolina; Iowa City, Iowa; and Nogales, Arizona. The five large utilities we selected were Houston, Texas; Miami-Dade County, Florida; New York City, New York; Norfolk, Virginia; and San Diego, California.

[28]To characterize the views of utility representatives throughout this report, we defined the modifiers “almost all” to represent 12 to 14 representatives, “most” to represent eight to 13 representatives, “several” to represent four to seven representatives, and “a few” to represent two to three representatives.

questionnaire and interviewed utility representatives from the 15 selected drinking water and wastewater utilities to understand what technical and financial assistance they received to enhance the climate resilience of their infrastructure. In the questionnaire and interviews, we discussed utility efforts to plan for climate resilience and the technical and financial assistance they used for such efforts, which could include other federal agencies and nonfederal entities in addition to the four agencies we selected to review.

To examine the second parts of the second and third objectives, the options experts identified for providing additional technical and financial assistance to utilities, we conducted semistructured interviews with the 10 climate change and disaster resilience experts. To develop the semistructured interview documents, we used articles identified in a literature search on climate change resilience and drinking water and wastewater infrastructure to develop a list of nine actions that the federal government could take to make drinking water and wastewater infrastructure more resilient to the effects of climate change. We asked the selected experts to discuss the actions, the advantages and disadvantages of those actions, and how they could be implemented. All of the selected experts confirmed that the list of actions was comprehensive and did not have additional actions to add to the list. We then analyzed the results of our interviews to identify five options for providing technical assistance and developed a questionnaire asking the selected experts to rate the effectiveness of the five options, describe the advantages and disadvantages of each option, and describe how the options could be implemented.[29]

As part of analyzing the federal financial assistance to drinking water and wastewater utilities, we estimated FEMA's pre- and post-disaster spending to help such utilities recover from natural disasters. We queried FEMA's Public Assistance, Hazard Mitigation, and Pre-Disaster Mitigation Grant Program data using a list of search terms associated with drinking water and wastewater infrastructure and then reviewed a generalizable random sample of records to estimate FEMA's obligations for fiscal years 2011 through 2018. To assess the reliability of the disaster recovery spending data, we performed electronic testing, reviewed related documentation, interviewed agency officials knowledgeable about the

[29]To characterize experts' views throughout this report, we defined the modifiers "nearly all" to represent eight to nine experts, "most" to represent six to seven experts, and "several" to represent two to five experts.

data, and resolved data discrepancies. We also analyzed data on federal obligations for drinking water and wastewater infrastructure from HUD's Community Development Block Grant Disaster Recovery program. We determined that the data were sufficiently reliable for the purposes of our reporting objectives. For more details about our scope and methodology, see appendix I.

We conducted this performance audit from October 2017 to January 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Approximately 51,000 drinking water systems and 15,000 public wastewater systems provide clean and safe water to communities nationwide.[30] About 9,000 drinking water systems provide service to 92 percent of the total population, or approximately 273 million people nationwide. The remaining 8 percent of the population is served by small systems that according to the American Society of Engineers frequently do not have the financial, managerial, and technical capabilities necessary to meet state and federal requirements for safe drinking water, such as limits in the levels of specific contaminants in drinking water.[31]

Drinking water and wastewater facilities include infrastructure such as tanks, pipes, pumps, and buildings that contain electrical, chemical, and mechanical equipment to treat and test water. The infrastructure is often built to last for over 50 years or longer, depending on the equipment. Many utilities in the country were built decades ago and therefore have existing and aging infrastructure that they must operate and maintain. Utilities generally develop long-term capital plans to identify the infrastructure they will need to replace or rebuild in the future.

[30]In total, there are approximately 155,000 active public drinking water systems across the country. Most Americans—just under 300 million people—receive their drinking water from one of the nation's 51,356 community water systems. The remaining 103,644 public water systems are noncommunity systems that do not provide water on a regular or year-round basis. See American Society of Civil Engineers, *2017 Infrastructure Report Card*.

[31]American Society of Civil Engineers, *2017 Infrastructure Report Card*.

Utilities generally use historic records of seasonal precipitation, runoff, water temperature, and snow pack levels to determine how their systems should be designed and operated. According to the Water Research Foundation's 2014 study, utilities have designed their infrastructure based on the expectation that future climate conditions will remain the same and have used historical climate or other data within a 100-year range.[32] Generally, the study reported that utility infrastructure is designed and operated to convey or treat water up to a specific threshold amount based on these historic records.

As they plan to rebuild or replace their infrastructure, utilities employ or contract with engineers to ensure that their infrastructure treats and transports water appropriately to meet standards under the Safe Drinking Water Act or the Clean Water Act. Under the Safe Drinking Water Act, EPA, among other actions, sets standards to protect the nation's drinking water from contaminants, such as lead and arsenic. The Clean Water Act generally prohibits the discharge of pollutants from "point sources"—such as discharge pipes from industrial facilities and wastewater treatment facilities—without a permit.[33]

Drinking water and wastewater infrastructure remain the largest financial investment by communities nationwide, according to the Water Research Foundation's 2014 Study.[34] To pay for operations, maintenance, repair, and replacement of their infrastructure, drinking water and wastewater utilities generally raise revenues by charging their customers for the services they provide. In addition, the federal government invests in drinking water and wastewater infrastructure, as we reported in

[32]Water Research Foundation, *Water/Wastewater Utilities and Extreme Climate and Weather Events.*

[33]Under each act, EPA may authorize a state to carry out its own program in lieu of the federal program, if, among other things, the state program is at least as stringent as the federal program. As a result, states with authorized programs generally have primary responsibility for implementing safe drinking water and clean water requirements. Specifically, for drinking water utilities, all states except Wyoming and the District of Columbia have primary permitting and enforcement authority under the Safe Drinking Water Act. For wastewater utilities, all states except Idaho, Massachusetts, New Hampshire, and New Mexico have full or partial permitting and enforcement responsibility under the Clean Water Act.

[34]Water Research Foundation, *Water/Wastewater Utilities and Extreme Climate and Weather Events.*

September 2017.[35] In 2017, the most recent year for which data were available, state and local governments spent approximately $109 billion on their drinking water and wastewater infrastructure, according to Congressional Budget Office data. During the same time period, the federal government spent approximately $4 billion on drinking water and wastewater infrastructure.[36]

Climate Information Provided by the Federal Government

Agencies across the federal government, such as NOAA and the National Aeronautics and Space Administration, collect and manage many types of climate information and provide technical assistance to make this information more meaningful to federal, state, local, and private decision makers. Decision makers from all levels of government and the private sector use different types of climate information in their planning processes to reduce the potential impacts of climate change. To be useful, climate information must be tailored to meet the needs of each decision maker, such as an engineer responsible for building a bridge in a specific location, a county planner responsible for managing development in a large region, or a federal official managing a national-scale program. Decision makers also need climate information at different timescales corresponding to the short-, medium-, or long-term nature of their planning processes. A 2011 World Meteorological Organization report stated that decision makers need access to expert advice and support to help them select and properly apply climate information.[37]

According to a 2010 National Research Council report on making informed decisions about climate change and our November 2015 report on climate information, most decision makers need a basic set of information to understand and make choices about how to adapt to climate change.[38] The set of information includes the following:

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[35]GAO, *Drinking Water and Wastewater Infrastructure: Information on Identified Needs, Planning for Future Conditions, and Coordination of Project Funding*, GAO-17-559 (Washington, D.C.: Sept. 20, 2017).

[36]Congressional Budget Office, *Public Spending on Transportation and Water Infrastructure, 1956 to 2017* (October 2018).

[37]World Meteorological Organization, *Climate Knowledge for Action: A Global Framework for Climate Services*, WMO-No. 1065 (Geneva, Switzerland: 2011).

[38]National Research Council, *America's Climate Choices: Panel on Informing Effective Decisions and Actions Related to Climate Change, Informing an Effective Response to Climate Change* (Washington, D.C.: 2010) and GAO-16-37.

- **Information and analysis about observed climate conditions.** This includes information on, for example, temperature, precipitation, drought, storms, and sea level rise and how they may be changing in a local area.
- **Information about observed climate impacts and vulnerabilities.** This includes site-specific and relevant information on environmental, social, and economic impacts and vulnerabilities, resulting from observed changes in the climate against which past and current decisions can be monitored, evaluated, and modified over time.
- **Projections of what climate change may mean for a local area.** This includes, for example, projections based on easily understandable best- and worst-case scenarios with confidence intervals and probability estimates and examples of potential climate impacts. The primary source is NOAA's online Climate Explorer, which provides climate projections in a range of climate variables relevant to decision makers for every county in the contiguous United States, enabling users to compare historical climate observations under two possible climate change scenarios that could occur this century.
- **Information on the economic and health impacts of climate change.** Observed and projected local impacts must be translated into costs and benefits, as this information is needed for many decision-making processes.

Agencies across the federal government collect and manage many types of climate information, including observational records from satellites and weather monitoring stations on temperature and precipitation, among other things; projections from complex climate models; and other tools to make this information more meaningful to decision makers.[39]

[39]The 2013 Federal Open Data Policy directs federal agencies to make newly generated government data available in open, machine-readable formats, while continuing to ensure privacy and security. Data.gov was created to serve this purpose, and www.data.gov/climate provides climate data and resources related to coastal flooding, food resilience, water, ecosystem vulnerability, human health, energy infrastructure, and transportation.

Federal Planning for Critical Infrastructure Resilience

Presidential Policy Directive 21 directs federal agencies to work with owners and operators and state, local, tribal, and territorial entities to manage risks and strengthen the security and resilience of critical infrastructure against all hazards.[40] The directive, issued in 2013, identifies 16 critical infrastructure sectors whose assets, systems, and networks—either physical or virtual—are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on the nation's security, economy, and public health or safety. One of the sectors is the Water and Wastewater Sector. The directive established a national policy on critical infrastructure security and resilience and made DHS the lead agency to coordinate the overall federal effort to promote security and resilience of the nation's critical infrastructure.

The directive assigned protection responsibilities to selected federal government agencies and departments, called Sector Specific Agencies, and designated EPA as the Sector Specific Agency for the Water and Wastewater Sector. As the Sector Specific Agency, EPA organized a Water and Wastewater Government Coordinating Council, including federal, state, and local decision makers. In turn, water utility owners and operators organized the Water and Wastewater Sector Coordinating Council. EPA and the councils work together and are responsible for planning and implementing the sector's security and resilience activities.[41]

Presidential Policy Directive 21 also directed the DHS to update the National Infrastructure Protection Plan to provide a framework for how federal, state and local decision makers and private sector stakeholders can coordinate to improve the security and resilience of critical infrastructure. The DHS updated the National Infrastructure Protection

[40]Presidential Policy Directive 21, *Critical Infrastructure Security and Resilience*, (Washington, D.C.: Feb. 12, 2013).

[41]The Water and Wastewater Sector Coordinating Council is a policy, strategy and coordination mechanism for the U.S. Water and Wastewater Systems Sector in interactions with the government and other sectors on critical infrastructure security and resilience issues. The Water and Wastewater Sector Coordinating Council coordinates and collaborates with the EPA, the Department of Homeland Security, state primacy administrators and other government agencies primarily through the Government Coordinating Council. Council representatives are appointed by the member organizations including the American Water Works Association, Association of Metropolitan Water Agencies, National Association of Water Companies, National Rural Water Association, Water Environment Federation, Water Information Sharing & Analysis Center (nonvoting), and Water Research Foundation.

Plan in 2013 and EPA issued the Water and Wastewater Sector-Specific Plan in 2015.[42]

In 2016, the Water and Wastewater Government Coordinating Council and the Water and Wastewater Sector Coordinating Council chartered the Water and Wastewater Sector Strategic Roadmap Work Group to review key threats and vulnerabilities of the sector, identify gaps in the sector's capabilities relative to the key threats and vulnerabilities, and develop priorities and associated actions to address those gaps. In 2017, the work group issued the report, *Roadmap to a Secure and Resilient Water and Wastewater Sector (Roadmap)*, in part, to help inform utilities', industry groups', and government agencies' planning processes and to support collaboration and leverage resources between stakeholders in the sector.[43] The resulting report identified weather-related disasters, such as floods and earthquakes, and long-term climate-related hazards, such as drought and sea level rise, as among the most significant risks to drinking water and wastewater infrastructure.[44]

GAO Work on Climate Information and Disaster Resilience

Our previous work on climate change found that the federal government could improve the way that it provides information to facilitate more informed local infrastructure adaptation decisions. In November 2015, we reported that federal agencies could help local infrastructure decision

[42]Department of Homeland Security, *NIPP 2013 Partnering for Critical Infrastructure Security and Resilience*, (2013), and Department of Homeland Security and Environmental Protection Agency, *Water and Wastewater Systems: Sector-Specific Plan*, (2015). To support the National Infrastructure Protection Plan, each designated critical infrastructure Sector Specific Agency was directed to develop a Sector Specific Plan to reflect the unique operating conditions within that sector, including the interdependence between various critical infrastructure sectors, risks associated with climate change, aging and outdated infrastructure, and workforce continuity.

[43]Water and Wastewater Sector Strategic Work Group, *Roadmap to a Secure and Resilient Water and Wastewater Sector*.

[44]The purpose of the *Roadmap* was to establish a strategic framework that (1) articulates the priorities of industry and government in the Water and Wastewater Sector to manage and reduce risk; (2) produces an actionable path forward for the councils and security partners to improve the security and resilience of the sector over the near-term (within 2 years) and mid-term (within 5 years); (3) guides sector partners in developing new products and services and formulating budgets; (4) creates a shared understanding of and collectively advocates for sector priorities, while recognizing sector partners' institutional constraints and different accountabilities; and (5) encourages extensive engagement among all key stakeholders to strengthen public-private partnerships and reduce risk throughout the sector.

makers by providing the best available climate-related information and by clarifying federal sources of technical assistance for incorporating climate-related information into their planning.[45] In November 2015, we found that federal efforts to provide climate information could be improved by incorporating key organizational and data elements, including (1) a focused and accountable organization; (2) authoritative data that define the best available information for decision makers; and (3) technical assistance to help decision makers assess, translate, and use climate information in planning.[46] We recommended that the Executive Office of the President direct a federal entity to develop a set of authoritative climate change projections and observations and create a national climate information system with defined roles for federal and nonfederal entities. The Executive Office of the President neither agreed nor disagreed with the recommendations and, as of May 2018, had not implemented them.

Our previous work on natural disasters found that disaster costs are a key source of federal fiscal exposure. In our July 2015 report on Hurricane Sandy, we found that there was no comprehensive, strategic approach to identifying, prioritizing, and implementing investments for disaster resilience, which increases the risk that the federal government and nonfederal partners will experience lower returns on investments or lost opportunities to strengthen critical infrastructure.[47] We recommended that the Mitigation Framework Leadership Group—an interagency group chaired by FEMA that organizes mitigation efforts across the federal government and assesses the effectiveness of mitigation strategies—establish an investment strategy to identify, prioritize, and guide federal investments in disaster resilience and hazard mitigation-related activities and make recommendations to the President and Congress on how the nation should prioritize future disaster resilience investments. The Mitigation Framework Leadership Group agreed and issued the National Mitigation Investment Strategy in August 2019.[48]

[45]GAO-13-242.

[46]GAO-16-37.

[47]GAO-15-515.

[48]Department of Homeland Security, Mitigation Framework Leadership Group, *National Mitigation Investment Strategy*, (August 2019).

In September 2018, we reported that four near-sequential disasters in 2017—Hurricane Harvey, Hurricane Irma, Hurricane Maria, and the California wildfires—created an unprecedented demand for federal disaster response and recovery resources and that Hurricanes Harvey, Irma, and Maria ranked among the top five costliest hurricanes on record.[49] As of June 2018, Congress had appropriated over $120 billion in supplemental funding for response and recovery related to the 2017 hurricanes and wildfires.[50]

In October 2019, we issued a Disaster Resilience Framework that identifies federal actions and opportunities to enhance and promote disaster and climate change resilience nationwide focusing on three principles where the federal government can influence decision-making.[51] First, the framework states that federal action can help ensure that decision makers at all levels of government and across industrial sectors can access, understand, and use information on current and future disaster risk. As part of this, federal agencies can use risk reduction strategies, such as providing technical assistance to help decision makers use climate information in their infrastructure investment decisions. Second, the framework stated that federal agencies can help decision makers use risk reduction strategies and prioritize all types of risk. For example, federal agencies can ensure that federal programs and policies that support disaster risk reduction are well coordinated. Third, the framework stated that federal agencies can provide decision makers at all levels of government and across sectors with incentives to make long-term, forward-looking risk reduction investments and remove barriers to such investments.

[49]GAO, *2017 Hurricanes and Wildfires: Initial Observations on the Federal Response and Key Recovery Challenges*, GAO-18-472 (Washington, D.C.: Sept. 4, 2018).

[50]GAO-18-472.

[51]GAO-20-100SP.

Potential Climate Change Impacts Could Have Various Effects on Drinking Water and Wastewater Infrastructure, and the Type and Severity of the Effects Will Vary by Region

Projected increases in the frequency, severity, and duration of extreme temperature changes or precipitation events, as well as rising sea levels, are among the potential impacts of climate change that may affect drinking water and wastewater infrastructure. The type and severity of these potential impacts on drinking water and wastewater infrastructure will vary by region.

EPA, the USGCRP, NOAA, and other federal agencies have identified a variety of potential climate change impacts that may affect drinking water and wastewater infrastructure, as well as other critical and interconnected industries. EPA's *Adaptation Strategies Guide for Water Utilities* (*Guide*) identifies five general categories of climate change impacts that can affect drinking water and wastewater utilities: ecosystem changes, droughts, floods, water quality degradation, and changes in service demand and use.[52] Within these five general categories, EPA has identified specific climate change impacts that may affect drinking water and wastewater infrastructure systems. For example, degraded water quality from decreased stream flows may lead to higher treatment costs and the need for capital improvements to treat wastewater before discharging it from wastewater treatment facilities to meet more stringent regulatory requirements. Additionally, projected sea level rise can lead to saltwater intrusion in coastal groundwater aquifers and in estuaries. This may degrade water quality and increase treatment costs for drinking water treatment facilities or require new desalination facilities to treat water supplies with higher salt content.

According to the *Fourth National Climate Assessment*, compound extreme events—the combination of two or more hazard events or climate variables (e.g., extreme rainfall and storm surge) that occur simultaneously or consecutively that lead to an extreme impact—have a multiplying effect on the risk to drinking water and wastewater infrastructure systems. Compound extreme events can also increase the risk of cascading infrastructure failure since some infrastructure systems rely on others and the failure of one system can lead to the failure of interconnected systems.[53] This includes a water infrastructure system

[52]Environmental Protection Agency, *Climate Ready Water Utilities: Adaptation Strategies Guide for Water Utilities* (February 2015). According to the *Guide*, it contains adaptation options for drinking water and wastewater utilities based on region and projected climate impacts. In July 2019, EPA issued the *Resilient Strategies Guide for Water Utilities*, an updated online version of the *Guide*.

[53]Lall et al., *Fourth National Climate Assessment*, ch. 3.

relying on the energy sector for power to operate pump stations and drinking water and wastewater treatment facilities. For example, during Hurricane Sandy in 2012, extreme rainfall coincided with high tides creating a storm surge. Hurricane Sandy caused power outages and flooding at eight of New York City's 14 wastewater treatment facilities and 42 of the city's 96 pumping stations. Further, power outages and flooding of wastewater treatment facilities and the large influx of floodwater in the sewer system resulted in the release of approximately 562 million gallons of untreated and diluted sewage into local waterways, as shown in figure 1.

Figure 1: Sewage Overflow in Western Long Island South Shore Estuary from Bay Park Sewage Treatment Plant in East Rockaway, New York after Hurricane Sandy, 2012

Source: Doug Kuntz. | GAO-20-24

The *Fourth National Climate Assessment* states that drinking water and wastewater infrastructure in every region in the United States are sensitive to weather- and climate-related events and noted that the effects of such events will vary in severity and type by region, meaning different measures will be required to make infrastructure more resilient.[54] The *Fourth National Climate Assessment* established 10 climate regions to better address the risks and needs of specific regions across the

[54]Within each region, variations in magnitude of risk level from impacts on drinking water and wastewater infrastructure remain based on geographic factors, population and demand on a given utility, and age and condition of the infrastructure.

United States.[55] Further, EPA's *Guide* states that the type and severity of potential climate impacts on utilities will vary by region, and identifies the impacts that have the greatest likelihood of affecting utilities in the different regions and along the U.S. coast.

For example, in the Southwest, increased duration and intensity of drought may stress water supplies and increase water demand for agricultural uses, increase energy requirements to treat and cool drinking water and wastewater effluent, and require investments in new water sources and options for reusing water. In the Northwest, increased water temperatures, as well as wildfires that create increased nutrient runoff, may degrade drinking water quality from higher levels of harmful toxins and algal blooms, and require drinking water utilities to develop increased treatment capabilities.

The interactive map in figure 2 displays the 10 climate regions as established in the *Fourth National Climate Assessment* and the U.S. coasts, the most relevant potential climate change impacts for each region and the coast, and examples of the potential effects on drinking water and wastewater utilities, according to EPA's *Guide*.

[55]U.S. Global Change Research Program, *Fourth National Climate Assessment*.

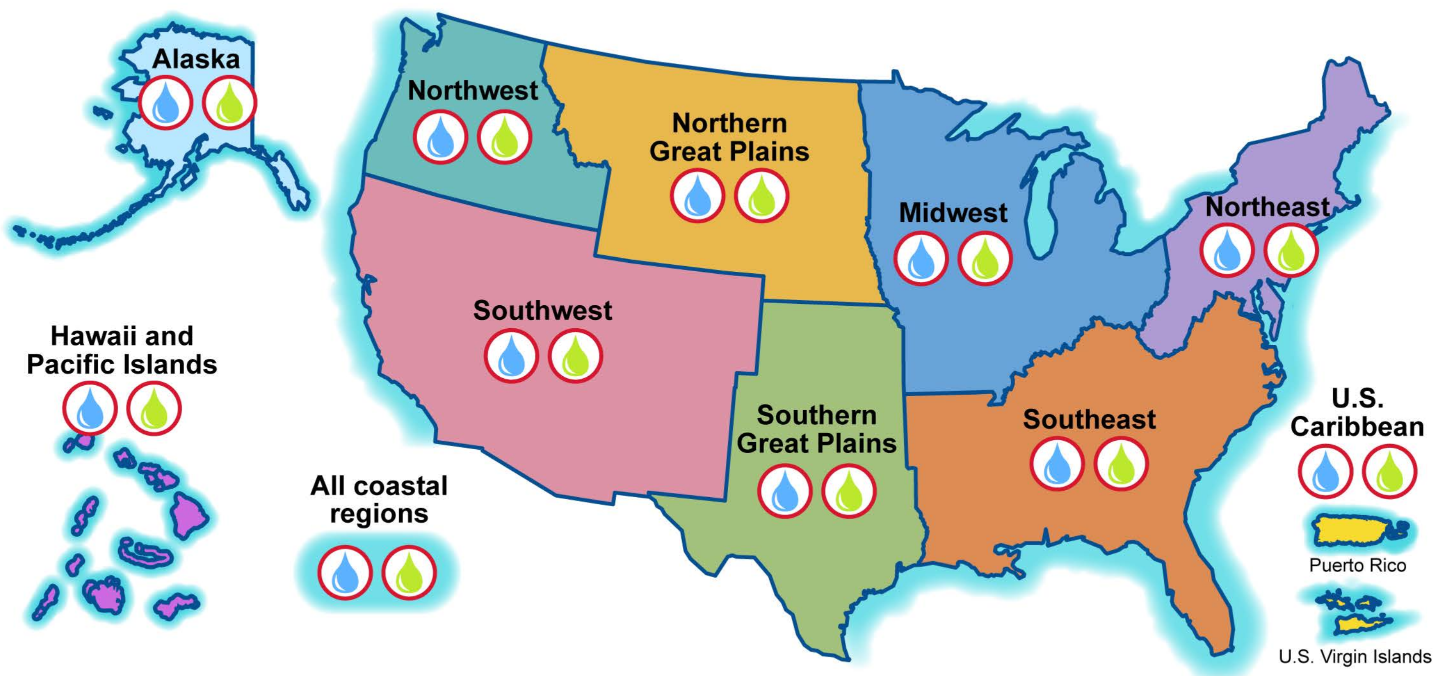
Interactive Graphic

Figure 2: Interactive Graphic of 10 Climate Regions and U.S. Coasts, Their Most Relevant Potential Climate Change Impacts, and Examples of Potential Effects on Drinking Water and Wastewater Utilities

Instructions: To read examples of potential climate change impacts and potential effects on utilities, hover cursor over these category icons within the region:

Drinking water | Wastewater

To print a version containing text, see appendix II, table 4, and appendix III, table 5.



Sources: Environmental Protection Agency and United States Global Change Research Program; Map Resources (map). | GAO-20-24

One Federal Program Is Designed to Provide Technical Assistance to Water Utilities for Climate Resilience, but Options Exist for Coordinating Additional Technical Assistance

One federal program—EPA's Creating Resilient Water Utilities initiative—is designed to provide technical assistance to drinking water and wastewater utilities for planning climate resilient infrastructure, although the 15 selected utilities used a mix of sources, including other federal programs, to obtain technical assistance with understanding climate impacts and designing resilient infrastructure. To provide additional technical assistance for climate resilience, selected experts generally supported the option of developing a coordinated network of technical assistance providers including federal and state agencies, universities, consultants, and industry groups.

EPA's Creating Resilient Water Utilities Initiative Is Designed to Provide Technical Assistance to Water Utilities for Climate Resilience

Our review of the programs federal agencies' used to provide technical assistance to 15 selected utilities to help make drinking water and wastewater infrastructure more climate resilient found that one program—EPA's Creating Resilient Water Utilities initiative (CRWU)—was specifically designed to provide drinking water, wastewater, and stormwater utilities with the practical tools, resources, training, and technical assistance needed to increase resilience to extreme weather events. The initiative provides web-based tools and resources in the form of an interactive guide, a case studies map, a risk assessment tool, climate scenario projection maps, and storm surge inundation maps to help drinking water and wastewater utilities understand potential long-term risks and options to enhance their resilience to climate impacts, including extreme weather events. Furthermore, CRWU provides direct utility technical assistance and training through workshops and onsite exercises with utilities. As part of the initiative, EPA developed the Climate Resilience Evaluation and Assessment Tool (CREAT), a web-based application to assist drinking water and wastewater utilities in understanding potential climate change impacts and assessing the related risks to their systems. EPA also developed a *Resilient Strategies Guide for Water Utilities*, a web-based interactive guide to help drinking water and wastewater utilities identify resilience strategies to prepare for droughts, protect water quality, build flood protections, preserve ecosystems, maintain service levels, improve energy efficiency, implement green infrastructure, and conserve water. In addition, from 2010 through 2013, EPA collaborated with the Water Research Foundation and NOAA to publish the results of a series of workshops assessing the information and tools necessary to incorporate climate risks into utility planning.

As part of a pilot program to help EPA develop CREAT, most of the drinking water and wastewater utilities we reviewed used CREAT to conduct climate risk assessments of their systems.[56] Utility representatives said the tool was a helpful starting point for thinking about potential climate risks and vulnerable infrastructure qualitatively. For example, Bozeman Water and Sewer (Bozeman, Montana) used CREAT to assess potential consequences of drought, water quality changes, and wildfires on their drinking water assets and operations to better understand their systems' vulnerabilities and start thinking about potential resilience measures. Keene Public Works (Keene, New Hampshire) also used CREAT to assess potential climate change impacts from extreme precipitation events on their water supplies and drinking water system and evaluate the performance and costs of additional short-term and long-term resilience measures. However, representatives from a few drinking water and wastewater utilities said they used additional assistance from consulting firms to help them use CREAT, and to complete assessments on the current and future climate risks to their infrastructure systems.

A few other federal agencies have been involved in efforts to help utilities incorporate climate resilience into their planning, but their programs were not specifically designed to provide technical assistance to water utilities. NOAA's Regional Integrated Science Assessments (RISA) program[57] and the National Center for Atmospheric Research (NCAR)[58] worked with

[56]EPA's CRWU initiative created a working group composed of representatives from drinking water and wastewater utilities, water sector associations (or industry groups), climate science experts, risk assessment experts, and federal partners to help develop CREAT.

[57]NOAA's RISA program supports research teams that help expand and build the nation's capacity to prepare for and adapt to climate variability and change. RISA teams work with public and private user communities to (1) advance understanding of context and risk; (2) support knowledge of action networks; (3) innovate services, products, and tools to enhance the use of science in decision-making; and (4) advance science policy.

[58]NCAR was founded in 1960 to provide the university atmospheric science community with world-class facilities and services. NCAR is managed by the University Corporation of Atmospheric Research, a nonprofit consortium of more than 115 colleges and universities, and receives its funding from the National Science Foundation. NCAR was created to provide the atmospheric research community in academia, government, and the private sector with the shared resources necessary to conduct their research.

utilities and EPA, through an effort called the Water Utility Climate Alliance which aims to enhance the quality and accessibility of regional climate change data to help improve water resource planning, develop adaptation strategies, and assist overall decision-making for water-related policies. The alliance, which was formed in 2007 and includes 12 of the nation's largest drinking water utilities, provides leadership and collaboration on climate change issues affecting the country's water agencies.[59] The alliance collaborates with member agencies, federal agencies, industry groups, academia, and consulting firms to provide workshops on planning for climate change uncertainty for drinking water and wastewater sector professionals.[60]

Representatives from the New York City Department of Environmental Protection (New York City, New York) and the San Diego County Water Authority (San Diego, California), stated that through their membership in the alliance, they have used technical assistance from NOAA's RISA program research teams and the Water Research Foundation to manage their climate risks. Specifically, in 2010, four Water Utility Climate Alliance members, including the New York Department of Environmental Protection (New York City, New York), contributed to a pilot project to better understand how climate change might affect their water systems through collaboration between climate experts and utilities, with the goal of improving the process of producing climate information utilities need for decision-making.[61] Two RISA research teams, the Consortium on Climate Risk in the Urban Northeast at Columbia University and the Pacific Northwest Climate Impacts Research Consortium at Oregon State University, provided technical assistance on climate information and

[59]Water Utility Climate Alliance members include: (1) Austin Water, (2) Central Arizona Project, (3) Denver Water, (4) Metropolitan Water District of Southern California, (5) New York City Department of Environmental Protection, (6) Philadelphia Water Department, (7) Portland Water Bureau, (8) San Diego County Water Authority, (9) San Francisco Public Utilities Commission, (10) Seattle Public Utilities, (11) Southern Nevada Water Authority, and (12) Tampa Bay Water.

[60]In 2018, NOAA's Climate Program Office provided additional funding and technical support for the training workshop.

[61]The four Water Utility Climate Alliance members contributing to the Piloting Utility Modeling Applications Project include the New York Department of Environmental Protection, Portland Water Bureau, Seattle Public Utilities, and Tampa Bay Water.

modeling to support the effort.[62] In 2013, three Water Utility Climate Alliance members, including the San Diego County Water Authority (San Diego, California), contributed to a research study to increase the adaptive capacity of water utilities in planning for and responding to pressures that may result from climate change, particularly related to the demand for water.[63] The Water Research Foundation led the study.

We found that other federal programs offer technical assistance, but the assistance is either not targeted to drinking water and wastewater utilities or it is not specific to climate impacts. For example, San Diego Public Utilities (San Diego, California) worked with the Bureau of Reclamation to assess the region's water supply and demand, determine the potential effects from climate change impacts within the region, and explore alternatives for addressing future water management challenges.[64] Utilities in Estes Park, Colorado and Iowa City, Iowa worked with FEMA after flood events to develop long-term recovery plans that made their river pipeline crossings stronger and moved a wastewater treatment plant from the floodplain, respectively. In addition, several of the selected utilities worked with NOAA or the U.S. Geological Survey to collect data necessary for planning efforts, including monitoring weather and storms, rainfall levels from stream gauges, and salt water intrusion into water supplies. Houston Water (Houston, Texas) also used NOAA's Atlas 14 Precipitation-Frequency Atlas to update its floodplain regulations and redefine the amount of rainfall it takes to qualify as a 100-year or 1,000-year flood event (see fig. 3 for pictures of flooded infrastructure).

[62]Stratus Consulting, Inc. (now Abt Associates), *Actionable Science in Practice: Co-producing Climate Change Information for Water Utility Vulnerability Assessments, Final Report of the Piloting Utility Modeling Applications (PUMA) Project* (Boulder, Colo.: Water Utility Climate Alliance, May 2015).

[63]The three Water Utility Climate Alliance members contributing to the research study included the Southern Nevada Water Authority, San Diego County Water Authority, and Tampa Bay Water.

[64]Bureau of Reclamation and San Diego Public Utilities Department, *San Diego Basin Study - Task 2.3 – Existing Structural and Operations Guidelines Response Analysis*. (San Diego, Calif.: August 2017).

Figure 3: Upper Thompson Sanitation District's 8-Inch Main Collapse during 2013 Flood and Houston Water's Flooded Wastewater Treatment Plant during Hurricane Harvey, 2017

Sources: Upper Thompson Sanitation District (left photo); Houston Water (right photo). | GAO-20-24

To date, federal efforts to provide technical assistance to help drinking water and wastewater utilities manage climate risks have been small-scale or pilot efforts to develop tools and information. For example, EPA's CRWU has developed a number of tools and guides for utilities and has provided training and assisted a number of utilities, but the number of utilities that EPA helped directly is small—about 50—and EPA does not have the resources to provide assistance to all utilities, according to EPA officials. Similarly, the Water Utility Climate Alliance's membership consists of 12 utilities in large metropolitan areas, and has focused on large utilities when developing examples of how drinking water utilities can plan for climate risks according to Water Utility Climate Alliance representatives; however, these alliance members are large enough to have in-house climate expertise and have established relationships with federal or university-based climate services providers. According to industry group officials, the majority of the 70,000 utilities across the country are small and do not have resources to work with consultants or research climate information.

While water utilities used federal technical assistance, we found that almost all of the selected drinking water and wastewater utilities, regardless of size, used a mix of technical assistance providers including consultants, industry groups, academia, or federal programs to help them plan for resilience projects, as shown in appendix IV. Most of the selected utilities said they used a mix of assistance because they needed help understanding what climate information and climate models were appropriate to use for their regions and locales. For example, Anacortes Public Works (Anacortes, Washington) worked with the Skagit Climate Science Consortium—a nonprofit organization—to conduct a climate risk assessment for their drinking water system.[65] Anacortes Public Works used the initial climate risk assessment to implement projects that will increase their resilience to the most significant effects from climate-related impacts, flooding, and increased sediment levels in their water supply (see fig. 4). Anacortes Public Works plans to work with the consortium again to better understand how rising sea levels and increasing salinity levels will affect their drinking water supply in the future. A few utilities said that technical assistance efforts should be a collaborative process between the utilities using climate information to make decisions and the scientists providing the technical assistance to ensure that climate information and models are what drinking water and wastewater utilities need to plan for climate resilience.

[65]The Skagit Climate Science Consortium is a nonprofit organization consisting of scientists working with local people to assess, plan, and adapt to climate-related impacts. To support Skagit communities as they adapt to climate change, the consortium (1) fosters collaborative scientific research to understand the diverse and interrelated impacts of climate change from the Skagit headwaters to Puget Sound, (2) produces relevant climate-related products closely integrated with the Skagit community's needs and concerns, and (3) serves as a conduit between Skagit communities and consortium scientists to assist in developing adaptation strategies.

Figure 4: New Waterproof Drinking Water Treatment Plant, City of Anacortes Public Works

Source: Anacortes Public Works. | GAO-20-24

Selected Experts Stated That Additional Technical Assistance and a Network of Technical Assistance Providers Could Help Utilities Enhance Climate Resilience

All 10 of the selected experts we interviewed said that drinking water and wastewater utilities need additional technical assistance to manage climate risks. Specifically, these experts stated that utilities need technical assistance to use key climate information to incorporate climate resilience into their planning and operations. This information includes the following:

- forward-looking climate information and models to identify vulnerabilities to specific geographic regions;
- potential climate change impacts on regional and local socioeconomic and demographic trends for utility users;
- hydrologic information on the movement, distribution, and quality of water at the local, regional, and/or watershed level; and
- estimates of benefits and costs of incorporating resilience into utility projects.

According to several of the selected experts we interviewed, such information is provided through a mix of sources, depending on what is available, and all sources are needed. Several selected experts also said that the utilities could obtain forward-looking climate information and models from federal agencies, such as NOAA, and could obtain information on potential climate change impacts from CREAT. In addition, several experts stated that they could obtain local socioeconomic and demographic data, hydrologic information, and benefit-cost information from industry sources, universities, and consultants.

Several of the experts we interviewed also said that such assistance is not a one-time event, but requires consistent and continuous collaborative efforts between utilities and technical assistance providers. For example, several experts said that utilities need technical assistance on an ongoing basis to reevaluate their planning and operations regularly given the uncertainty associated with the severity of some potential climate risks. In addition, several experts said that individual utilities need help understanding which climate information and analytical tools are appropriate for assessing the climate risks specific to their regions or localities, and how to use them to manage climate risks to their infrastructure. Almost all of the experts said that small and rural utilities would need additional technical assistance to collect and use the information necessary to enhance their resilience to climate change impacts. Specifically, several experts said that, as opposed to many large utilities, small utilities lack the technical capacity to use climate information and do not have the financial resources to hire consultants or develop the internal expertise necessary to manage climate risks to their drinking water and wastewater infrastructure.

Further, most of the selected experts we interviewed stated that a network of providers would be needed to provide assistance to water utilities. This is consistent with what we and others have previously reported. For example, we reported in November 2015 that clearly organized technical assistance would improve federal climate information efforts by helping different types of decision makers—ranging from those who can define their needs to those who have limited experience using climate information—access, translate, and use climate information.[66] We also found that key stakeholders and relevant studies generally called for a system of nonfederal technical assistance providers, with federal leadership to help federal, state, and local decision makers, including utility decision makers, use climate information. In addition, a 2014 task force of state, local, and tribal leaders stated that the greatest need for enhancing climate resilience is often not the creation of new data or information, but assistance and tools for decision makers, including utility managers, in navigating the wide array of resources already available.[67]

[66] GAO-16-37.

[67] State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience, *Recommendations to the President* (Washington, D.C: Nov. 17, 2014).

Further, in August 2019, the National Mitigation Investment Strategy recommended that the federal government increase investment in hazard mitigation by building the capacity of communities to address their risks, including climate-related risks.[68] To implement the recommendation, the strategy said that the federal government should create a professional network to encourage collaboration and information sharing across different levels of government and the water and wastewater sector, and that the federal government and its nonfederal partners should work together to develop a pool of skilled mitigation professionals.

The following is a list of options for providing a network of technical assistance providers that selected experts we interviewed discussed, as well as the advantages and disadvantages of each.

- **Existing utility technical assistance providers.** A strengthened and expanded network of existing federal technical assistance providers, including EPA's Environmental Finance Centers, USDA's Rural Utilities Service, the National Rural Water Association, and the Rural Community Assistance Partnership, could help consolidate climate information and provide technical assistance to utilities to improve their resilience. Most experts said that a network of existing utility technical assistance providers would have the advantage of established relationships with communities and utilities or could ensure that small and rural utilities obtain needed information and assistance to improve their resilience to climate change. However, several experts said that the network may lack the expertise necessary to effectively identify or develop climate information and planning tools to provide the technical assistance necessary to meet the specific needs of utilities to improve their resilience. See appendix V for additional information on these programs.
- **Existing federal climate services providers.** A strengthened and expanded network of existing federal climate services providers, such as USDA's Climate Hubs, Interior's Landscape Conservation Cooperatives, Interior's Climate Science Centers, and NOAA's RISA program could provide technical assistance to utilities to improve their resilience. Several experts said that a network of existing federal climate services providers would have a good understanding of the available climate information and would, for example, be best positioned to develop the specific tools and guidance necessary to

[68]Department of Homeland Security, Mitigation Framework Leadership Group, *National Mitigation Investment Strategy*.

provide the technical assistance utilities need to improve their resilience. In contrast, several experts said that federal climate services providers may not have the established relationships with utilities necessary to understand and tailor technical assistance to the needs of individual utilities. In addition, one expert said that the climate services providers may not have the funding to provide these services to utilities in a comprehensive way. See appendix V for additional information on these programs.

- **Universities and university-based research centers.** A new network of academic or university-based technical assistance providers, such as NCAR, organized by state, region, or watershed could provide technical assistance to all types of utilities to improve their resilience. According to several experts, this option would be advantageous because many universities and centers already have the technical capacity to use climate information to provide risk assessment and planning tools necessary to provide technical assistance to utilities at the local or regional level. Several experts also said that it would be cost-effective to expand this option because some universities and centers are already providing technical assistance. However, several experts said that without a clear shift in federal incentives to prioritize the applied research necessary to provide the technical assistance that utilities need, universities and centers are unlikely to provide sustained assistance nationwide. Similarly, several experts said that federal coordination would be needed to ensure that the universities and centers were consistently providing information, planning tools, and assistance that meet the specific needs of utilities. See appendix V for additional information on these programs.
- **Industry groups and private-engineering consultants.** A new network of nonfederal industry and nonprofit groups, such as the American Water Works Association and the Association of Municipal Water Utilities, could provide technical assistance to utilities to improve their resilience. Several experts said that this option would be advantageous because it could leverage existing relationships, for example, to strengthen information sharing between utilities regarding the best available climate information and approaches to resilience planning. In addition, several experts said that industry groups and private engineering consultants would have a better understanding of utility operations and management when compared to other options for providing technical assistance. In contrast, half of the experts said that this network would need additional federal oversight and coordination. For example, several experts said that there would need to be a certification process for industry groups and private

consultants to ensure that the technical assistance being provided to utilities was sufficient and transparent. In addition, several experts said that the network would not be effective unless it was coordinated among stakeholders from, for example, the private sector; industry groups; and federal, state, and local governments.

- **A network of utilities.** A network of utilities, similar to the Water Utility Climate Alliance, could consolidate and update information and provide technical assistance for all types of utilities to improve their resilience. Similar to a network of industry groups and consultants, several experts said a network of utilities could help coordinate and strengthen information sharing between utilities on best practices and lessons learned from resilience planning. However, several other experts said that it would be difficult to develop and expand a network of utilities that was capable of providing technical assistance to utilities of different sizes or geographic locations. One expert also said that utilities that provide technical assistance would need to be certified by the federal government, academics, or industry groups to ensure the technical assistance being provided to utilities was sufficient.

When asked how they would design a network to provide technical assistance, most experts supported an approach in which federal agencies organized a network of technical assistance providers for drinking water and wastewater utilities, a network that would include federal and state agencies, universities, consultants, and industry groups. For example, one expert said that EPA and other relevant federal agencies could provide guidance and leadership for a network of (1) university and federal climate services providers that would assess the risks that potential climate impacts pose to utilities and (2) utility technical assistance providers, including consultants and industry groups, to help utilities apply those assessments to their infrastructure to make it more resilient.

Another expert said that existing networks of universities, industry groups and consultants, or utilities would not be as effective unless they were part of a larger networked effort with clear leadership that provides continuous technical assistance to utilities. Similarly, several experts stated that it was important that the network be a collaboration of different technical assistance providers to be able to tailor the technical assistance to the needs of different types of utilities, in different locations, with differing technical capabilities. For example, one expert said that universities, industry groups, and federal programs have different levels of resources and expertise in different regions of the country and a coordinated network could help utilities identify the sources of technical assistance in their regions or localities. Further, another expert said that it was important that the network have the capability to help utilities understand and respond to climate risks that other types of infrastructure create. Specifically, the expert said that while EPA has a role in regulating drinking water and wastewater infrastructure, the agency does not regulate larger-scale infrastructure, such as dams and reservoirs that need to be operational to reduce risks to utilities.[69]

Under Presidential Policy Directive 21, EPA, as the Sector Specific Agency for the water and wastewater systems sector, is to work to enable efficient information exchange between federal agencies and infrastructure owners and operators, and to implement an integration and analysis function to inform planning and operational decisions regarding critical infrastructure.[70] In addition, one of the key activities of the Water Sector Government Coordinating Council, which EPA chairs, is to facilitate information sharing between federal, state, and local decision makers on critical infrastructure protection.[71] This is consistent with our disaster resilience framework, which states that federal efforts should improve the availability of authoritative, understandable, and comprehensive information on disaster risks and risk reduction strategies to help entities effectively assess their climate risks, determine what viable alternatives are available to increase resilience to those risks, and better understand and measure the impact of resilience strategies.[72] Our framework also states that federal efforts can help by providing technical assistance and capacity building to nonfederal partners.

[69]Federal agencies, including the U.S. Army Corps of Engineers, the Bureau of Reclamation, and the Federal Energy Regulatory Council, manage and regulate large-scale infrastructure, such as dams and reservoirs.

[70]See Presidential Policy Directive 21, 2013. According to the Directive, critical infrastructure must be secure and able to withstand and rapidly recover from all hazards. Three strategic imperatives are to drive the federal approach to strengthen critical infrastructure security and resilience: (1) refine and clarify functional relationships across the federal government to strengthen critical infrastructure security and resilience; (2) enable effective information exchange by identifying baseline data and systems requirements for the federal government; and (3) implement an integration and analysis function to inform planning and operations decisions regarding critical infrastructure. For each sector, a designated Sector-Specific Agency is to carry out certain specified roles and responsibilities, such as coordination of sector-specific activities.

[71]Environmental Protection Agency, *Water Sector Government Coordinating Council Charter*. (Washington, D.C.: November 2014).

[72]GAO-20-100SP.

To date, however, federal efforts to provide technical assistance to drinking water and wastewater utilities do not provide the ongoing technical assistance that according to experts utilities need to plan and build climate resilient infrastructure. In addition, current efforts may not be widespread enough to provide comprehensive coverage of the drinking water and wastewater utilities across the nation. The 2017 Roadmap shows actions for the short term (2 years) and midterm (5 years), but it does not include actions such as developing guidance on technical assistance, building networks of technical assistance providers, or developing other methods to help utilities build capacity to manage their climate change risks and plan for resilient infrastructure.[73] According to EPA officials we interviewed, the agency has worked within its existing authorities and available resources to prioritize developing voluntary guidance, tools, training, and webinars that utilities can use to identify potential risks from climate change and plan to improve their resilience. Further, EPA officials said that while the agency has collaborated closely with key federal, state, and local decision makers; industry groups; and utilities in its role as chair of the Water Sector Government Coordinating Council, the council has focused on other short-term threats to utilities, such as disasters and terrorism, and has not assessed how it could develop and coordinate a network to effectively provide the technical assistance that utilities need to enhance their climate resilience. By identifying and engaging existing technical assistance providers in a network to help drinking water and wastewater utilities incorporate climate resilience into their projects and planning on an ongoing basis, EPA would have more reasonable assurance that climate information was effectively exchanged among federal agencies and infrastructure owners and operators.

Supporting the need for a broader collaborative approach, several of the selected utilities are already members of organizations that coordinate and collaborate among members and various technical assistance providers, including federal agencies, to understand the potential climate impacts for their regions, use similar climate models, and share best practices for projects to enhance climate resilience. For example, the Southeast Florida Regional Climate Change Compact is a decade-old partnership between Miami-Dade, Broward, Monroe, and Palm Beach Counties to coordinate mitigation and adaptation activities across county

[73]Water and Wastewater Sector Strategic Roadmap Work Group, *Roadmap to a Secure and Resilient Water and Wastewater Sector*.

lines in response to the effects of climate change, including sea level rise, flooding, and economic and social disruptions.[74] The compact and its partners work with various federal, state, regional, municipal, nonprofit, academic, and private sector partners to provide technical assistance and support for utilities in southeast Florida to help the region identify emerging issues and all move in one direction for resilience planning efforts. The supporting federal agencies include NOAA, EPA, and the Army Corps of Engineers. Another example is Charleston Water (Charleston, South Carolina), a member of the Charleston Resilience Network—a collaborative group of public, private, and nonprofit organizations in the region that work to increase resilience of communities, critical infrastructure, and the economy to natural disasters and chronic coastal hazards, such as rising sea levels. The network provides a forum to share science-based information, educate stakeholders, and enhance long-term resilience planning decisions. The network also works to provide consistent information for planning decisions. The federal agencies that advise the Charleston Resilience Network include NOAA, DHS, and the Army Corps of Engineers.

The Federal Agencies Do Not Consistently Provide Financial Assistance for Projects That Could Enhance Climate Change Resilience and Limit Future Fiscal Exposure

The four selected federal agencies in our review provide broad financial assistance to help drinking water and wastewater utilities plan and build infrastructure projects. The agencies have taken some actions to promote climate resilience when providing financial assistance for water infrastructure projects, but they do not consistently include the consideration of climate resilience when funding such projects. Most selected experts we interviewed suggested that requiring the consideration of climate change risks in the planning and design of all federally funded water and wastewater infrastructure projects could help enhance climate resilience and limit future federal fiscal exposure.

[74]Each county, through its adoption of the compact, committed to work cooperatively and dedicate staff and resources to the creation and implementation of the Regional Climate Action Plan. Miami-Dade Water and Sewer, as a county utility, is actively implementing these recommendations and supporting compact efforts.

Four Federal Agencies Provide Financial Assistance for Projects But Do Not Consider Climate Resilience Consistently

The four federal agencies we reviewed have nine programs that provide broad financial assistance, through loans or grants, for drinking water and wastewater infrastructure (see table 1). However, federal programs generally do not have selection criteria or requirements for utilities to incorporate climate resilience in the planning and design of projects that receive federal financial assistance.

Table 1: Federal Programs GAO Reviewed That Fund Drinking Water and Wastewater Infrastructure

Agency	Program	Type of funding	Eligible projects
Environmental Protection Agency	Clean Water State Revolving Fund	Loans	Wastewater infrastructure
	Drinking Water State Revolving Fund	Loans	Drinking water infrastructure
	Water Infrastructure Finance and Innovation Act Program	Loans	Drinking water and wastewater infrastructure
Department of Homeland Security's Federal Emergency Management Agency	Hazard Mitigation Grant Program	Grants	Hazard mitigation and resilience
	Pre-Disaster Mitigation Grant Program	Grants	Hazard mitigation and resilience
	Public Assistance Grant Program	Grants	Disaster recovery
Department of Housing and Urban Development	Community Development Block Grant Program	Grants	Community development needs
	Community Development Block Grant-Disaster Recovery Fund	Grants	Community development needs related to disaster recovery
US Department of Agriculture's Rural Utilities Service	Water and Waste Disposal Program	Grants and loans	Drinking water and wastewater infrastructure

Source: GAO analysis of agency documents | GAO-20-24

Each of the programs used different selection criteria for providing financial assistance to drinking water and wastewater utilities. EPA's Drinking Water State Revolving Fund, Clean Water State Revolving Fund, and Water Infrastructure Finance and Innovation Act (WIFIA) programs generally provide financial assistance to projects that address the most serious risks to human health and ensure compliance with the Safe Drinking Water Act or Clean Water Act.[75] Other programs, such as

[75]Congress enacted the WIFIA program as part of the Water Resources Reform and Development Act of 2014. Pub. L. No. 113-121, §§ 5022-5035, 128 Stat. 1193, 1332 (codified as amended at 33 U.S.C. §§ 3901-3914). An EPA administered federal credit program, the WIFIA program accelerates investment in water and wastewater infrastructure of national and regional significance by offering creditworthy borrowers secured (direct) loans and loan guarantees for up to 49 percent of eligible project costs.

FEMA's Public Assistance and Hazard Mitigation Grant programs provide financial assistance to repair or replace infrastructure damaged during natural disasters, or to enhance disaster resilience against future damage. HUD's Community Development Block Grant-Disaster Recovery funding is used for, among other things, projects to help cities, communities, and states recover from presidentially-declared disasters or enhance disaster resilience of damaged infrastructure, especially in low-income areas. USDA provides financial assistance for drinking water and wastewater infrastructure in small and rural communities. According to EPA, FEMA, HUD, and USDA officials we interviewed, drinking water and wastewater utilities can use financial assistance from their programs to pay for projects that, in addition to other benefits, can help enhance climate resilience.

We have previously reported that the federal government invests billions of dollars annually in infrastructure—such as roads, bridges, and wastewater infrastructure—but faces increasing risks from climate change.[76] When the climate changes, infrastructure—typically designed to operate within past climate conditions—may not operate as well or for as long as planned, leading to economic, environmental, and social impacts. We have also reported that some federal agencies have made efforts to manage climate change risk within existing programs and operations—a concept known as mainstreaming—and these efforts may convey some climate resilience benefits.[77] For example, an agency planning to build a seawall to protect a coastal facility might build it higher to account for rising sea level projections, but may not track this spending as related to climate change.

Representatives of several of the drinking water and wastewater utilities we reviewed reported using selected federal financial assistance programs to help fund projects for fiscal years 2011 through 2018 that, in addition to other benefits, enhanced their climate resilience. For example, Iowa City Public Works used financial assistance from HUD Community Development Block Grant-Disaster Recovery funding and FEMA's Public Assistance grant program to increase their resilience to floods by relocating a flood-prone wastewater treatment facility after flooding in 2008, as shown in figure 5.

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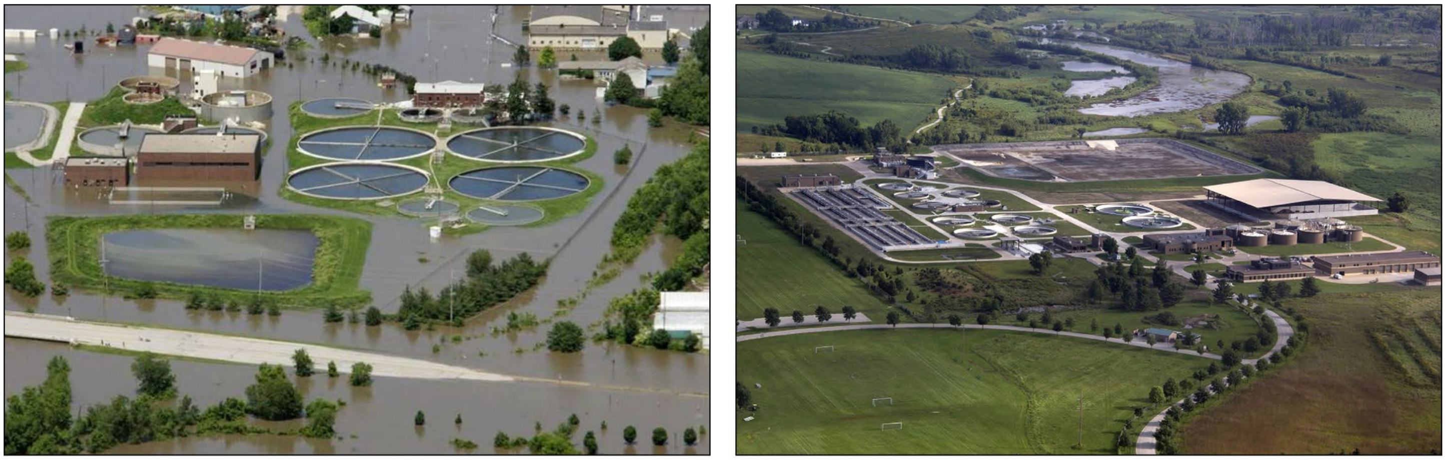
[76]GAO-13-242.

[77]GAO, *Climate Resilience: A Strategic Investment Approach for High-Priority Projects Could Help Target Federal Resources*, GAO-20-127 (Washington, D.C.: Oct. 23rd, 2019).

Figure 5: Relocation of Iowa City’s North Wastewater Treatment Facility Because of 2008 Flooding



Source: Iowa City Public Works. | GAO-20-24

Similarly, as of December 2018, Houston Water was working with FEMA to use Public Assistance grants and Hazard Mitigation grants to increase the utility’s resilience to floods and extreme storm events when rebuilding the wastewater infrastructure damaged by Hurricane Harvey in 2017, according to Houston Water representatives. In addition, the San Diego Public Utilities Department received an EPA WIFIA loan to increase its resilience to droughts by building a new recycled wastewater treatment facility that will provide an additional source of drinking water and reduce the need for water imported from the Colorado River Basin (see app. VI for details on completed and ongoing infrastructure projects that utilities undertook to enhance their climate resilience, according to selected drinking water and wastewater utility representatives).

The remaining selected utilities relied on other sources of funding such as municipal bonds and funds raised primarily through user rates and fees for fiscal years 2011 through 2018 to enhance their climate resilience (see app. VII for details on the financial assistance drinking water and wastewater utilities used for infrastructure projects). However, making the nation’s drinking water and wastewater infrastructure resilient will be expensive, costing anywhere from $448 billion to $944 billion, including operations and maintenance through 2050, according to a 2009 Association of Metropolitan Water Agencies study, the most recent such study.[78] These costs would likely be in addition to the EPA-estimated $774 billion in costs for replacing and repairing existing infrastructure over the next 20 years. According to representatives of several of the selected utilities in our review, additional financial assistance will be necessary to enhance the resilience of drinking water and wastewater infrastructure. Representatives from several utilities said they would not be able to make the necessary upgrades to incorporate climate resilience into their drinking water or wastewater systems without additional grant assistance. Based on estimates from one of the selected utilities, the costs to enhance their resilience will be high. For example, in 2013, the New York Department of Environmental Protection estimated that it would cost about $315 million to build the protective measures necessary to make its wastewater treatment facilities and pump stations resilient to future flood projections.

Officials from EPA, FEMA, HUD, and USDA said that federal agencies have taken action to change program requirements or selection criteria to provide financial assistance for projects that enhance climate resilience. However, according to federal officials, some federal agencies are providing financial assistance to utilities for projects that do not consider climate resilience in their planning and design consistently. In addition, federal officials stated that their ability to require that climate resilience be incorporated in the projects they fund is limited by requirements specific to their programs. Examples of their efforts, and limited authorities, include the following:

- **EPA.** EPA provides annual grants to states to capitalize their state-level drinking water and wastewater state revolving fund programs. The states use the revolving funds to provide low-cost loans or other financial assistance to communities for, among other things, a wide range of drinking water and wastewater infrastructure projects. According to EPA officials, states establish program criteria and do not consider climate resilience consistently in planning and designing projects that receive financial assistance from state revolving fund programs. Specifically, EPA officials said that despite agency efforts to promote climate resilience, states have discretion in setting project funding criteria and priorities for their state revolving fund programs, and that the agency does not have the authority to require that states prioritize projects that incorporate climate resilience. EPA continued to encourage the states to incorporate resilience planning in their priority

[78]CH2M Hill, Inc., *Confronting Climate Change*.

systems. In documents released in May 2016, September 2016, and June 2017, the EPA described the types of climate resilience projects eligible for drinking water and clean water state revolving fund assistance. The September 2016 document also describes how programs can encourage resilient infrastructure through financial incentives.[79] According to fiscal year 2015 data that EPA provided, 17 state clean water revolving fund programs have created additional financial incentives that utilities could use to fund climate resilience projects, and only New York's program requires that climate risks from sea level rise be incorporated into the projects that receive financial assistance.[80] In addition, utilities have discretion in whether to incorporate climate resilience into their state revolving fund project applications, and EPA cannot require utilities to incorporate climate resilience into the planning and construction of projects that states fund, according to EPA officials. Similarly, while EPA manages the WIFIA program and its application process and criteria, EPA officials said that the 2018 and 2019 program guidance did not prioritize protection against the impacts of climate change in its selection criteria, and that the agency does not require that applicants incorporate climate resilience into project planning and design.

- **FEMA.** FEMA's Public Assistance Grant Program provides grants to state, tribal, territorial, and local governments, and nonprofits that can be used to repair and replace damaged infrastructure, including drinking water and wastewater infrastructure. In addition, FEMA's Pre-Disaster Mitigation and Hazard Mitigation Grant Programs can provide financial assistance to states, communities, or tribes that can be used to reduce the risks to drinking water and wastewater infrastructure from future disasters. FEMA officials said they have developed guidance for states and communities to incorporate climate resilience into the planning for projects funded by all three programs.[81] However, officials said that states and utilities do not consider climate

[79]EPA, *Overview of Clean Water State Revolving Fund Eligibilities*. (Washington, D.C., May 2016); EPA, Fact Sheet on CWSRF Resiliency Funding Eligibility. Washington, D.C.: September 2016); and EPA, *Drinking Water State Revolving Fund Eligibility Handbook*. (Washington, D.C., June 2017).

[80]According to EPA officials, while not all states offer financial incentives for these types of projects, many projects funded by the state revolving funds have resiliency components embedded within them.

[81]The Disaster Recovery Reform Act of 2018 (DRRA) authorized a new program to fund Pre-Disaster Hazard Mitigation. Pub. L. No. 115-254, 132 Stat. 3462 Div. D, § 1234 (2018).

change resilience consistently in planning and designing of projects that use financial assistance from FEMA. Specifically, according to FEMA officials, funding through the Public Assistance Program and the Hazard Mitigation Grant Program is limited to states and localities with a presidentially-declared disaster and generally is not provided for projects that incorporate climate resilience into their planning and design.[82] In addition, according to FEMA officials, states and localities have discretion over the projects they choose to submit for funding and FEMA cannot require them to incorporate climate resilience into the planning and construction of projects that states fund without a change to program requirements.

- **HUD.** HUD provides grants to states and local governments through its Community Development Block Grant program to fund housing; economic development; neighborhood revitalization; and other community development activities, including drinking water and wastewater infrastructure.[83] In addition, HUD can provide grants that can be used for reconstruction of drinking water and wastewater infrastructure to help communities recover from presidentially declared disasters through its Community Development Block Grant program. According to HUD officials, the agency has taken action to encourage states and local governments to incorporate climate resilience planning in the projects they fund after disasters. Officials also said that HUD provides guidance on how financial assistance requirements for states and entitlement communities can be waived so that states and communities can use Community Development Block Grant funding for disaster recovery and resilience in presidentially-declared disaster areas. In addition, in 2016, HUD finalized rules requiring states and localities to consider incorporating

[82]DRRA could improve state and local resilience to disasters, according to FEMA officials. DRRA, among other things, authorizes the President to set aside, with respect to each major disaster, a percentage of the estimated aggregate amount of certain grants to use for predisaster hazard mitigation and makes federal assistance available to state and local governments for building code administration and enforcement. Pub. L. No. 115-254, Div. D, §§ 1206(a)(3), 1234(a).

[83]The annual appropriation for the block grants is allocated according to formulas so that after setting aside specified amounts for Indian tribes, insular areas, and special purposes, 70 percent is allocated among participating metropolitan cities and urban counties (entitlement communities) and 30 percent is allocated among the states to serve nonentitlement communities, generally cities and towns with populations fewer than 50,000 and counties with fewer than 200,000 persons. In addition, federal law requires that not less than 70 percent of the total Community Development Block Grant funding be used for activities that benefit low- and moderate-income persons. *See* 42 U.S.C. §§ 5306, 5308.

resilience to natural hazard risks and climate change into their planning documents for Community Development Block Grant funding in low- and moderate-income communities.[84] However, officials said that states do not consider climate change resilience consistently when planning and designing projects using financial assistance from HUD. Specifically, according to HUD officials, the agency can only directly provide financial assistance to projects that enhance climate resilience using Community Development Block Grant-Disaster Recovery Grants if climate change resilience is specified in disaster relief appropriations language. Further, states and localities have discretion regarding whether to incorporate climate resilience into their project applications, and HUD cannot require them to incorporate climate resilience into the planning of projects that receive financial assistance, according to HUD officials.

- **USDA.** USDA's Rural Utilities Service provides grants and loans for drinking water, wastewater, and stormwater projects in rural areas—defined as any area not in a city or town with a population in excess of 10,000 inhabitants. According to USDA officials, the agency has promoted climate resilience planning through its Water and Waste Disposal Program by requiring small and rural utilities to complete planning and vulnerability assessments for natural disasters.[85] In addition, USDA officials said the agency has collaborated with EPA to develop guidance and training through the Sustainable Rural and Small Utility Management Initiative to help small and rural utilities create plans for improving their sustainability, including planning to help make the utilities resilient to potential climate impacts. According to USDA officials, utilities have discretion in whether to incorporate climate resilience into their Water and Waste Disposal project applications, and USDA cannot under its current regulations require them to incorporate climate resilience into the planning and construction of projects that receive financial assistance. As a result, according to officials, utilities do not consider climate resilience consistently when planning and designing projects that receive financial assistance from USDA.

[84]*See* 81 Fed. Reg. 90,997 (Dec. 16, 2016).

[85]For example, the USDA implements the floodplain management provision of 7 CFR Part 1970, which encompasses climate resiliency for flood risks by requiring that proposals for water and waste disposal systems located in a 100-year floodplain, 500-year floodplain, or floodway to evaluate alternatives to locating the project in the floodplain and floodway. If other alternatives do not exist, then applicants must adopt mitigation for flood risks.

Most Selected Experts Said That Requiring Climate Resilience in Federal Projects Would Help Address Future Climate Impacts and Limit Future Federal Fiscal Exposure

According to most selected experts, requiring the consideration of climate risks in projects that receive financial assistance will help limit the future fiscal exposure of the federal government and help enhance the climate resilience of drinking water and wastewater infrastructure. Specifically, most of the experts we interviewed said that a federal requirement that potential climate impacts be considered and, if necessary, incorporated into the design of all new drinking water and wastewater infrastructure projects that receive federal financial assistance, should be a high or very high priority for the federal government. Several of the experts said that this option would be advantageous because it could help ensure more effective and efficient use of federal dollars on drinking water and wastewater infrastructure. For example, several experts said that this option would help ensure that infrastructure funded by the federal government incorporated climate risks during the planning stages, helping avoid expensive retrofits or the abandonment of federally funded infrastructure that was not climate resilient. Several other experts said that such a federal requirement could help make consideration of future climate risks to enhance resilience a standard industry practice within the drinking water and wastewater sector.[86]

Several of the selected utilities said that a federal requirement for potential climate impacts to be considered and, if necessary, incorporated into the design of all new drinking water and wastewater infrastructure projects that receive federal financial assistance, would be moderately to extremely effective in helping utilities enhance their resilience. These selected utilities also said that it would be at least moderately feasible to implement. Several of the selected utilities are already required to consider some potential climate risks in the planning and design of their drinking water and wastewater infrastructure. For example, according to

[86]Selected experts discussed the advantages and disadvantages of other options to incentivize climate change resilience among drinking water and wastewater utilities but did not agree on them. Several selected experts said that including criteria in existing funding programs to invest in projects that incorporate climate resilience into their planning could ensure that climate resilience planning and projects are fundable by a large number of federal programs. However, several other experts said that differences in application requirements may make this option difficult to implement across the large number of federal programs and may create confusion for applicants. Several other selected experts said that creating a new federal funding program to incorporate climate resilience into water utility planning could fund resilience projects independent of other federal programs. However, several selected experts said that such an option could be difficult to implement and could be inefficient given the large number of funding programs that already exist, placing additional burdens on utilities to meet the selection criteria and application requirements of a new program.

representatives from the Miami-Dade County Water and Sewer Department, Miami-Dade County adopted an ordinance requiring that potential climate risks be considered in the design of county-funded infrastructure. According to the same officials, this requirement has shifted the culture of the Miami-Dade County Water and Sewer Department to emphasize potential future climate change risks in the planning and design of all of the county's drinking water and wastewater infrastructure. Representatives from a few selected utilities also said that a requirement could make it easier to access federal financial assistance programs for projects that enhance climate resilience.

Several selected experts cautioned that many utilities do not have the climate information and technical capacity to carry out such requirements or that the uncertainty of the available climate science would make it difficult to implement for some utilities. In addition, several experts said that such a requirement may force utilities with limited funding to prioritize planning and investment in projects to improve climate resilience over more pressing concerns, such as repairing and replacing damaged or obsolete infrastructure. Several selected utilities said that it will be difficult to implement these new requirements, but added that additional technical and financial assistance could help. For example, representatives from Cottage Grove Public Utilities said that the federal government will need to provide additional financial and technical assistance opportunities for small and medium-sized public utilities that do not have the capacity to plan, implement, and fund large climate resilience projects.

However, if the federal agencies do not require the incorporation of climate resilience into the projects that receive financial assistance, they may continue to fund drinking water and wastewater infrastructure projects that may be damaged or incapacitated by future floods, drought, water quality problems, and other climate change impacts. This increases the risk that critical infrastructure will not be well protected and drinking water and wastewater utilities will not be able to continue operations that provide critical public health and environmental services to the public.

EPA and other federal, state, local, and sector-level officials, recognizing the need to incorporate climate resilience into drinking water and wastewater infrastructure, have taken action to promote climate resilience but generally do not require it to be incorporated in these projects. Specifically, the 2017 Roadmap calls for the Water Government Coordinating Council and the Water Sector Coordinating Council to promote eligibility criteria for financial assistance programs to support resilience activities by 2019.[87] In addition, in a 2019 report, EPA's Environmental Finance Advisory Board recommended that EPA create a coordination group to set priorities and reduce gaps in funding predisaster resilience for drinking water and wastewater infrastructure, and that EPA consider expanding the state revolving fund program to include financial assistance for flooding and storm-related damages. Further, the National Mitigation Investment Strategy, issued in draft in January 2018, and finalized in August 2019, states that successful mitigation of natural hazard risks requires shared priorities, consistent approaches, aligned funding, expanded incentives, and coordination between the federal government and nonfederal partners.[88] It also states that the federal government and nonfederal partners should look at risk and resilience consistently by, for example, having similar requirements for assessing risk and rebuilding for long-term resilience. It emphasizes the need to focus on critical infrastructure in communities, such as drinking water and wastewater infrastructure.

Incorporating climate resilience likely decreases the risk that water and wastewater infrastructure, some of which is paid for with federal financial assistance, will fail during extreme events. According to the National Research Council, as the climate changes and historical patterns—in particular, those related to extreme weather events—no longer provide reliable predictions of the future, infrastructure designs may underestimate the climate-related impacts to infrastructure over its design life, which can range as long as 50 to 100 years.[89] In April 2013, we reported that according to one set of commonly used design standards, wastewater treatment plant components are typically designed for 25-, 50-, or 100-year storms.[90] We reported that changes in characteristics of strong storms—for instance, a storm that historically occurred once every 100 years may occur every 50 years in the future—could cause wastewater management systems to be overwhelmed more frequently.

[87]Water and Wastewater Sector Strategic Roadmap Work Group, *Roadmap to a Secure and Resilient Water and Wastewater Sector*.

[88]Department of Homeland Security, Mitigation Framework Leadership Group, *National Mitigation Investment Strategy*.

[89]See, for example, National Research Council, Panel on Strategies and Methods for Climate-Related Decision Support, Committee on the Human Dimensions of Global Change, *Informing Decisions in a Changing Climate* (Washington, D.C.: 2009).

[90]GAO-13-242.

Incorporating climate resilience into drinking water and wastewater infrastructure projects also likely decreases the risk that the federal government will need to pay to repair and replace damaged facilities. In our previous work, we said that building resilience can help reduce the federal fiscal exposure.[91] As we reported in April 2013, such resilience means reducing potential future losses rather than waiting for an event to occur and paying for recovery afterward.[92] We said that enhancing resilience can create additional up-front costs, but can also reduce potential future damage from climate-related events that—given expected budget pressures—would otherwise constrain federal programs. In 2018, the National Institute of Building Sciences found that every dollar spent on infrastructure hazard mitigation to enhance resilience to wind- and flooding-related disasters resulted in 7 to 8 dollars in avoided future losses, respectively.[93] This potential can be considered in light of recent costs that the federal government incurred to address losses. In particular, from fiscal year 2011 through fiscal year 2018, we estimate that FEMA's Public Assistance program and HUD's Community Development Block Grant-Disaster Recovery Grants have obligated at least $2.3 billion and at least $1.4 billion, respectively, in federal disaster recovery funding on drinking water and wastewater infrastructure-related projects.[94]

Conclusions

Drinking water and wastewater utilities face challenges in using climate information to identify actions that they can take to enhance their climate resilience. At the moment, utilities obtain technical assistance and use climate information from a mix of sources and that assistance is not organized to help ensure more comprehensive coverage of the more than 70,000 drinking water and wastewater utilities across the nation. As designated lead agency for the resilience and security of the drinking water and wastewater sector and as chair of the Water Sector Government Coordinating Council, EPA is tasked with coordinating federal and sector efforts to provide the information and assistance that

[91] GAO-13-283.

[92] GAO-13-242.

[93] Multihazard Mitigation Council, *Natural Hazard Mitigation Saves: 2018 Interim Report*. (Washington, D.C.: National Institute of Building Sciences, 2018).

[94] The FEMA obligation estimate is based, in part, on the results of a generalizable stratified random sample of projects and represents the one-sided 95 percent confidence lower bound. See app. I for more details.

state and local decision makers—including utilities—need to enhance their climate resilience. The councils have identified a number of actions to support the drinking water and wastewater sector, but EPA, other federal agencies, and the water and wastewater sector, have not assessed how they could organize a network of technical assistance providers to effectively provide the assistance that utilities need to enhance their resilience to climate change. By identifying existing technical assistance providers and engaging them in a network to help drinking water and wastewater utilities consider climate resilience in the planning and design of projects on an ongoing basis, EPA, as chair of the Water Sector Government Coordinating Council, would have more reasonable assurance that climate information was effectively exchanged among federal agencies and infrastructure owners and operators.

In recognition of the federal interest in protecting the health and economic benefits that clean and safe water provide, federal programs provide funding to support drinking water and wastewater infrastructure. In 2013, Presidential Policy Directive 21 identified the water and wastewater sector as critical infrastructure, with important implications for protecting and investing in that sector. Federal agencies such as EPA, FEMA, HUD, and USDA provide financial assistance to help ensure the long-term success of drinking water and wastewater utilities. These agencies have taken action to promote climate resilient infrastructure projects with the financial assistance they provide, but their abilities to ensure that projects receiving financial assistance are resilient are limited. To enable agencies to further drive climate resilient investments by drinking water and wastewater utilities, changes would be needed to programs that EPA, FEMA, HUD, and USDA administer to require that climate resilience be incorporated into planning for projects that receive federal financial assistance. Such changes could help ensure that drinking water and wastewater infrastructure projects that receive federal financial assistance adequately address risks from climate change and ensure that utilities carry out their critical operations. Such changes could also help limit the fiscal exposure to the federal government for future recovery costs.

Matter for Congressional Consideration

We are making the following matter for congressional consideration:

Congress should consider requiring that climate resilience be incorporated in the planning of all drinking water and wastewater projects that receive federal financial assistance from programs that EPA, FEMA, HUD, and USDA administer. (Matter for Consideration 1)

Recommendations for Executive Action

We are making one recommendation to EPA:

The Director of Water Security of EPA, as Chair of the Water Sector Government Coordinating Council, should work with the council to identify existing technical assistance providers and engage these providers in a network to help drinking water and wastewater utilities incorporate climate resilience into their projects and planning on an ongoing basis. (Recommendation 1)

Agency Comments and Our Evaluation

We provided a draft of this report to EPA, DHS, HUD, NOAA, and USDA for review and comment. EPA provided written comments, which are reproduced in appendix VIII. The other four agencies did not provide comments on our draft report. EPA and USDA provided technical comments, which we incorporated as appropriate.

In its written comments, EPA neither agreed nor disagreed with our recommendation that the Administrator, as Chair of the Water Sector Government Coordinating Council, should work with the council to identify existing technical assistance providers and engage these providers in a network to help drinking water and wastewater utilities incorporate climate resilience into their projects and planning on an ongoing basis. The agency noted in its technical comments that the Director of Water Security is the chair of the Water Sector Council, not the administrator. We made this change in the report.

In its written response, EPA made two points related to the recommendation. First, it stated that it will, consistent with our recommendation, continue to work with its wide-ranging, existing technical assistance providers and coordinate with its stakeholders to identify additional providers as applicable. We agree with this approach and highlighted several of these efforts in our report. For example, EPA noted that it provides annual training to over 5,000 water utilities, state officials, and federal emergency responders on how to become more resilient to natural or manmade incidents that could endanger water and wastewater services.

Second, in response to the part of the recommendation that EPA engage the providers in a network, the agency noted that states serve as a coordinating entity under its Small System Training and Technical Assistant grants. Further, EPA also noted that the providers work with states to identify the systems in greatest need of assistance and identify the training topics of greatest need for small public water systems. We agree that this could be a helpful approach, but note that EPA remained silent on how it plans to work with the states and the water and wastewater sector to develop a network of technical assistance providers. Our report showed that utilities obtain technical assistance from a number of different sources and that they could benefit from a larger network with continuous technical assistance. The Water Sector Coordinating Council functions as a forum to coordinate members of existing networks, and to ensure they have the most current and relevant information as they provide assistance to utilities. As EPA works with its wide-ranging technical assistance providers, consistent with our recommendation, we would encourage it to also work with the Water Sector Coordinating Council to ensure the coordination of the different networks that exist in the water and wastewater sector.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees; the Administrator of the Environmental Protection Agency; and the Secretaries of Homeland Security, Housing and Urban Development, Commerce, and Agriculture. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staffs have any questions about this report, please contact me at (202) 512-3841 or gomezj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff members who made key contributions to this report are listed in appendix IX.

Alfredo Gómez

J. Alfredo Gómez
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

The objectives of our review were to examine (1) the potential impacts of climate change and the effects of these impacts on drinking water and wastewater infrastructure; (2) technical assistance selected federal agencies provided to selected utilities to help make drinking water and wastewater infrastructure more resilient to the impacts of climate change, and options experts identified for providing additional technical assistance to utilities; and (3) financial assistance federal agencies provided to selected utilities to help make drinking water and wastewater infrastructure more resilient to the impacts of climate change, and options experts identified for providing additional financial assistance to utilities.

For the first objective, we reviewed the *Fourth National Climate Assessment*;[1] the Environmental Protection Agency's (EPA) *Adaptation Strategies Guide for Water Utilities*,[2] *Climate Resilience Evaluation and Awareness Tool Methodology Guide*,[3] and Climate Scenarios Projection Map,[4] and the U.S. Climate Resilience Toolkit, which the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) manages and hosts with oversight from the U.S. Global Change Research Program.[5] Based on our review of these sources, we first identified different categories of potential climate change impacts, and how those impacts may vary in the different climate regions identified in the *Fourth National Climate Assessment*.[6]

[1]U. Lall, T. Johnson, P. Colohan, A. Aghakouchak, C. Brown, G. McCabe, R. Pulwarty, and A. Sankarasubramanian, "Water," ch. 3 of *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* (Washington, D.C.: U.S. Global Change Research Program, 2018).

[2] Environmental Protection Agency, *Climate Ready Water Utilities Adaptation Strategies Guide* (Washington, D.C.: 2015).

[3]Environmental Protection Agency, *Climate Resilience Evaluation and Awareness Tool, Version 3.0 Methodology Guide* (Washington, D.C.: 2016).

[4]Environmental Protection Agency, *Climate Resilience Evaluation and Awareness Tool Climate Scenarios Projection Map*, accessed Oct. 31, 2019. https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=3805293158d54846a29f750d63c6890e.

[5]National Oceanic and Atmospheric Administration, *U.S. Climate Resilience Toolkit*, accessed Oct. 31, 2019, https://toolkit.climate.gov/topics/built-environment/water-and-wastewater.

[6]The Fourth National Climate Assessment identifies 10 climate regions for the United States and its territories: Northeast, Southeast, Midwest, Northern Great Plains, Southern Great Plains, Southwest, Northwest, Alaska, Hawaii and Pacific Islands, and Caribbean.

For both the second and third objectives, we reviewed the efforts of and interviewed five federal agencies and 15 drinking water and wastewater utilities.[7] We reviewed our previous reports to identify agencies that provide technical assistance or financial assistance, or both, to drinking water and wastewater utilities and identified five agencies: EPA, NOAA, the Department of Homeland Security's (DHS) Federal Emergency Management Agency (FEMA), the Department of Housing and Urban Development (HUD), and the Department of Agriculture's (USDA) Rural Utilities Service.

For the second and third objectives, we also selected a nongeneralizable sample of 15 drinking water and wastewater utilities in 13 communities using a stratified purposeful sampling approach.[8] We selected utilities to obtain variation in their size and climate region to capture similarities and differences among utilities. We classified utilities into small, medium, and large utilities based on the sizes of the populations that they serve. We defined small utilities (serving populations of 10,000 or less), medium utilities (serving populations of 10,001 to 999,999), and large utilities (serving populations of 1 million or more) for this report to capture utilities with the greatest resources available for climate resilience efforts. In order to ensure geographic diversity, we selected small, medium, and large utilities from different climate regions identified in the *Fourth National Climate Assessment.*[9] Because this was a nonprobability sample, the findings related to the 15 utilities cannot be generalized to all drinking water and wastewater utilities but provide illustrative examples of how the selected utilities used federal technical assistance and financial assistance.

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[7]To characterize the views of utility representatives throughout this report, we defined the modifiers "almost all" to represent 12 to 14 representatives, "most" to represent eight to 13 representatives, and "several" to represent two to seven representatives.

[8]The five small utilities we selected were (1) Cottage Grove, Oregon; (2) Estes Park, Colorado; (3) Fredericktown, Missouri; (4) Hillsboro, Kansas; and (5) Keene, New Hampshire. The five medium utilities we selected were (1) Anacortes, Washington; (2) Bozeman, Montana; (3) Charleston, South Carolina; (4) Iowa City, Iowa; and (5) Nogales, Arizona. The five large utilities we selected were (1) Houston, Texas; (2) Miami-Dade County, Florida; (3) New York City, New York; (4) Norfolk, Virginia; and (5) San Diego, California. Because this was a nonprobability sample, the findings related to the 15 utilities cannot be generalized to all drinking water and wastewater utilities but provide illustrative examples of how the selected utilities used federal technical assistance and financial assistance. Fredericktown, Missouri, and Hillsboro, Kansas, were not included in our final utility sample because utility representatives declined to participate

[9]Lall et al., *Fourth National Climate Assessment*, ch. 3.

Further, for the second and third objectives, we selected 10 experts in the climate change and disaster fields to interview about options for providing additional technical and financial assistance to drinking water and wastewater utilities. To identify experts on the resilience of water infrastructure to climate change, we searched Elsevier's Scopus database for peer-reviewed articles published from January 2003 through September 2018 searching titles, abstracts, and keywords for "drinking water" or "wastewater" in close proximity to terms such as "infrastructure," "climate change," and "resiliency." We identified approximately 300 studies from this search, identified the relevant studies from that group, and then found an additional eight studies from their citations. We reviewed the abstracts of these studies and found 96 that were within the scope of our objectives. To develop a list of potential experts, we extracted the names of the authors of these studies and the names of authors cited in these studies using the Python programming language and the Scopus Application Programming Interface.

Next, we used statistical software to calculate the number of times that each author cited every other author. Using these calculations, we arrayed the authors into a network graph, in which authors who frequently cited each other were situated closer together and authors who did not cite each other were situated further apart. We analyzed this network using social network analysis techniques.[10] Specifically, to measure each author's prominence in the network, we calculated the number of times that each author was cited in the articles written by other authors in the network. To divide the network into groups, we used an algorithm known as hierarchical clustering. This algorithm allowed us to identify groups of authors who cited each other frequently and who cited authors in the rest of the network infrequently.[11] We sorted authors by group and by the number of times they were cited. For the most frequently cited authors in the largest groups in the network, we examined biographical details and publication details via web searches, such as their geographic location and the relevance of their publications to our research topic. We selected a final list of 15 frequently cited experts who were primarily from the largest clusters in the network, who were based in North America, whose

[10]Social network analysis is a field of quantitative research that identifies patterns of relationships among multiple entities such as individuals, countries, organizations, or, in this case, experts.

[11]In social network analysis, individuals in a cluster are typically similar in important dimensions. In this context, those dimensions include examining similar research questions, using similar analytic approaches or having similar expertise.

research was topically relevant, and who were still active in the field. Eight of these experts agreed to be interviewed and we included them in our final sample. We supplemented this list with two experts who served as lead authors for the water chapter of the Fourth National Climate Assessment. While these 10 experts are prominent researchers and correspond to a range of major fields of research on the topic, their views do not represent the views of all experts on the resilience of drinking water and wastewater infrastructure to climate change.

To examine the first part of the second objective, the technical assistance selected federal agencies provided to selected utilities, we reviewed relevant laws, regulations, and planning guidance about programs that can provide technical assistance to drinking water and wastewater utilities to help enhance climate resilience for each selected federal agency. We also interviewed federal officials at each agency. To examine the first part of the third objective, the financial assistance selected federal agencies provided to selected utilities, we reviewed project eligibility criteria and appropriation amounts for EPA's Clean Water State Revolving Fund, Drinking Water State Revolving Fund, and Water Infrastructure Finance and Innovation Act Programs; HUD's Community Development Block Grant Program and Community Development Block Grant-Disaster Recovery Fund; and USDA's Water and Wastewater Disposal Program for fiscal years 2011 through 2018. We also interviewed federal officials at each agency.

As part of analyzing the federal financial assistance to drinking water and wastewater utilities, we estimated FEMA's pre- and post-disaster spending to help such utilities recover from natural disasters. To identify federal disaster recovery and hazard mitigation obligations on drinking water and wastewater infrastructure, we analyzed federal financial assistance that FEMA's Public Assistance, Hazard Mitigation, and Pre-disaster Mitigation Programs provide for disaster recovery for drinking water and wastewater infrastructure. Specifically, using a list of search terms associated with drinking water and wastewater infrastructure, we queried FEMA's disaster recovery spending database to identify a list of drinking water and wastewater infrastructure disaster recovery and hazard mitigation projects funded from fiscal years 2011 through 2018. After we queried FEMA's disaster recovery spending database, we manually reviewed records from a stratified sample to ensure that each project was related to water and wastewater infrastructure. We reviewed all 25 records with the highest obligated amounts, 15 records in which a project was associated with more than one site, and 35 records in which a project was associated with just one site.

We chose this sample design to ensure that we were capturing projects with the highest dollar amounts as well as all other projects, while also ensuring that if one site in a project was water related, the rest of the sites under the project were also water related (manual review showed that if one site in a project was water related, 98 percent of the other sites in the project were also water related). After manual review, we generated an estimate of total obligated funds from the ratio of number of projects that we reviewed that were related to water and wastewater infrastructure to the total number of projects in our sample.

The estimate we used was the lower bound of a 95 percent confidence interval. We chose this estimate in order to give a conservative estimate of the amount that FEMA's public assistance program has obligated. The relative error was 0.07. To assess the reliability of the disaster recovery obligations data, we (1) performed electronic testing for errors in accuracy and completeness, (2) reviewed related documentation about the data and the system that produced them, (3) interviewed agency officials knowledgeable about the data, and (4) worked closely with agency officials to identify and resolve data discrepancies before conducting our analyses. We determined that the data were sufficiently reliable for the purposes of our reporting objectives.

To examine what technical assistance and financial assistance selected drinking water and wastewater utilities used for the second and third objectives, we provided a short questionnaire and interviewed utility representatives from the 15 selected drinking water and wastewater utilities to understand what technical and financial assistance they used to enhance their climate resilience for fiscal years 2011 through 2018. In the questionnaire and interviews, we discussed their efforts to plan for climate resilience and the technical and financial assistance they used for such efforts, which could include the five agencies we selected to review or other federal and nonfederal entities we did not review, but knew could potentially be sources of technical and financial assistance for utilities based on our prior work. Specifically, the federal agencies we did not review, but included in our questionnaire were: NOAA, the Department of Defense's U.S. Army Corps of Engineers, and the Department of the Interior's Bureau of Reclamation (Reclamation).

To examine the second parts of the second and third objectives, the options experts identified for providing additional technical and financial assistance to utilities, we conducted semistructured interviews with the 10 climate change and disaster resilience experts. To develop the semistructured interview documents, we assessed the content of the 96 articles identified in our literature review to develop a list of actions that the federal government could take to make drinking water and wastewater infrastructure more resilient to the effects of climate change. The articles used to develop this list of actions were identified by searching resources such as Agricola, ProQuest's Environmental Databases, Policyfile, Harvard's Think Tank Search, and Scopus. We searched for both peer-reviewed articles and reports from nonprofits and think tanks published between January 2003 and September 2018 searching titles, abstracts and keywords for "water" in close proximity to "climate change," "utilities," and terms such as "project," "program," "policy," or "recommendation." We asked the 10 experts about the list of actions during our interviews (see table 2).

Table 2: Federal Actions That Could Help Drinking Water and Wastewater Utilities Become More Resilient to Potential Climate Change Impacts

Federal actions	
Action 1	Provide an authoritative source and meaningful translation of scientific and technical information to (a) improve the usefulness and reliability of modeling projections and available tools for decision-making on drinking water and wastewater infrastructure and (b) better target the analysis of model outputs to address the needs of drinking water and wastewater utilities.
Action 2	Include a category for projects to improve the resilience of drinking water and wastewater infrastructure in the Environmental Protection Agency's Drinking Water and Clean Water Needs Assessments to help identify resilience needs and prioritize federal funding.
Action 3	Conduct a nationwide assessment of the potential impacts from climate change to drinking water and wastewater infrastructure to identify locations of greatest risk and to help direct federal drinking water and wastewater infrastructure investment.
Action 4	Develop a generally accepted tool and associated guidance to help utilities estimate the short- and long-term financial costs and benefits (e.g., avoided costs) of projects to improve the resilience of drinking water and wastewater infrastructure.
Action 5	Require that potential climate impacts be identified, prioritized, and, if necessary, incorporated into the design of all new drinking water and wastewater infrastructure projects funded by the federal government.
Action 6	Broaden existing federal programs that fund drinking water and wastewater infrastructure to invest in projects to make drinking water and wastewater infrastructure more resilient.
Action 7	Shift federal investment from federal disaster recovery funding to federal disaster mitigation funding programs to prioritize projects that improve the short- and long-term resilience of critical infrastructure, including drinking water and wastewater infrastructure, prior to disasters.
Action 8	Create a new federal funding mechanism (e.g., a National Infrastructure Bank or revolving fund) to pay for planning and projects to make drinking water and wastewater infrastructure more resilient.
Action 9	Develop generally accepted design standards and associated guidance to help drinking water and wastewater utilities incorporate resilience to the potential impacts of climate change into drinking water and wastewater infrastructure planning and projects.

Source: GAO analysis of literature review. | GAO-20-24

We conducted semistructured interviews with the 10 selected experts and asked the experts to rate the effectiveness of the nine actions we provided for making drinking water and wastewater infrastructure more resilient to the impacts of climate change, describe the advantages and disadvantages of each action, and describe how the actions could be implemented. We also asked experts to rate the administrative feasibility and cost of the actions. Finally, we asked the experts if any additional actions should be added to our list.

We then analyzed the results of our interviews to identify five options to provide technical assistance and developed a follow-up questionnaire. The questionnaire asked the 10 selected experts to rate the effectiveness of the five options for providing additional technical assistance, describe the advantages and disadvantages of each option, and describe how the options could be implemented (see table 3). We also asked experts to rate the overall effectiveness, administrative feasibility, and cost of the options. We also requested written responses from the 15 selected utilities on the 5 technical assistance options and the 4 financial assistance options identified in our interviews with experts.[12]

Table 3: Options the Federal Government Could Use to Provide Technical Assistance and Financial Assistance to Help Drinking Water and Wastewater Utilities Become More Climate Resilient

Options		Examples
Technical assistance options	Existing federally supported drinking water and wastewater utility technical assistance providers	The Environmental Protection Agency (EPA) could coordinate a strengthened and expanded existing network of federal technical assistance providers, including EPA's Environmental Finance Centers, the Department of Agriculture's (USDA) Rural Utilities Service, the National Rural Water Association, and the Rural Community Assistance Program, to help consolidate information and provide technical assistance to all types of utilities to improve their resilience.
	Existing federal climate services technical assistance providers	EPA could coordinate a strengthened and expanded network of existing federal climate services providers, such as USDA's Climate Hubs, the Department of the Interior's Landscape Conservation Cooperatives and Climate Science Centers, and the National Oceanic and Atmospheric Administration's Regional Integrated Sciences and Assessments program, to help consolidate information and provide technical assistance to all types of utilities to improve their resilience.
	A network of university and laboratory centers	EPA could coordinate a new network of academic or university–based technical assistance providers, such as the National Center for Atmospheric Research, organized by state, region, or watershed to help consolidate information and provide technical assistance to all types of utilities to improve their resilience.

[12]To characterize the views of utility representatives throughout this report, we defined the modifiers "almost all" to represent 12 to 14 representatives, "most" to represent eight to 13 representatives, and "some" to represent two to seven representatives.

Options		Examples
	A network of industry groups and private engineering consultants	EPA could coordinate a network of nonfederal industry and nonprofit groups to help share information and provide technical assistance to utilities. Groups such as the American Water Works Association, Water Utility Climate Alliance, Association of Municipal Water Utilities, American Society of Civil Engineers, National Rural Water Association, and Rural Community Assistance Program could help consolidate and update information and through the engineering consultant network to provide technical assistance to all types of utilities to improve their resilience.
	A network of utilities	EPA could coordinate a network of utilities, similar to the networks created through the Water Utility Climate Alliance or the Southeast Florida Regional Climate Change Compact, to consolidate and update information and provide technical assistance to all types of utilities to improve their resilience.
Financial incentive options	Require resilience	Federal agencies could require that potential climate impacts be identified and, if necessary, prioritized and incorporated into the design of all new drinking water and wastewater infrastructure projects funded by the federal government.
	Prioritize hazard mitigation programs	Congress and the federal government could prioritize funding for federal programs, such as Federal Emergency Management Agency’s Pre-disaster Mitigation Grant Program and Hazard Mitigation Grant Program, which fund projects to improve the short- and long-term resilience of critical infrastructure, including drinking water and wastewater infrastructure, prior to disasters.
	Broaden criteria for existing programs	Federal agencies could broaden the criteria for existing federal programs (for example, EPA’s State Revolving Fund Program, USDA Rural Utilities Service’s Water and Waste Disposal Program, and the Department of Housing and Urban Development’s Community Development Block Grant Program) that fund drinking water and wastewater infrastructure to include criteria for making drinking water and wastewater infrastructure more resilient.
	A new program	Congress and the federal government could create a new program to invest in projects to make drinking water and wastewater infrastructure more resilient.

Source: GAO analysis of expert responses. | GAO-20-24

We conducted this performance audit from October 2017 to January 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Examples of the Most-Relevant Potential Climate Change Impacts and Their Potential Effects on Drinking Water Utilities by Region

Table 4 corresponds with figure 2 in the report, which is an interactive figure and contains the text for drinking water utilities that is not accessible to readers of print copies of this report. As readers scroll over the water-drop icons in the figure, separate pop-up boxes appear describing specific regional impacts.

Table 4: Interactive Graphic of 10 Climate Regions and the U.S. Coast, Their Most Relevant Potential Climate Change Impacts, and Examples of Potential Effects on Drinking Water Utilities

Region	Description of potential climate change impacts on drinking water infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
Northeast	Drought	Seasonal runoff and loss of snowpack	Higher temperatures, more winter precipitation as rain, and shorter winters could lead to less snowpack, resulting in decreased streamflow, water supply shortages in the summer, and service disruptions.
	Ecosystem changes	Loss of coastal landforms, wetlands, or both	Loss of coastal wetlands, beaches, sand dunes, or a combination of these can reduce the buffer against coastal storms and flooding, resulting in water service disruptions, treatment failure, and damaged infrastructure.
	Floods	High stream or river flow events Coastal storm surges	Coastal and riverine flooding is likely to occur more frequently, resulting in service disruptions, damaged infrastructure, treatment failures, and higher treatment costs to remove higher sediment and contaminant levels from water resources.
	Service demand and use	Volume and temperature Utilities' energy needs	Less snowpack and decreased streamflow may result in water supply shortages, and service disruptions. Increased water demand and use of water sources that require additional treatment (e.g. surface water, recycled water, and salt water) may increase utilities' energy needs and treatment costs.
Southeast	Drought	Reduced groundwater recharge Lower lake and reservoir levels	Reduced precipitation may diminish groundwater recharge rates, which may result in water shortages, service disruptions, and possibly the need to use alternative water sources. Lower lake and reservoir levels may limit utilities' ability to meet water demands, especially during summer months, and may drop water levels below intake infrastructure.
	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of coastal wetlands, beaches, sand dunes or a combination of these can reduce the buffer against coastal storms and flooding, resulting in water service disruptions, treatment failure, and damaged infrastructure. Wildfires may damage infrastructure, increase sediment and pollutant levels in surface water, reduce reservoir capacity, and increase treatment costs.
	Floods	Coastal storm surges	Severe flooding from sea level rise and higher storm surge is likely to occur more frequently, causing water service disruptions, treatment failures, damaged infrastructure, and additional costs.
	Service demand and use	Agricultural water demand Utilities' energy needs	Increased agricultural water demand may lead to shortfalls in water supply in the summer growing period. Increased water demand and use of water sources that require additional treatment (e.g. surface water, recycled water, and salt water) may increase utilities' energy needs and treatment costs.

Region	Description of potential climate change impacts on drinking water infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
	Water quality degradation	Saltwater intrusion into aquifers Altered surface water quality	Rising sea levels and higher water demand may lead to saltwater intrusion into freshwater aquifers, causing contaminated source water, water shortages, and increased treatment costs. Increased sediment and pollutant levels from extreme storms and algal blooms from higher temperatures may degrade water quality, increasing costs because of additional treatment needs and greater energy demand.
Caribbean	Drought	Reduced groundwater recharge Lower lake and reservoir levels	Reduced precipitation may diminish groundwater recharge rates, which may result in water shortages, service disruptions, and possibly the need to use alternative water sources. Lower lake and reservoir levels may limit utilities' ability to meet water demands, especially during summer months, and may drop water levels below intake infrastructure.
	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of coastal wetlands, beaches, sand dunes, or a combination of these can reduce the buffer against coastal storms and flooding, resulting in water service disruptions, treatment failure, and damaged infrastructure. Wildfires may damage infrastructure, increase sediment and pollutant levels in surface water, reduce reservoir capacity, and increase treatment costs.
	Floods	Coastal storm surges	Rising sea levels, stronger wave action, and higher storm surges may worsen coastal flooding and increase coastal erosion, causing water service disruptions, treatment failures, and damaged infrastructure.
	Service demand and use	Agricultural water demand Utilities' energy needs	Increased agricultural water demand may lead to shortfalls in water supply in the summer growing period. Increased water demand and use of water sources that require additional treatment (e.g., surface water, recycled water, and salt water) may increase utilities' energy needs and treatment costs.
	Water quality degradation	Saltwater intrusion into aquifers Altered surface water quality	Rising sea levels and higher water demand may lead to saltwater intrusion into freshwater aquifers, causing contaminated source water, water shortages, and increased treatment costs. Algal blooms from higher temperatures may degrade water quality, increasing costs because of additional treatment needs and greater energy demand.
Midwest	Drought	Reduced groundwater recharge Lower lake and reservoir levels	Reduced precipitation may diminish groundwater recharge rates, which may result in water shortages, service disruptions, and possibly the need to use alternative water sources. Lower lake and reservoir levels may worsen utilities' ability to meet water demands, especially during summer months, and may drop water levels below intake infrastructure.
	Floods	High stream or river flow events	Rainfall-induced flooding is likely to occur more frequently, resulting in service disruptions, damaged infrastructure, and higher treatment costs to remove higher sediment and contaminant levels from overland flows.
	Service demand and use	Volume and temperature Agricultural water demand Energy sector needs Utilities' energy needs	Decreased streamflow and groundwater recharge may reduce water supplies and potentially lead to service disruptions, and increased agricultural water demand for crops may lead to shortfalls in water supply in the summer growing period. Temperature extremes and increasing energy demands could cause the energy sector to increase energy production and use more water, resulting in water shortfalls during periods of peak energy consumption. Increased water demand and use of water sources that require additional treatment (e.g., surface water and recycled water) may increase utilities' energy needs and treatment costs.

Region	Description of potential climate change impacts on drinking water infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
	Water quality degradation	Altered surface water quality	Increased sediments and other pollutants from high flow events and algal blooms from higher temperatures may degrade water quality, requiring additional treatment or different water sources. Lakes with contaminated sediment may release more mercury and persistent pollutants into surface water because of warmer water and low-oxygen conditions, requiring additional treatment or different water sources.
Northern Great Plains	Drought	Reduced groundwater recharge Lower lake and reservoir levels	Reduced precipitation may diminish groundwater recharge rates, which may result in water shortages, service disruptions, and possibly the need to use alternative water sources. Lower lake and reservoir levels may worsen utilities' ability to meet water demands, especially during summer months, and may drop water levels below intake infrastructure.
	Ecosystem changes	Increased fire risk	Wildfires may damage infrastructure, increase sediment and pollutant levels in surface water, reduce reservoir capacity, and increase treatment costs.
	Floods	High stream or river flow events	Riverine flooding is likely to occur more frequently, resulting in service disruptions, damaged infrastructure, and higher treatment costs to remove higher sediment and contaminant levels from overland flows.
	Service demand and use	Volume and temperature Agricultural water demand Utilities' energy needs	Decreased streamflow and groundwater recharge may reduce water supplies and potentially lead to service disruptions, and increased agricultural water demand for crops may lead to shortfalls in water supply in the summer growing period. Increased water demand and use of water sources that require additional treatment (e.g. surface water and recycled water) may increase utilities' energy needs and treatment costs.
Southern Great Plains	Drought	Reduced groundwater recharge Lower lake and reservoir levels	Reduced precipitation may diminish groundwater recharge rates, which may result in water shortages, service disruptions, and possibly the need to use alternative water sources. Lower lake and reservoir levels may worsen utilities' ability to meet water demands, especially during summer months, and may drop water levels below intake infrastructure.
	Ecosystem changes	Increased fire risk	Wildfires may damage infrastructure, increase sediment and pollutant levels in surface water, reduce reservoir capacity, and increase treatment costs.
	Floods	High stream or river flow events	Riverine flooding is likely to occur more frequently, resulting in service disruptions, damaged infrastructure, treatment failures, and higher treatment costs to remove increased sediment and contaminant levels in water resources.
	Service demand and use	Volume and temperature Agricultural water demand Utilities' energy needs	Decreased streamflow and groundwater recharge may reduce water supplies and potentially lead to service disruptions, and increased agricultural water demand for crops may lead to shortfalls in water supply in the summer growing period. Increased water demand and use of water sources that require additional treatment (e.g. surface water and recycled water) may increase utilities' energy needs and treatment costs.
Southwest	Drought	Seasonal runoff and loss of snowpack	Higher temperatures, more winter precipitation as rain, and shorter winters could lead to less snowpack, resulting in decreased streamflow, water supply shortages in the summer, and service disruptions.

Region	Description of potential climate change impacts on drinking water infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
	Ecosystem changes	Increased fire risk	Wildfires may damage infrastructure, increase sediment and pollutant levels in surface water, reduce reservoir capacity, and increase treatment costs.
	Floods	High stream or river flow events	Rainfall-induced flooding is likely to occur more frequently, resulting in service disruptions, damaged infrastructure, and higher treatment costs to remove higher sediment and contaminant levels from overland flows.
	Service demand and use	Volume and temperature Agricultural water demand Energy sector needs Utilities' energy needs	Decreased streamflow and groundwater recharge may reduce water supplies and potentially lead to service disruptions, and increased agricultural water demand for crops may lead to shortfalls in water supply in the summer growing period. Temperature extremes and increasing energy demands could cause the energy sector to increase energy production and use more water, resulting in water shortfalls during periods of peak energy consumption. Increased water demand and use of water sources that require additional treatment (e.g. surface water and recycled water) may increase utilities' energy needs and treatment costs.
Northwest	Drought	Seasonal runoff and loss of snowpack	Increasing temperatures and more winter precipitation as rain may cause less snowpack and earlier peak streamflow, resulting in water shortages during the summer and service disruptions.
	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of coastal wetlands can reduce the buffer against coastal storms and flooding, resulting in water service disruptions, treatment failure, and damaged infrastructure. Wildfires may damage infrastructure, increase sediment and pollutant levels in surface water, reduce reservoir capacity, and increase treatment costs.
	Floods	High stream or river flow events	More winter precipitation as rain could lead to winter flooding, increased erosion, and more frequent landslides because of saturated soils, resulting in damaged infrastructure and higher sediment levels that may require additional treatment.
	Service demand and use	Volume and temperature Utilities' energy needs	Decreased streamflow and groundwater recharge may reduce water supplies and potentially lead to service disruptions. Increased water demand and use of water sources that require additional treatment (e.g.,surface water and recycled water) may increase utilities' energy needs and treatment costs.
Alaska	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of low-lying coastlines from the melting of protective sea-ice buffers, increasing storm activity, and thawing coastal permafrost may diminish the buffer against storm surge and flooding, resulting in water service disruptions, treatment failure, and damaged infrastructure. Wildfires may damage infrastructure, increase sediment and pollutant levels in surface water and increase treatment costs.
	Service demand and use	Energy sector needs Utilities' energy needs	Temperature extremes and increasing energy demands could cause the energy sector to increase energy production and use more water, resulting in water shortfalls during peak energy consumption periods. Thawing coastal permafrost could increase sediment levels in water supplies and require additional treatment, which may increase utilities' energy needs and treatment costs.
Hawaii and the US Affiliated Pacific Islands	Ecosystem changes	Loss of coastal landforms, wetlands, or both	Loss of coastal wetlands, beaches, sand dunes, or a combination of these, can reduce the buffer against coastal storms and flooding, resulting in water service disruptions, treatment failure, and damaged infrastructure.

Region	Description of potential climate change impacts on drinking water infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
	Floods	High stream or river flow events Coastal storm surges	Coastal and riverine flooding is likely to occur more frequently, resulting in service disruptions, damaged infrastructure, treatment failures, and higher treatment costs to remove increased sediment and contaminant levels in water resources.
	Service demand and use	Utilities' energy needs	Increased contamination of freshwater sources from saltwater may require additional treatment and may increase utilities' energy needs and treatment costs.
	Water quality degradation	Saltwater intrusion into aquifers	Rising sea levels may lead to saltwater intrusion into freshwater aquifers, causing contaminated source water, water shortages, and increased treatment costs.
US Coastal	Drought	Seasonal runoff and loss of snowpack	Increasing temperatures and more winter precipitation as rain may cause less snowpack and earlier peak streamflow, resulting in water shortages during the summer and service disruptions.
	Ecosystem changes	Loss of coastal Loss of coastal landforms, wetlands, or both	Loss of coastal wetlands can reduce the buffer against storm surge, erosion, and flooding, resulting in water service disruptions, treatment failure, and damaged infrastructure.
	Floods	High stream or river flow events Coastal storm surges	Coastal and riverine flooding is likely to occur more frequently, resulting in service disruptions, damaged infrastructure, treatment failures, and higher treatment costs to remove increased sediment and contaminant levels in water resources.
	Service demand and use	Volume and temperature Utilities' energy needs	Decreased streamflow and groundwater recharge may reduce water supplies and potentially lead to service disruptions. Increased water demand and use of water sources that require additional treatment (e.g. surface water and recycled water) may increase utilities' energy needs and treatment costs.

Source: GAO analysis of Environmental Protection Agency and U.S. Global Change Research Program data. | GAO-20-24

Appendix III: Examples of the Most-Relevant Potential Climate Change Impacts and Their Potential Effects on Wastewater Utilities

Table 5 corresponds with figure 2 in the report, which is an interactive figure and contains the text for wastewater utilities that is not accessible to readers of print copies of this report. As readers scroll over the water-drop icons in the figure, separate pop-up boxes appear describing specific regional impacts.

Table 5: Interactive Graphic of 10 Climate Regions and U.S. Coasts, Their Most Relevant Potential Climate Change Impacts, and Examples of Potential Effects on Wastewater Utilities

Region	Description of potential climate change impacts on wastewater infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
Northeast	Ecosystem changes	Loss of coastal landforms, wetlands, or both	Loss of coastal land and wetlands may result in less protection against coastal storms for key infrastructure located on the coast, such as treatment plants and sewage conveyance systems, leading to additional damages and disruptions in service.
	Floods	High stream or river flow events Coastal storm surges	Coastal and riverine flooding and storm surge may increase, placing wastewater treatment facilities at increased risk of flooding because they are typically located at lower elevations in watersheds or coastal regions. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the system.
	Service demand and use	Volume and temperature Utilities' energy needs	Increasing temperatures and treatment costs may cause wastewater treatment plants to increase their already significant energy requirements. Increased energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when water and electricity demand peak.
	Water quality degradation	Altered surface water quality	Higher temperatures can lead to diminished water quality in the bodies of water into which treated wastewater is released. This may result in utilities needing to use advanced treatment processes to stay in compliance with state or federal regulatory requirements for treated wastewater.
Southeast	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of coastal land and wetlands may result in less protection against coastal storms for key infrastructure, such as treatment plants and sewage conveyance systems located on the coast, leading to additional damages, and disruptions in service. Wildfires present a direct risk to property, personnel, and infrastructure and can increase pollutant and sediment runoff into reservoirs and rivers.
	Floods	Coastal storm surges	Coastal flooding and storm surge may increase, placing wastewater treatment plants at increased risk of flooding because they are typically located at lower elevations in coastal regions. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.
	Service demand and use	Utilities' energy needs	Increasing temperatures and treatment costs may cause wastewater treatment plants to increase their already significant energy requirements. Increased water and energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when water and electricity demand peak.

Region	Description of potential climate change impacts on wastewater infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
	Water quality degradation	Altered surface water quality	Higher temperatures can lead to diminished water quality in the bodies of water into which treated wastewater is released. This may result in utilities needing to use advanced treatment processes, increasing costs to meet state or federal requirements for treated wastewater.
Caribbean	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of coastal land and wetlands may result in less protection against coastal storms for key infrastructure, such as treatment plants and sewage conveyance systems located on the coast, leading to additional damages, and disruptions in service. Wildfires present a direct risk to property, personnel, and infrastructure and can increase pollutant and sediment runoff into reservoirs, lowering water quality.
	Floods	Coastal storm surges	Coastal flooding and storm surge may increase, placing wastewater treatment plants at increased risk of flooding because they are typically located at lower elevations in watersheds or coastal regions. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.
	Service demand and use	Utilities’ energy needs	As temperatures increase treating wastewater can require more energy to reach the same level of treatment as during cooler periods. If water utilities need to replace used groundwater with wastewater treated to a high level of purity, it may require new technologies and even more energy use to meet this level.
	Water quality degradation	Altered surface water quality	Higher temperatures can lead to diminished water quality in the bodies of water into which treated wastewater is released. This may result in utilities needing to use advanced treatment processes, increasing costs to meet state or federal requirements for treated wastewater.
Midwest	Floods	High stream or river flow events	Stronger storms and precipitation may increase, placing wastewater treatment plants at increased risk of flooding because they are typically located at lower elevations in watersheds. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.
	Service demand and use	Volume and temperature Utilities’ energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased water and energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when water and electricity demand peak.
	Water quality degradation	Altered surface water quality	Higher temperatures can lead to diminished water quality in the bodies of water into which treated wastewater is released. This may result in utilities needing to use advanced treatment processes, increasing costs to meet state or federal requirements for treated wastewater.
Northern Great Plains	Ecosystem changes	Increased fire risk	Increases in temperatures and potential for drought can increase the potential for wildfires. Wildfires present a direct risk to property, personnel, and infrastructure and can increase pollutant and sediment runoff into reservoirs because of erosion, lowering water quality.

Region	Description of potential climate change impacts on wastewater infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
	Floods	High stream or river flow events	Stronger storms and precipitation may increase, placing wastewater treatment facilities at increased risk of flooding because they are typically located at lower elevations in watersheds. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.
	Service demand and use	Volume and temperature Utilities' energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased water and energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when water and electricity demand peak.
Southern Great Plains	Ecosystem changes	Increased fire risk	Increases in temperatures and potential for drought can increase the potential for wildfires. Wildfires present a direct risk to property, personnel, and infrastructure and can increase pollutant and sediment runoff into reservoirs because of erosion, lowering water quality.
	Floods	High stream or river flow events	Stronger storms and precipitation may increase, placing wastewater treatment facilities at increased risk of flooding because they are typically located at lower elevations in watersheds. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacity of the system.
	Service demand and use	Volume and temperature Utilities' energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased water and energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when water and electricity demand peak.
Southwest	Ecosystem changes	Increased fire risk	Increases in temperatures and potential for drought can increase the potential for wildfires. Wildfires present a direct risk to property, personnel, and infrastructure and can increase pollutant and sediment runoff into reservoirs, lowering water quality.
	Floods	High stream or river flow events	Stronger storms and precipitation may increase, placing wastewater treatment facilities at increased risk of flooding because they are typically located at lower elevations in watersheds. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.
	Service demand and use	Volume and temperature Utilities' energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased water and energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when water and electricity demand peak.
	Water quality degradation	Low flow conditions	Higher temperatures and decreased flow can lead to diminished water quality in the bodies of water into which treated wastewater is released. This may result in the need for utilities to use advanced treatment processes, increasing costs to meet state or federal requirements for treated wastewater.

Region	Description of potential climate change impacts on wastewater infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
Northwest	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of coastal land and wetlands may result in less protection against coastal storms for key infrastructure, such as treatment facilities and sewage conveyance systems located on the coast, leading to additional damages, and disruptions in service. Wildfires present a direct risk to property, personnel, and infrastructure and can increase pollutant and sediment runoff into reservoirs, lowering water quality.
	Floods	High stream or river flow events	Stronger storms and precipitation may increase, placing wastewater treatment facilities at increased risk of flooding because they are typically located at lower elevations in watersheds. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.
	Service demand and use	Volume and temperature Utilities' energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased water and energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when water and electricity demand peak.
	Water quality degradation	Low flow conditions	Higher temperatures and decreased flow can lead to diminished water quality in the bodies of water into which treated wastewater is released. This may result in the need for utilities to use advanced treatment processes, increasing costs to meet state or federal requirements for treated wastewater.
Alaska	Ecosystem changes	Loss of coastal landforms, wetlands, or both Increased fire risk	Loss of low-lying coastlines from the melting of protective sea-ice buffers, increasing storm activity, and thawing coastal permafrost may result in less protection against coastal storms for key infrastructure, such as treatment facilities and sewage conveyance systems located on the coast, leading to additional damages, and disruptions in service. Wildfires present a direct risk to property, personnel, and infrastructure and can increase pollutant and sediment runoff into reservoirs, lowering water quality.
	Service demand and use	Utilities' energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when electricity demand peaks.
Hawaii and the US Affiliated Pacific Islands	Ecosystem changes	Loss of coastal landforms, wetlands, or both	Loss of coastal land and wetlands may result in less protection against coastal storms for key infrastructure such as treatment facilities and sewage conveyance systems located on the coast, leading to additional damages, and disruptions in service.
	Floods	High stream or river flow events Coastal storm surges	Coastal and riverine flooding and storm surge may increase, placing wastewater treatment facilities at increased risk of flooding because they are typically located at lower elevations in watersheds or coastal regions. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.

Region	Description of potential climate change impacts on wastewater infrastructure (displayed in individual pop-up boxes associated with each water-drop icon)		
	Service demand and use	Utilities’ energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when electricity demand peaks.
US Coastal	Ecosystem changes	Loss of coastal landforms, wetlands, or both	Loss of coastal land and wetlands may result in less protection against coastal storms for key infrastructure, such as treatment facilities and sewage conveyance systems located on the coast, leading to additional damages, and disruptions in service.
	Floods	High stream or river flow events Coastal storm surges	Coastal and riverine flooding and storm surge may increase, placing wastewater treatment facilities at increased risk of flooding because they are typically located at lower elevations in watersheds or coastal regions. In addition, combined wastewater and stormwater systems may experience more frequent overflows when flooding overwhelms the treatment capacities of the systems.
	Service demand and use	Utilities’ energy needs	Increasing temperatures and treatment costs may cause wastewater treatment facilities to increase their already significant energy requirements. Increased energy demands for cooling may result in higher operating costs and loss of power if energy demand exceeds supply. These effects may be exacerbated during the summer, when electricity demand peaks.
	Water quality degradation	Low flow conditions	Higher temperatures and decreased flow can lead to diminished water quality in the bodies of water into which treated wastewater is released. This may result in the need for utilities to use advanced treatment processes, increasing costs to meet state or federal requirements for treated wastewater.

Source: GAO analysis of Environmental Protection Agency and U.S. Global Change Research Program data. | GAO-20-24

Appendix IV: Technical Assistance Providers That Selected Drinking Water and Wastewater Utilities Used

Table 6 provides additional information on the selected drinking water and wastewater utilities and the sources of technical assistance they used for climate resilience planning for fiscal years 2011 through 2018.

Table 6: Technical Assistance Providers That 15 Selected Drinking Water and Wastewater Utilities Used to Plan for Climate Resilience Projects, Fiscal Years 2011 through 2018

	Nonfederal technical assistance providers					Federal technical assistance providers								
City, utility (services provided)	**Academia**	**Consulting firms**	**Industry groups**	**In-house expertise**	**State agencies**	**U.S. Army Corps of Engineers**	**Environmental Protection Agency**	**Federal Emergency Management Agency**	**Department of Housing and Urban Development**	**National Oceanic and Atmospheric Administration**	**National Center for Atmospheric Research/University Corporation for Atmospheric Research**	**Bureau of Reclamation**	**Department of Agriculture**	Other
Anacortes, Washington														
City of Anacortes Public Works (DW)	—	—	●	—	—	—	—	—	—	—	—	—	—	—
Bozeman, Montana														
City of Bozeman Water and Sewer Division (DW,WW)	○	●	—	—	○	—	○[a]	—	—	—	—	—	—	—
Charleston, South Carolina														
Charleston Water System (DW,WW)	○	●	●	—	○	—	—	—	—	—	—	—	—	○[b]
Cottage Grove, Oregon														

	Nonfederal technical assistance providers					Federal technical assistance providers								
City, utility (services provided)	**Academia**	**Consulting firms**	**Industry groups**	**In-house expertise**	**State agencies**	**U.S. Army Corps of Engineers**	**Environmental Protection Agency**	**Federal Emergency Management Agency**	**Department of Housing and Urban Development**	**National Oceanic and Atmospheric Administration**	**National Center for Atmospheric Research/University Corporation for Atmospheric Research**	**Bureau of Reclamation**	**Department of Agriculture**	Other
City of Cottage Grove Public Works (DW,WW)	—	●	○	—	○	—	○[a]	—	—	—	—	—	—	—
Estes Park, Colorado														
Town of Estes Park Utilities' Water Division (DW)	—	●	—	—	—	○	—	○	—	—	—	—	—	—
Estes Park Sanitation District & Upper Thompson Sanitation District (WW)	—	●	—	—	○	—	○	○	—	—	—	—	—	—
Houston, Texas														
Houston Water (DW,WW)	○	●	○	●	○	○	○[a]	—	—	○	—	—	—	○[c]
Iowa City, Iowa														

	Nonfederal technical assistance providers					Federal technical assistance providers								
City, utility (services provided)	**Academia**	**Consulting firms**	**Industry groups**	**In-house expertise**	**State agencies**	**U.S. Army Corps of Engineers**	**Environmental Protection Agency**	**Federal Emergency Management Agency**	**Department of Housing and Urban Development**	**National Oceanic and Atmospheric Administration**	**National Center for Atmospheric Research/University Corporation for Atmospheric Research**	**Bureau of Reclamation**	**Department of Agriculture**	Other
City of Iowa City Public Works (DW, WW)	○	●	●	—	●	○	○[a]	○	○	○	—	—	—	—
Keene, New Hampshire														
City of Keene Public Works Department (DW,WW)	—	●	○	—	—	—	○[a]	—	—	—	—	—	—	○[d]
Miami, Florida														
Miami-Dade County Water and Sewer Department (DW,WW)	○	●	○	●	○	●	○[a]	—	—	○	—	—	—	●[e]
New York City, New York														

	Nonfederal technical assistance providers					Federal technical assistance providers								
City, utility (services provided)	Academia	Consulting firms	Industry groups	In-house expertise	State agencies	U.S. Army Corps of Engineers	Environmental Protection Agency	Federal Emergency Management Agency	Department of Housing and Urban Development	National Oceanic and Atmospheric Administration	National Center for Atmospheric Research/University Corporation for Atmospheric Research	Bureau of Reclamation	Department of Agriculture	Other
New York City Department of Environmental Protection (DW,WW)	○	●	●[f]	●	○	○	—	—	○	○	○	—	—	○[g]
Nogales, Arizona														
City of Nogales Public Works (DW)	○	—	○	—	○	○	●	—	—	○	—	○	—	●[h]
Norfolk, Virginia														
City of Norfolk Department of Utilities (DW,WW)	—	●	●	—	—	—	○[a]	—	—	—	—	—	—	—
San Diego, California														
San Diego Public Utilities Department (DW,WW)	○	●	○	●	○	—	○[a]	—	—	○	—	○	—	—

	Nonfederal technical assistance providers					Federal technical assistance providers								
City, utility (services provided)	Academia	Consulting firms	Industry groups	In-house expertise	State agencies	U.S. Army Corps of Engineers	Environmental Protection Agency	Federal Emergency Management Agency	Department of Housing and Urban Development	National Oceanic and Atmospheric Administration	National Center for Atmospheric Research/University Corporation for Atmospheric Research	Bureau of Reclamation	Department of Agriculture	Other
San Diego County Water Authority (DW)	—	●	○[f]	—	○	—	—	—	—	—	—	●	—	—

Legend:
DW = drinking water services provided
WW = wastewater services provided
● = Technical assistance provider primarily used by the drinking water and wastewater utility
○ = Technical assistance provider sometimes used by the drinking water and wastewater utility
— = Drinking water and wastewater utilities did not use this technical assistance provider

Source: GAO analysis of drinking water and wastewater utility response to GAO interview questions. | GAO-20-24

Notes:

[a]Utility representatives said that they used the Environmental Protection Agency's Climate Resilience Evaluation and Assessment Tool to identify potential climate change impacts and identify critical assets and measures to increase resilience.

[b]Charleston Water System representatives said that the U.S. Geological Survey conducted a chemical spill vulnerability assessment and developed flow models for the water system's 23-mile tunnel that supplies river water to the treatment facility. Charleston Water System representatives also said that the system is a member of the Charleston Resilience Network—a collaboration of local, regional, and state governmental leaders; public and private entities; and research institutions with a commitment to increasing resilience of communities, critical infrastructure, and socioeconomic continuity to episodic natural disasters and chronic coastal hazards.

[c]Houston Water used U.S. Geological Survey rainfall data.

[d]Keene Public Works Department representatives said they received technical assistance from vendors.

[e]Miami-Dade County Water and Sewer Department representatives said that they work with the U.S. Geological Survey to monitor groundwater levels, surface and groundwater interactions, and saltwater intrusion. The Miami-Dade County Water and Sewer Department is also a partner of the Southeast Florida Regional Climate Change Compact—a compact of four counties that coordinate climate-related mitigation and adaptation activities across county lines and work with state and federal agencies.

[f]The utility is a member of the Water Utility Climate Alliance.

[g]New York City Department of Environmental Protection representatives said they used USGS stream gauge data for planning.

[h]Nogales Public Works representatives said that they used technical assistance from the North American Development Bank and the U.S. Geological Survey.

Appendix V: Federal Programs That Provide Technical Assistance

The following federal programs have the potential to help drinking water and wastewater utilities, in particular smaller utilities that do not have the resources to conduct climate risk assessments and plan for measures to help make their drinking water and wastewater infrastructure more resilient to climate change impacts.

Several of the federal efforts we reviewed provide general assistance with planning and operating drinking water and wastewater infrastructure. Specifically:

- **Environmental Protection Agency's (EPA) Environmental Finance Centers.** The Environmental Finance Centers provide targeted technical assistance to, and partner with states and the private sector to help manage the costs of environmental financing. Environmental Finance Centers can provide technical assistance for financing drinking water and wastewater infrastructure and its operations and maintenance.
- **EPA's Training and Technical Assistance for Small Systems Grants.** EPA's Training and Technical Assistance to Small Systems grants provide funding to nonprofit organizations to provide training and technical assistance to small public water systems, small wastewater systems, and private well owners, located in urban and rural communities in the U.S. and its territories. According to EPA officials, training and technical assistance to small systems facing drought, flooding, and other weather-related challenges is an eligible activity for the grants.
- **Department of Agriculture's (USDA) Rural Water and Wastewater Technical Assistance and Training Program.** USDA's Rural Water and Wastewater Technical Assistance and Training Program provides grants to nonprofits such as the National Rural Water Association and the Rural Community Assistance Partnership to provide training and technical assistance to small and rural utilities for operating, managing, and financing drinking water and wastewater infrastructure.[1]
- **USDA's Rural Water and Wastewater Circuit Rider Program.** USDA contracts with a qualified national organization, through its Circuit Rider program, to provide technical assistance to rural water and wastewater systems to provide technical assistance to rural

[1]According to USDA officials, they also award grant funding to universities, industry groups, tribal associations, and engineering and environmental consultants.

utilities for operating, managing, and financing water and wastewater infrastructure. Circuit riders also provide critical assistance in disaster response and recovery. The circuit rider contract was awarded to the National Rural Water Association in fiscal year 2019.

Other federal efforts help decision makers use climate information in existing planning processes. Specifically:

- **USDA Climate Hubs.** USDA established regional Climate Hubs to deliver science-based knowledge and practical information to farmers, ranchers, and forest landowners to support decision-making related to climate change.
- **Department of the Interior's (Interior) Landscape Conservation Cooperatives.** Interior developed a network of collaborative Landscape Conservation Cooperatives composed of federal, state, local, and tribal governments; nongovernmental organizations; universities; and interested public and private organizations to, manage large landscapes such as national forests, grasslands, and wetlands. As part of this program, the groups develop and provide the science and technical expertise needed to apply climate data in natural resources decision-making.
- **U.S. Geological Survey's Climate Adaptation Science Centers.** Climate Adaptation Science Centers partner with natural and cultural resource managers to provide science that helps fish, wildlife, ecosystems, and the communities they support adapt to climate change by, among other things, providing climate, water, and ecosystem information to decision makers.[2]
- **National Oceanic and Atmospheric Administration's (NOAA) Regional Integrated Sciences and Assessments (RISA) Program.** NOAA's RISA program supports a network of 11 regional research teams that work with public and private decision makers to identify and provide specific climate information and models to identify risks and adaptation options to increase resilience to climate variability and change. One area of emphasis for the RISA teams is conducting research on climate and water management issues while engaging with a range of water management organizations, including some water utilities.

[2]The Climate Adaptation Science Centers were formerly known as the Climate Science Centers. The name of the centers changed in March 2018.

- **National Center for Atmospheric Research (NCAR).** NCAR carries out interdisciplinary research on adaptation to climate change by generating scenarios of projected climate change, developing scientific tools and methods for analyzing current and future vulnerability, and conducting integrated analyses of climate change impacts and adaptation. An important component of NCAR's program is the integration of decision makers and users of climate information, including water utilities, into its research activities. NCAR provides the atmospheric research community in academia, government, and the private sector with the shared resources necessary to conduct their research.

Appendix VI: Examples of Ongoing and Completed Drinking Water and Wastewater Capital Improvement Projects to Enhance Climate Resilience

Table 7 presents examples of drinking water and wastewater capital improvement projects to enhance climate resilience, according to utility representatives, from fiscal years 2011 through 2018.

Table 7: Examples of Drinking Water Infrastructure and Wastewater Capital Improvement Projects to Enhance Climate Resilience, According to 15 Selected Utilities, Fiscal Years 2011 through 2018

City, utility	Examples of drinking water infrastructure projects to enhance climate resilience	Examples of wastewater infrastructure projects to enhance climate resilience
Anacortes, Washington		
Anacortes Public Works[a]	Replaced the existing drinking water treatment facility with a new facility on the same site, and incorporated flood-resistant and sediment-tolerant resilience measures.	—
Bozeman, Montana		
Bozeman Water and Sewer	Replaced drinking water treatment facility and increased the ability to treat water with high sediment levels post-wildfires.	Replaced wastewater treatment facility and increased filtration capacity for nitrogen and phosphorus, and installed backup power generators at the wastewater treatment facility and pump stations.
Charleston, South Carolina		
Charleston Water System	Hired source water manager to improve source water quality and elevated flood control panels.	Consolidated power generators at the wastewater treatment facility and regional pump stations to increase capacity if a generator stops working during a storm, and replaced a network of deep tunnels that carry raw sewage to the wastewater treatment facility.
Cottage Grove, Oregon		
Cottage Grove Public Works	Upgraded drinking water treatment facility to increase treatment capacity, upgraded the source water intake pipe to ensure adequate water supply during droughts, implemented blue-green algae cyanotoxin testing at the water intake pipe, and installed a backup power generator at drinking water treatment facility.	Installing green infrastructure to increase stormwater capacity.
Estes Park, Colorado		
Estes Park Utilities	Modified source water intake pipe to enhance drought and flood resilience, and collaborating with other utilities to build a new reservoir for additional water supply.	—
Estes Park Sanitation District & Upper Thompson Sanitation District	—	Fortified the wastewater collection system, built a new grit removal filtration system, installed backup generators and pumps, and relocated, replaced, or reinforced vulnerable sewer lines crossing rivers.
Houston, Texas		
Houston Water	Diversified water supply by expanding use of surface water and recycled water, and built a deeper intake and pump station at reservoir.	Hardening treatment plants and lift stations, consolidating treatment plants and lift stations, and building large sewer tunnels to hold wastewater.
Iowa City, Iowa		

City, utility	Examples of drinking water infrastructure projects to enhance climate resilience	Examples of wastewater infrastructure projects to enhance climate resilience
Iowa City Public Works	Installed flood doors, elevated electrical panels, built an elevated generation docking station and switchgear pads, and replaced exposed water mains at two river crossings.	Decommissioned and relocated treatment plant to a low-risk area outside the floodplain.
Keene, New Hampshire		
Keene Public Works	Strengthened and increased the capacity of two dams with articulated locks, and built larger flood spillways.	Raised the elevation of the effluent system at the treatment plant above 500-year flood level.
Miami, Florida		
Miami-Dade County Water and Sewer Department	Performed a vulnerability analysis of drinking water facilities and is considering storm surge and sea level rise in the design of new drinking water assets.	Hardening, replacing, or elevating wastewater treatment facilities and pump stations, installed backup generators at wastewater treatment facilities and pumping stations, stockpiled critical supplies and spare parts at storage facilities in less vulnerable areas. Design flood elevations and implementation guidelines have been developed for each of the three wastewater treatment plants and pump stations
New York City, New York		
New York City Department of Environmental Protection	Implemented watershed protection programs in the Catskill and Delaware watersheds, including rehabilitating upstate septic systems and buying land surrounding the reservoirs to protect water quality. Building large tunnels to provide critical drinking water supply capacity.	Adopted new wastewater facility design standards to account for critical flood elevations, upgraded and hardened wastewater treatment plants and pumping stations for sea level rise, infiltration and inflow, and saltwater intrusion, and installed green infrastructure to help manage stormwater.
Nogales, Arizona		
Nogales Public Works[a]	Developed a modeling tool to simulate climate impacts on surface water and groundwater sources to optimize different water sources. Increased protective banks surrounding wells, and raised water supply wells to protect water supply against floods.	—
Norfolk, Virginia		
Norfolk Department of Utilities	Installed multiple water intakes for redundancy and built emergency spillways at reservoir. Constructed earthen berm, installed flood stop plates and sealing doors, and elevated generators at treatment facility.	Elevated critical electrical equipment and pumps, and installed backup generators and bypass pumps.
San Diego, California		
San Diego Public Utilities Department	Building a wastewater pump station and pipelines to transport increased wastewater flows to the expanded water reclamation treatment facility, building a new reclamation treatment facility to further clean recycled water to meet state and federal drinking water standards, and building a recycled water pump station and pipelines to transport treated recycled water to a reservoir.	Changed the wastewater treatment process to better handle reduced wastewater flows, and relocated canyon sewer pipelines vulnerable to severe erosion from storms.

City, utility	Examples of drinking water infrastructure projects to enhance climate resilience	Examples of wastewater infrastructure projects to enhance climate resilience
San Diego County Water Authority[a]	Diversifying water supply with groundwater, recycled water, and seawater desalination. Built a new reservoir and connected it to existing reservoirs to increase water storage capacity and improve water distribution throughout the region.	—

Legend:
— = Not applicable. The utility does not provide these services or GAO did not interview the utility.

Source: GAO analysis of information from drinking water and wastewater utility officials. | GAO-20-24

Appendix VII: Types of Financial Assistance Used by Selected Drinking Water and Wastewater Utilities on Capital Improvement Projects to Enhance Climate Resilience

Table 8 presents additional information on financial assistance used by utilities we reviewed for capital improvement projects to enhance their climate resilience for fiscal years 2011 through 2018.

Table 8: Types of Financial Assistance That 15 Selected Drinking Water and Wastewater Utilities Used for Capital Improvement Projects to Enhance Climate Resilience, Fiscal Years 2011 through 2018

			Environmental Protection Agency			Federal Emergency Management Agency		Department of Housing and Urban Development		Department of Agriculture	
City, state, utility (services provided)	Municipal bonds	User rates and fees	Clean Water State Revolving Fund	Drinking Water State Revolving Fund	Water Infrastructure and Finance Innovation Act	Hazard Mitigation Grant Program	Public Assistance	Community Development Block Grant	Community Development Block Grant-Disaster Recovery	Water and Waste Disposal Program	Other
Anacortes, Washington											
City of Anacortes Public Works (DW)	●	●	NA	○	—	—	—	—	—	—	—
Bozeman, Montana											
City of Bozeman Water and Sewer (DW,WW)	●	●	○	●	—	—	—	—	—	—	—
Charleston, South Carolina											
Charleston Water System (DW,WW)	●	●	—	—	—	—	—	—	—	—	—
Cottage Grove, Oregon											
Cottage Grove Public Works (DW,WW)	●	●	—	—	—	—	—	—	—	—	—
Estes Park, Colorado											
Estes Park Utilities (DW)	—	●	NA	○	—	○	○	—	○	○	—
Estes Park Sanitation District & Upper Thompson Sanitation District (WW)	—	●	○	NA	—	—	○	—	—	—	—

			Environmental Protection Agency			Federal Emergency Management Agency		Department of Housing and Urban Development		Department of Agriculture	
City, state, utility (services provided)	Municipal bonds	User rates and fees	Clean Water State Revolving Fund	Drinking Water State Revolving Fund	Water Infrastructure and Finance Innovation Act	Hazard Mitigation Grant Program	Public Assistance	Community Development Block Grant	Community Development Block Grant-Disaster Recovery	Water and Waste Disposal Program	Other
Houston, Texas											
Houston Water (DW,WW)	●	●	○	○	—	○[a]	○[a]	—	—	—	—
Iowa City, Iowa											
Iowa City Public Works (DW,WW)	●	●	○	—	—	●	●	—	●	—	○[b]
Keene, New Hampshire											
Keene Public Works (DW,WW)	●	●	○	—	—	—	—	—	—	—	—
Miami, Florida											
Miami-Dade County Water and Sewer Department (DW,WW)	●	●	●	●	○	○	○	—	—	—	—
New York City, New York											
New York City Department of Environmental Protection (DW,WW)	●	●		—	—	○	○	—	—	—	—
Nogales, Arizona											
Nogales Public Works (DW)	●	●	NA	○	—	—	—	○	—	—	○[d]
Norfolk, Virginia											
Norfolk Department of Utilities (DW,WW)	●	●	●	—	—	—	○	○	—	—	—
San Diego, California											

			Environmental Protection Agency			Federal Emergency Management Agency		Department of Housing and Urban Development		Department of Agriculture	
City, state, utility (services provided)	Municipal bonds	User rates and fees	Clean Water State Revolving Fund	Drinking Water State Revolving Fund	Water Infrastructure and Finance Innovation Act	Hazard Mitigation Grant Program	Public Assistance	Community Development Block Grant	Community Development Block Grant-Disaster Recovery	Water and Waste Disposal Program	Other
San Diego Public Utilities Department (DW,WW)	●	●	○	○	○[c]	—	—	—	—	—	—
San Diego County Water Authority (DW)	●	●	NA	—	—	—	—	—	—	—	—

Legend:
DW = drinking water services provided
WW = wastewater services provided
NA = not applicable
● = Financial assistance provider primarily used by the utility
○ = Financial assistance provider sometimes used by the utility
— = Utility did not use this financial assistance

Source: GAO analysis of information from drinking water and wastewater utility officials | GAO-20-24

[a]As of December 2018, Houston Water representatives said that they are still assessing the damage to their wastewater infrastructure from Hurricane Harvey in 2017 and plan to apply for Federal Emergency Management Agency Public Assistance and Hazard Mitigation Grant Program grants.

[b]Iowa City Public Works representatives said that they used Economic Development Administration funding.

[c]Utility representatives said that they are applying for the Environmental Protection Agency's Water Infrastructure and Financing Innovation Act loans to help fund climate resilience projects.

[d]Nogales Public Works used grants from the North American Development Bank.

Appendix VIII: Comments from the Environmental Protection Agency

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC 5 2019

OFFICE OF WATER

Mr. Alfredo Gomez
Director
Natural Resources and Environment
U.S. Government Accountability Office
Washington, D.C. 20548

Dear Mr. Gomez:

Thank you for the opportunity to review and comment on the U.S. Government Accountability Office's (GAO) draft report, "Water Infrastructure: Technical Assistance and Climate Resilience Planning Could Help Utilities Prepare for Potential Climate Change Impacts" (GAO-20-24). The purpose of this letter is to provide the EPA's responses to the draft report's findings, conclusions, and the recommendation for the EPA.

In this report, GAO recommends that: ***"The Administrator of EPA, as the chair of the Water Sector Government Coordinating Council, should work with the Council to identify existing technical assistance providers and engage these providers in a network to help drinking water and wastewater utilities incorporate climate resilience into their projects and planning on an ongoing basis. (Recommendation 1)"***

The resiliency of drinking water and wastewater utilities is important to the sustainability of those systems, the local economies in which they operate, and to the American public, all of which rely on safe drinking water and clean wastewater management on a daily basis. The EPA's Office of Water currently works with partners through numerous programs and forums across the water sector to provide knowledge, technical assistance, financing, and other tools to ensure investments made in water infrastructure are sustainable and resilient in the long term. The EPA Office of Water has developed a robust suite of resources and assistance to improve the resilience of the water sector to all types of hazards, including climate impacts. As noted in the GAO report, the EPA leads the Creating Resilient Water Utilities (CRWU) initiative, which assists drinking water and wastewater utilities in addressing long term resiliency planning. Through CRWU and other initiatives and programs, the EPA actively engages with water sector stakeholders and technical assistance providers to promote the integration of resilience into drinking water and wastewater projects as well as utilities' routine planning efforts. This initiative has provided drinking water, wastewater, and stormwater utilities with practical tools, resources, training, and technical assistance needed to increase resilience to extreme weather events.

The Agency continues to provide training and technical assistance support to states and public water systems to improve system operations and management practices, promote sustainability and support the EPA's mission to protect public health and the environment. For example, the EPA provides annual training to over 5,000 water utilities, state officials, and federal emergency responders on how to become more resilient to any natural or manmade incident that could endanger water and wastewater services. In regard to assistance, the Agency currently works with a variety of training and technical assistance providers to support compliance with regulations and to improve the ability of drinking water and wastewater systems to respond to weather-related events. Under the EPA's Small System Training and Technical Assistance Grant, a specific eligible activity is training and technical assistance to small drinking water utilities facing earthquake impacts, drought, flooding, severe storms, and other weather-related challenges. The technical assistance providers referenced in the report (e.g., the National Rural Water Association and the Rural Community Assistance Program) are currently funded by the EPA to work with utilities on compliance and resiliency issues. Under the EPA's Small System Training and Technical Assistance grant, states serve as a point of coordination for technical assistance work. Also as noted in the report, the Environmental Finance Centers provide targeted technical assistance to states, utilities, and the private sector to help manage the costs of environmental financing, drinking water and wastewater infrastructure projects, operating and maintaining water utilities, and long-term asset management planning. An Environmental Finance Center is currently located in each of the ten EPA Regions and is funded through discretionary Agency extramural funds through a five-year cooperative agreement.

Consistent with the GAO's recommendation, the EPA will continue to work with its wide-ranging, existing technical assistance providers and coordinate with its stakeholders to identify additional providers as applicable. In response to the GAO recommendation that the EPA engage the providers in a network, the EPA notes that states serve as a coordinating entity under the EPA's Small System Training and Technical Assistance grant. The providers work with the states to identify the systems in greatest need of assistance and identify the training topics of greatest need for small public water systems.

Technical comments on the draft report are provided as an enclosure to this letter.

We appreciate the opportunity to review the draft report. If you have further questions, please contact David Travers at 202-564-4638 or travers.david@epa.gov, or Raffael Stein at 202-564-5385 or stein.raffael@epa.gov.

Sincerely,

Charlotte Bertrand

for David P. Ross
Assistant Administrator

Enclosures

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Appendix IX: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, Susan Iott (Assistant Director), Micah McMillan (Analyst-in-Charge), Jim Ashley, Mark Braza, Colleen Candrl, Caitlin Cusati, John Delicath, David Dornisch, Kathryn Godfrey, Holly Halifax, Karen Howard, Rob Letzler, Jon Melhus, Patricia Moye, Eve Nealon, Sam Portnow, Dan Royer, Kiki Theodoropoulos, Joe Thompson, Seyda Wentworth, and Melissa Wolf provided key contributions to this report.

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