



July 2015

# ARMY CORPS OF ENGINEERS

## Efforts to Assess the Impact of Extreme Weather Events

Highlights of GAO-15-660, a report to congressional committees

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### Efforts to Assess the Impact of Extreme Weather Events

#### Why GAO Did This Study

The Corps plans, designs, and constructs water resources infrastructure, such as dams and levees. According to the U.S. Global Change Research Program, the frequency and intensity of extreme weather events are increasing. Much of the Corps' infrastructure was built over 50 years ago and may not be designed to operate within current climate patterns, according to the U.S. Geological Survey.

The Water Resources Reform and Development Act of 2014 included a provision for GAO to study the Corps' management of water resources in preparation for extreme weather. This is the first in a series of reports GAO is issuing on this topic. GAO's other reports will examine operations and dam and levee safety, which GAO plans to issue in fiscal year 2016. This report explores (1) how the Corps prepares for and responds to extreme weather events in its planning and operation of water resources projects, and (2) the extent to which the Corps has assessed whether existing water resources infrastructure is prepared for extreme weather events. GAO reviewed Corps guidance on planning, operations, and assessments, and interviewed Corps officials from headquarters and eight districts—selected, in part, on number of projects.

#### What GAO Recommends

GAO previously recommended that the Corps work with Congress to develop a more stable funding approach. The Corps has not taken action, but GAO continues to believe the recommendation is valid. Agencies had no comments on a draft of this report.

View [GAO-15-660](#). For more information, contact Anne-Marie Fennell at (202) 512-3841 or [fennella@gao.gov](mailto:fennella@gao.gov)

#### What GAO Found

The U.S. Army Corps of Engineers (Corps) considers the potential impact of extreme weather events in its planning and operations of water resources infrastructure projects by, among other things, updating and developing guidance on how to incorporate different extreme weather scenarios in its planning of projects. For example, in 2014, the Corps issued guidance on how to evaluate the effects of projected future sea level change on its projects and what to consider when adapting projects to this projected change. In addition, Corps districts prepare water control manuals, guidance outlining project operations. The Corps can approve deviations from the manuals to alleviate critical situations, such as extreme weather events. For example, in December 2014, the Corps approved a deviation from operations at a southern California dam, which allowed the Corps to retain rainwater to help respond to the state's extreme drought conditions.

The Corps has assessed certain water resources infrastructure projects to determine whether they are designed to withstand extreme weather events. Specifically, the Corps has national programs in place to perform risk assessments on dams and levees, as required by law. Unlike the requirements for dams and levees, the Corps is not required to perform systematic, national risk assessments on other types of existing infrastructure, such as hurricane barriers and floodwalls and has not done so (see table). However, the Corps has been required to assess such infrastructure after an extreme weather event in response to statutory requirements, as it did in November 2013 and in January 2015, after Hurricane Sandy. Also, the Corps has performed initial vulnerability assessments for sea level rise on its coastal projects and has begun conducting such assessments at inland watersheds.

#### U.S. Army Corps of Engineers' Systematic, National Infrastructure Risk Assessments, 2006-June 2015

Type of infrastructure	Number of projects	Number of assessments
Dams	707	706
Levees (in segments)	2,887	1,232
Other <sup>a</sup>	<sup>b</sup>	0

Source: GAO analysis of Corps data. | GAO-15-660

<sup>a</sup>Other includes infrastructure, such as hurricane barriers and floodwalls.

<sup>b</sup>The Corps has not yet completed an inventory of other types of infrastructure.

Unlike federal agencies that have budgets established for broad program activities, most Corps civil works funds are appropriated for specific projects. However, the Corps has not worked with Congress to develop a more stable funding approach, as GAO recommended in September 2010, which could facilitate conducting risk assessments. The Corps partially concurred with this recommendation, stating that it would promote efficient funding. As the frequency and intensity of some extreme weather events are increasing, without performing systematic, national risk assessments on other types of infrastructure, such as hurricane barriers and floodwalls, the Corps will continue to take a piecemeal approach to assessing risk on such infrastructure.

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## Abbreviations

CEQ	Council on Environmental Quality
Corps	U.S. Army Corps of Engineers
CWMS	Corps Water Management System
NDBC	National Data Buoy Center
NEPA	National Environmental Policy Act of 1969
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWC	National Water Center
NWS	National Weather Service
SCAN	Soil Climate Analysis Network
SNOTEL	Snow Telemetry
USGS	U.S. Geological Survey
WRDA	Water Resources Development Act
WRRDA	Water Resources Reform and Development Act of 2014

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U.S. GOVERNMENT ACCOUNTABILITY OFFICE

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Washington, DC 20548

July 22, 2015

The Honorable James Inhofe  
Chairman  
The Honorable Barbara Boxer  
Ranking Member  
Committee on Environment and Public Works  
United States Senate

The Honorable Bill Shuster  
Chairman  
The Honorable Peter DeFazio  
Ranking Member  
Committee on Transportation and Infrastructure  
House of Representatives

The U.S. Army Corps of Engineers (Corps) is the world's largest public engineering, design, and construction management agency, with water resources infrastructure in every state, authorized for various purposes including navigation, flood and coastal storm damage reduction, hydropower, and water supply. The Corps plans, designs, and operates water resources infrastructure projects, such as dams, levees, hurricane barriers, floodwalls, and floodgates, that may be affected by extreme weather events. These extreme weather events include, among other things, flood, drought, and severe storms. According to the National Research Council and the U. S. Global Change Research Program's May 2014 National Climate Assessment, precipitation patterns are changing, and the frequency and intensity of some extreme weather events are increasing.<sup>1</sup> The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) found that, from 2010 through 2014, there have been 49 extreme weather events with losses exceeding \$1 billion. Much of the Corps' infrastructure was built more than 50 years ago and, according to the Department of the Interior's U.S. Geological Survey (USGS), aging infrastructure may not meet its design level of performance under the current climate and could be more vulnerable to

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<sup>1</sup>Jerry M. Melillo, Terese (T.C.) Richmond, and Gary W. Yohe, eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program (Washington D.C.: May 2014).

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failure under future climate scenarios. Moreover, the USGS has reported that, of all the potential threats posed by changing weather patterns, those associated with water resources are arguably the most consequential for both society and the environment.<sup>2</sup> Federal agencies, such as NOAA, USGS, and the Department of Agriculture's Natural Resources Conservation Service (NRCS), all collect and interpret weather and climate information the Corps uses in its management of water resources.

Section 3024 of the Water Resources Reform and Development Act of 2014 (WRRDA) included a provision for GAO to conduct a study of the strategies used by the Corps for management of water resources in preparation for and response to extreme weather. This report explores (1) how the Corps prepares for and responds to extreme weather events in its planning and operation of water resources infrastructure projects and (2) the extent to which the Corps has assessed whether existing water resources infrastructure is prepared for extreme weather events. This is the first in a series of reports we are issuing related to efforts by the Corps to manage water infrastructure resources. Specifically, we have work ongoing or commencing that will look more in depth at Corps project operations, dam safety, and levee safety, which we plan to issue in fiscal year 2016.

To determine how the Corps prepares for and responds to extreme weather events in its planning and operation of water resources infrastructure projects, we reviewed executive orders and Corps guidance on planning, operations, and assessments of infrastructure relating to extreme weather. For example, we reviewed Corps guidance for incorporating sea level rise into studies of new water resources projects, as well as water control manuals used to manage existing water resources projects. We reviewed and analyzed reports, studies, and plans from the Corps, including annual Corps Climate Change Adaptation Plans and the Corps' Climate Preparedness and Resilience Policy Statement. We interviewed Corps headquarters officials to obtain additional information about the agency's policies, procedures, and processes for planning, operations, and assessments of infrastructure to prepare for and respond to extreme weather events, as well as any

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<sup>2</sup>Harry F. Lins, Hirsch, Robert M., and Kiang, Julie, *Water—the Nation's Fundamental Climate Issue: A White Paper on the U.S. Geological Survey Role and Capabilities: U.S. Geological Survey Circular 1347* (2010).

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challenges associated with incorporating that information. We also reviewed reports and spoke to agency officials that represent the Corps in interagency efforts such as the Climate Change and Water Resource Working Group.<sup>3</sup> In addition to officials from the Corps, we also interviewed officials from USGS, NOAA, and NOAA's National Weather Service (NWS), NRCS, and the Bureau of Reclamation to learn about how the Corps interacts with these agencies and what extreme weather data they obtain from these agencies.

To determine the extent to which the Corps has assessed whether existing water resources infrastructure is prepared for extreme weather events, we reviewed relevant Corps policies and guidance related to conducting infrastructure assessments. We also interviewed officials from the Corps' Response to Climate Change Program who led vulnerability assessments. We spoke to Corps officials responsible for carrying out the dam and levee safety programs to obtain additional information regarding the development of each program. Finally, we reviewed reports on the Corps' vulnerability assessments to learn the extent to which the Corps has considered extreme weather impacts on its existing water infrastructure projects.

In addition to conducting interviews with officials from Corps headquarters, for both of our objectives, we also interviewed officials from a nongeneralizable sample of eight districts to determine their procedures for incorporating information on extreme weather events into their planning, operations, and assessments.<sup>4</sup> We selected these district offices to get a range of perspectives based on geographical location, number of ongoing water resources infrastructure projects, as well as

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<sup>3</sup>According to its website, the Climate Change and Water Resource Working Group is a working-level forum that fosters communication and research partnerships around these needs across the water and science communities of practice. The participating federal agencies include: the Bureau of Reclamation, the Corps, the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, the Environmental Protection Agency, the Federal Emergency Management Agency, the National Aeronautics and Space Administration, and the U.S. Department of Agriculture.

<sup>4</sup>We spoke with Corps officials from the following districts: Baltimore, Maryland (North Atlantic Division); Savannah, Georgia (South Atlantic Division); Vicksburg, Mississippi (Mississippi Valley Division); Louisville, Kentucky (Great Lakes and Ohio River Division); Little Rock, Arkansas (Southwestern Division); Walla Walla, Washington (Northwestern Division); Los Angeles, California (South Pacific Division); and Anchorage, Alaska (Pacific Ocean Division).

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types of recent extreme weather events a district may have experienced from 2011 through 2014. We chose this time frame because implementing guidance for a 2009 executive order on climate change and internal Corps guidance on planning and operating infrastructure were released or updated during these years.

We conducted this performance audit from November 2014 to July 2015 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.

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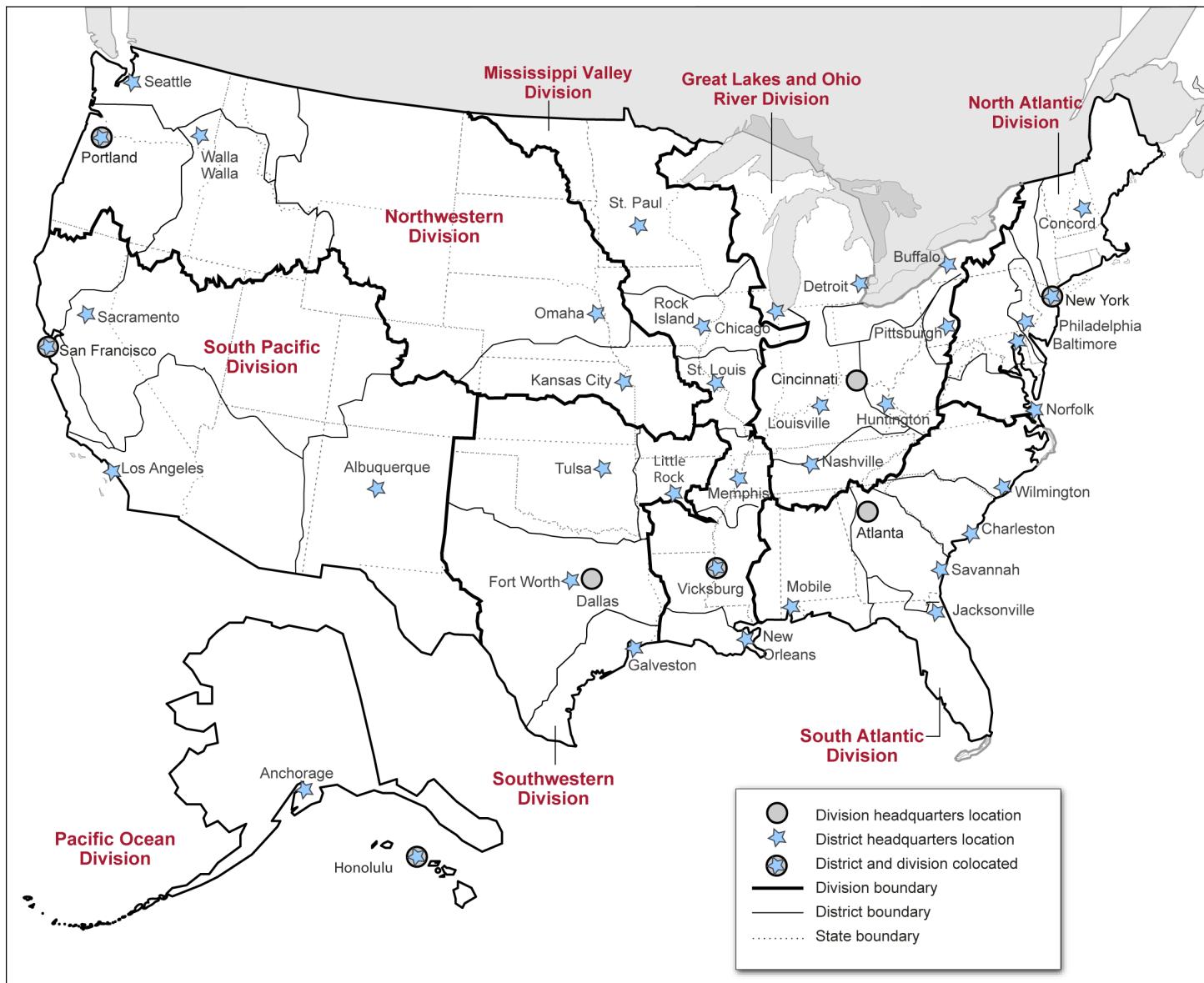
## Background

Located within the Department of Defense, the Corps has both military and civilian responsibilities.<sup>5</sup> Through its Civil Works program, the Corps plans, designs, constructs, operates, and maintains a wide range of water resources infrastructure projects for purposes such as flood control, navigation, and environmental restoration. The Civil Works program is organized into three tiers: a national headquarters in Washington, D.C.; eight regional divisions that were established generally according to watershed boundaries; and 38 districts nationwide (see fig. 1).

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<sup>5</sup>The Corps' Military program provides, among other things, engineering and construction services to other U.S. government agencies and foreign governments. This report only discusses the Civil Works program.

**Figure 1: Locations of the U.S. Army Corps of Engineers' Civil Works Divisions and Districts**



Sources: U.S. Army Corps of Engineers; Map Resources (map). | GAO-15-660

Note: In addition to the eight divisions that manage U.S. water resources, the Corps operates a Europe District as well as a Transatlantic Division composed of the Middle East District and the Transatlantic Afghanistan District.

Corps headquarters primarily develops policies and provides oversight. The Assistant Secretary of the Army for Civil Works, appointed by the President, establishes the policy direction for the Civil Works program.

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The Chief of Engineers, a military officer, oversees the Corps' civil works operations and reports on civil works matters to the Assistant Secretary of the Army for Civil Works. The eight divisions, commanded by military officers, coordinate civil works projects in the districts within their respective geographic areas. Corps districts, also commanded by military officers, are responsible for planning, engineering, constructing, and managing water resources infrastructure projects in their districts. Districts are responsible for coordinating with the nonfederal sponsors, which may be state, tribal, county, or local governments or agencies. Each project has a project delivery team of civilian employees that manages the project over its life cycle. The team is led by a project manager and comprises members from the planning, engineering, construction, operations, and real estate functions.

In addition, the Civil Works program maintains a number of centers of expertise and research laboratories to assist the Corps divisions and districts in the planning, design, and technical review of civil works projects.<sup>6</sup> The Corps established these centers to consolidate expertise, improve consistency, reduce redundancy, and enhance institutional knowledge, among other things.

Unlike many other federal agencies that have budgets established for broad program activities, most Corps civil works funds are appropriated for specific projects. In general, the Corps receives "no-year" appropriations through the Energy and Water Development Appropriations Act—that is, there are no time limits on when the funds may be obligated or expended, and the funds remain available for their original purposes until expended. The conference report accompanying the annual Energy and Water Development Appropriations Act generally lists individual projects and specific allocations of funding for each project. Through this report, the appropriations committees essentially outline their priorities for the Corps' water resources projects. Congress directs funds for many individual projects in increments over the course of several years.

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<sup>6</sup>The Centers of Expertise program is two-tiered with centers being mandatory or voluntary. For a full list of the Corps' centers of expertise, see <http://www.usace.army.mil/about/centersofexpertise.aspx>.

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## Steps for Developing Corps Projects

### The Corps' Planning and Design Process

The Corps is responsible for planning, designing, and operating much of the nation's water resources infrastructure. To do so, the Corps generally goes through a series of steps involving internal and external stakeholders.

Usually, the Corps becomes involved in water resources infrastructure projects when a local community perceives a need or experiences a problem that is beyond its ability to solve and contacts the Corps for assistance. If the Corps does not have the statutory authority required for studying the problem, the Corps must obtain authorization from Congress before proceeding.<sup>7</sup> Studies have been authorized through legislation, typically a Water Resources Development Act (WRDA), or, in some circumstances, through a committee resolution by an authorizing committee. Next, the Corps must receive an appropriation to study the project, which it seeks through its annual budget request to Congress.

After receiving authorization and an appropriation, a feasibility study is to be conducted.<sup>8</sup> A Corps district office is to conduct a feasibility study, the cost of which is generally shared by a nonfederal sponsor, which may be a state, tribal, county, or local government, or agency. The feasibility study investigates the problem and makes recommendations on whether the project is worth pursuing and how the problem should be addressed. The district office is to conduct the study and any needed environmental studies and document the results in a feasibility report.

At specific points within the feasibility stage, a new infrastructure project is to undergo a series of technical reviews at the district, regional, and national level to assess the project's methodology and to ensure that all relevant data and construction techniques are considered. At the district level, all decision documents and their supporting analysis for a new project are to undergo a district quality control review by district

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<sup>7</sup>If the Corps has previously performed an evaluation in the geographic area for a similar purpose, a new study can be authorized by an authorizing committee resolution. If the Corps has not previously investigated the area, the study needs to be authorized through legislation.

<sup>8</sup>Pub. L. No. 113-121, § 1002(a)(2), 128 Stat. 1193 (2014). Prior to WRRDA 2014, the Corps conducted studies in two phases: reconnaissance and feasibility. The reconnaissance study was conducted at full federal expense to determine if the problem warranted federal participation in a feasibility study and how the problem could be addressed. WRRDA 2014 eliminated the reconnaissance phase to accelerate the study process and allow the Corps to proceed directly to the feasibility study.

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leadership. This review is to assess the science and engineering work products to ensure that they are fulfilling project quality requirements. At the regional level, decision documents are to undergo an agency technical review by Corps officials from districts outside of the one conducting the study. This review verifies the district quality control review, assesses whether the analyses presented are technically correct and comply with published Corps guidance, and determines whether the documents explain the analyses and results in a reasonably clear manner for the public and decision makers. In some instances, a new project meeting certain criteria may also undergo an Independent External Peer Review.<sup>9</sup> For these Independent External Peer Reviews, the Corps is required by law to contract with the National Academy of Sciences, a similar independent scientific and technical advisory organization, or an “eligible organization” to establish a panel of experts that will review a project study.<sup>10</sup> Several criteria are used for selecting peer review panel members, including assessing and balancing members’ knowledge, experience, and perspectives in terms of the subtleties and complexities of the particular scientific, technical, and other issues to be addressed.<sup>11</sup>

After going through various levels of review, depending on the project, the Chief of Engineers is to review the report and decide whether to sign a final decision document, known as the Chief’s Report, recommending the project for construction. The Chief of Engineers is to transmit the Chief’s Report and the supporting documentation to Congress through the Assistant Secretary of the Army for Civil Works and the Office of

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<sup>9</sup>Section 2034 of WRDA 2007 as amended (Pub. L. No. 110-114, § 2034 (2007), as amended by Pub. L. No. 113-121, § 1044 (2014)). A project must be subject to Independent External Peer Review if it meets at least one of the following criteria, and it is not a project excluded from peer review: the project has an estimated total cost of more than \$200 million; the Governor of an affected state requests an independent peer review; or the Chief of Engineers determines that the project study is controversial (i.e., significant public dispute exists as to the project’s size, nature, or effects, or its economic or environmental costs or benefits). In addition, the Chief of Engineers must consider a project for peer review if heads of certain federal or state agencies request it.

<sup>10</sup>Section 2034(l)(3) of WRDA 2007 defines an eligible organization as one that: (1) is a 501(c)(3) tax-exempt organization, (2) is independent, (3) is free from conflicts of interest, (4) does not carry out or advocate for or against federal water resources projects, and (5) has experience in establishing and administering peer review panels.

<sup>11</sup>GAO examined the Corps’ project peer review process in GAO, *Army Corps of Engineers: Peer Review Process for Civil Works Project Studies Can Be Improved*, GAO-12-352 (Washington, D.C.: Mar. 8, 2012).

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Management and Budget. Congress may authorize the project's construction in a WRDA or other legislation.<sup>12</sup>

Most infrastructure projects are authorized during the preconstruction engineering and design phase, which begins after the feasibility study is complete. The purpose of this phase is to complete any additional planning studies and all of the detailed technical studies and designs needed to begin construction of the infrastructure project.<sup>13</sup> Once the construction project has been authorized, the Corps seeks funds to construct the infrastructure project through the annual budget formulation process. As part of the budget process, the Army, with input and data from Corps headquarters, division, and district offices, develops a budget request for the agency. In fiscal year 2006, the Corps introduced what it refers to as performance-based budgeting, which uses performance metrics to evaluate projects' estimated future outcomes and gives priority to those it determines have the highest expected returns for the national economy and the environment, as well as those that reduce risk to human life. Congress directs funds for individual projects in increments over the course of several years. If the infrastructure project has been appropriated funds, the district enters into a cost-sharing agreement with the nonfederal sponsor.

#### The Corps' Operations and Maintenance

Once construction is completed, the Corps may turn over operation and maintenance of the infrastructure project to the nonfederal sponsor, which then bears the full cost, or the Corps may operate and maintain the project itself. Typically, the Corps operates and maintains reservoirs, locks, dams, and other water control infrastructure projects in which water storage is managed and operated for multiple purposes authorized by Congress such as flood control, navigation, recreation, hydropower, and other uses. For those projects, Corps guidance directs districts to develop a water control manual that is used to manage all of the projects'

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<sup>12</sup>Corps officials estimated that about 75 percent of all feasibility studies result in a project authorized for construction.

<sup>13</sup>Section 2035 of WRDA 2007 as amended (Pub. L. No. 110-114, § 2035 (2007), as amended by Pub. L. No. 113-121, § 3028 (2014)) requires the Chief of Engineers to ensure that the design and construction activities for hurricane and storm damage reduction and flood damage reduction projects have a safety assurance review by independent experts if the Chief of Engineers determines that such a review is necessary to assure public health, safety, and welfare, prior to initiation of physical construction and periodically thereafter until construction activities are completed.

authorized purposes in consultation with interested stakeholders in the area of the project that may be impacted by its operations. In addition to water control manuals for individual projects, the Corps may also have master water control manuals that outline the operations of a system of projects.<sup>14</sup> The Corps may also develop operational guidance for non-Corps projects if, for example, the Corps has responsibility for flood control or other operations at that project. Water control manuals typically outline the operating criteria and guidelines for varying conditions and specifications for water storage and releases from a reservoir, including instructions for obtaining and reporting appropriate hydrologic data.

## Weather-Related Data

The Corps uses a variety of hydrologic data—data relating to the movement and distribution of water—and forecasting data in its planning, designing, and operation of water resources infrastructure that can help it plan for extreme weather events. Much of these data are collected by other federal agencies as part of nationwide efforts to gather weather and hydrologic data. Table 1 shows examples of the type of hydrologic data collected by various federal agencies and used by the Corps.

**Table 1: Selected Hydrologic Data Collected by Federal Agencies and Used by the U.S. Army Corps of Engineers to Manage Water Resources Infrastructure**

Type of data	Agency	Program description	Types of data used by the Corps
Streamflow	United States Geological Survey (USGS)	The National Streamflow Information Program collects streamflow data through its national streamgage network <sup>a</sup> which continuously measures the level and flow of rivers and streams at 8,025 active continuous streamgages nationwide for distribution on the Internet.	Streamgages can provide information on streamflow as a discharge measurement (the amount of water moving through the river, for example, measured in cubic feet per second) or as a river stage measurement (the current height of the water in the river in feet) to monitor or make predictions.
Mountain snowpack	Natural Resources Conservation Service (NRCS)	NRCS operates 885 Snow Telemetry (SNOWTELE) sites in 13 western states, which transmit snow depth, snow-water equivalent, and climate parameters in near real time. In addition, the NRCS snow course network conducts manual surveys of snow depth at about 956 sites in the United States.	Both SNOWTELE sites and snow courses gather information about snow depth, as well as the snow-water equivalent, which is the amount of water in the snowpack. This data is important to forecasting the water supply in the West.

<sup>14</sup>There may be multiple projects located along a river and several tributaries. In such cases, a master water control manual is prepared to define system regulation.

Type of data	Agency	Program description	Types of data used by the Corps
Plains snowpack	National Weather Service (NWS) <sup>b</sup>	The National Water Center (NWC) produces a map of snow conditions in the United States daily based on a combination of airborne surveys, satellite observations, and on-the-ground field measurements. <sup>c</sup>	NWC produces products, such as maps, of modeled snow-water equivalent across 31 states and 8 Canadian provinces. NWC also provides information about soil moisture based on their airborne surveys.
Precipitation	National Oceanic and Atmospheric Administration (NOAA)	NOAA collects snow and rain data in the continental United States with 143 weather radars and 10,000 precipitation gauges. Many of these gauges are owned and operated by other federal agencies; state, municipal, and tribal governments; and citizen observers.	Radar-detected precipitation and on-the-ground precipitation amounts from rain gauges are combined and analyzed to provide estimates of precipitation. Data collected by the U.S. Climate Reference Network is used in operational climate monitoring activities and for placing current climate anomalies into an historical perspective.
Soil moisture	NRCS	Through the Soil Climate Analysis Network (SCAN), NRCS collects information on climate and soil.	Soil moisture, in addition to soil temperature, air temperature, precipitation, wind speed, and direction, and many other climatic parameters, transmits data in near real time.
Oceanographic	NWS	Through the National Data Buoy Center (NDBC), NWS deploys buoys into the ocean to collect a variety of data.	Buoys collect data on wind direction and speed, wave height, and water temperature as well as other measures.

Source: GAO analysis of agency documents. | GAO-15-660

<sup>a</sup>USGS's National Streamflow Information Program defines a streamgage as an active, continuously functioning device placed in a river or stream to measure water levels to aid in the estimation of mean daily streamflow throughout the year.

<sup>b</sup>In addition to federal efforts to collect plains snowpack data, some states have their own programs. For example, the North Dakota State Water Commission's Atmospheric Resource Board Cooperative Observer Network collects data on daily snowfall, monthly snowpack, and snow-water equivalent through a network of volunteer observers in North Dakota.

<sup>c</sup>The Corps manages a cooperative snow survey program that collects on-the-ground measurements of plains snowpack and snow-water equivalent. The Corps provides information from these snow surveys to NWC to help verify and validate the NWC models.

Corps officials and reports by federal agencies have highlighted limitations in some of the data the Corps uses in its planning, design, and operations of water resources infrastructure. Examples include the following:

- **Streamflow.** The Corps uses streamflow information from the National Streamflow Information Program in its planning, designing, and daily operations. However, according to Corps officials and USGS data, loss of streamgages due to funding constraints has reduced the available information about streamflows. According to USGS, from 1995 to 2008, 948 critical streamgages with 30 or more years of records were discontinued. Further, a USGS report noted that the loss of long-record streamgages reduces the potential value of streamflow

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information for infrastructure operations and design applications. Streamgage data are also used to produce climate change information upon which the Corps bases its adaptation planning. Despite these losses, the Corps has a formal agreement to provide funding to USGS to operate streamgages that provide data for the Corps' water management activities and in fiscal year 2013 provided USGS with \$18 million.

- **Precipitation related to extreme storms.** Until 1999, the Corps used NWS Hydrometeorological Reports (site-specific probable maximum precipitation studies) for its designs. However, NWS discontinued providing these services in 1999 due to lack of funding, and some Corps officials said they have been using outdated data since that time. In response, the Corps has worked with the Interagency Federal Work Group on Extreme Storm Events since 2008 and established its own Extreme Storm Team to address Corps data needs, as well as the needs of other agencies.<sup>15</sup>
- **Plains snowpack.** The Corps uses plains snowpack data in its runoff forecasting for operations.<sup>16</sup> The Corps and NWS have found limitations in this snowpack data. For example, a NWS report assessing the 2011 Missouri River flood found that modeled information on snow-water equivalent is available, but observational data are sparse and not always representative of basin-wide conditions.<sup>17</sup> WRRDA 2014 included a requirement that the Secretary of the Army, in coordination with other specified agencies, carry out snowpack and soil moisture monitoring in the Upper Missouri Basin.<sup>18</sup> As of June 2015, those agencies had not yet developed the monitoring system due to funding constraints according to agency officials.<sup>19</sup>

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<sup>15</sup>For example, the Extreme Storm Team is working to develop up-to-date hydrometeorological reports, create regional and site-specific probable maximum precipitation studies, and create an extreme storm catalog as a data archive of extreme storm events.

<sup>16</sup>Runoff flows over the land surface, going downhill into rivers and streams.

<sup>17</sup>National Oceanic and Atmospheric Administration, National Weather Service, *Service Assessment: The Missouri/Souris River Floods of May – August 2011* (May 2012).

<sup>18</sup>Pub. L. No. 113-121, § 4003(a)(1)(A), 128 Stat. 1193, 1311 (2014).

<sup>19</sup>GAO, *Missouri River Basin: Agencies' Progress Improving Water Monitoring Is Limited*, GAO-15-558R (Washington, D.C.: June 9, 2015).

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## Executive Orders to Address a Changing Climate

Under Executive Orders 13514 and 13653, agencies are to create and update climate change adaptation plans that integrate consideration of climate change into their operations and overall mission objectives.<sup>20</sup> Specifically, Executive Order 13514, issued in 2009, directed agencies to participate in an existing Interagency Climate Change Adaptation Task Force. Based on the work of the task force, the Council on Environmental Quality (CEQ) issued implementing instructions for the executive order in March 2011.<sup>21</sup> The instructions directed agencies to, among other things, issue an agency-wide climate change adaptation policy statement and submit their climate adaptation plans to CEQ and the Office of Management and Budget. Executive Order 13653, issued in 2013, directed agencies to continue developing and regularly updating their climate adaptation plans.

In response to these executive orders, the Corps submitted its Climate Change Adaptation Plans in 2012, 2013, and 2014 (adaptation plan). The Corps' adaptation plan is implemented, in part, through its Responses to Climate Change Program. This program is charged with developing the methods, tools, and guidance to improve the resilience of the Corps' built and natural infrastructure through a collaborative, proactive, nationally consistent, and regionally sensitive framework and program of actions. According to the adaptation plan, these actions include improving the agency's understanding of climate impacts to missions and operations, assessing vulnerabilities, and identifying specific actions to minimize risk and capitalize on opportunities to improve infrastructure resilience. According to Corps documents, infrastructure resilience is the ability to anticipate, prepare for, respond to, and adapt to changing conditions and to withstand and recover rapidly from disruptions with minimal damage. As directed by CEQ instructions and guidance implementing Executive Order 13514, the Assistant Secretary of the Army for Civil Works released

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<sup>20</sup>Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance (Oct. 5, 2009). Executive Order 13653, Preparing the United States for the Impacts of Climate Change (Nov. 1, 2013). Executive Order 13514 was revoked by Executive Order 13693, Planning for Federal Sustainability in the Next Decade, on March 19, 2015.

<sup>21</sup>The Council of Environmental Quality (CEQ) coordinates federal environmental efforts and works closely with agencies and other White House offices in the development of environmental policies and initiatives. CEQ was established within the Executive Office of the President by the National Environmental Policy Act of 1969 (NEPA).

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the Corps' policy regarding adaptation in June 2014.<sup>22</sup> The policy states that "mainstreaming climate change adaptation means that it will be considered at every step in the project life cycle for all USACE [U.S. Army Corps of Engineers] projects, both existing and planned ... to reduce vulnerabilities and enhance the resilience of our water resource infrastructure." This policy also established the Corps' Committee on Climate Preparedness and Resilience to oversee and coordinate the agency's climate change adaptation planning and implementation.

In January 2015, Executive Order 13690 was issued establishing a federal flood risk management standard, which applies to federal actions—including the construction of facilities with federal funds—in, and affecting, floodplains. Under the standard, certain new construction, substantially improved structures, and substantially damaged projects must meet a certain elevation level, among other things. Draft floodplain management guidelines were issued in February 2015 and were available for public comment through May 6, 2015. Within 30 days of the close of this public comment period, Executive Order 13690 directed agencies to submit an implementation plan to the National Security Council that contains milestones and a timeline for implementation of the executive order and standard.<sup>23</sup> However, federal agencies are prohibited from using appropriated funds to implement the standard until input from Governors, Mayors, and other stakeholders has been solicited and considered. According to the executive order, agencies should not issue or amend regulations and procedures to implement the executive order until after implementing guidelines are issued. Thus, it is unclear how the standard will affect the Corps' operations.

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<sup>22</sup>The June 2014 policy statement reaffirmed and superseded the adaptation policy statement the Corps issued on June 3, 2011.

<sup>23</sup>The National Security Council is the President's principal forum for considering national security and foreign policy matters with his senior national security advisors and cabinet officials.

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## The Corps Considers the Potential Impact of Extreme Weather in Its Planning and Operations of Water Resources Infrastructure Projects

### Corps Guidance and Initiatives Call for the Consideration of the Potential Impacts of Extreme Weather Events in the Planning Process

The Corps addresses the potential impact of extreme weather events in its planning and operations of water resources infrastructure projects in various ways including updating and developing guidance to be used in the planning process; using tools, such as water control manuals, in its operation of projects; and through collaboration with key federal agencies and stakeholders.

The Corps considers the potential impacts of extreme weather in its planning process by updating and developing guidance, as well as incorporating the uncertainties of extreme weather events in planning for new infrastructure projects, and through its Civil Works Transformation Initiative. For example, in 2009, the Corps issued guidance for incorporating sea level change in its planning, construction, and operation of water resources infrastructure projects impacted by the rise and fall of sea levels.<sup>24</sup> This guidance, which was updated in 2011 and 2013, directs Corps districts to consider three scenarios of potential sea level change when designing and constructing new infrastructure, as well as managing existing water infrastructure.<sup>25</sup> According to Corps documents, sea level change can have a number of impacts on coastal and estuarine zones, including more severe storm and flood damages.<sup>26</sup> In 2014, the Corps issued additional guidance on how to evaluate the effects of projected future sea level change on Corps projects and what to consider when

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<sup>24</sup>U.S. Army Corps of Engineers, *Water Resources Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs*, Engineer Circular 1165-2-211 (Washington, D.C.: July 1, 2009).

<sup>25</sup>U.S. Army Corps of Engineers, *Incorporating Sea Level Change in Civil Works Programs*, Engineering Regulation 1165-2-212 (Washington, D.C.: Dec. 31, 2011); *Incorporating Sea Level Change in Civil Works Programs*, Engineering Regulation 1100-2-8162 (Washington, D.C.: December 31, 2013).

<sup>26</sup>Sea level change can also cause shoreline erosion, inundation or exposure of low-lying coastal areas, shifts in the extent and distribution of wetlands and other coastal habitats, changes to groundwater levels, and alterations to salinity intrusion into estuaries and groundwater systems. Estuaries are bodies of water formed where freshwater from rivers and streams flows into the ocean, mixing with the sea water.

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adapting projects to this projected change.<sup>27</sup> This guidance is intended to incorporate sea level change into the planning process to improve the resilience of projects and maximize performance over time.

In addition, in May 2014, the Corps issued guidance for how to incorporate potential impacts of extreme weather into the planning of inland infrastructure projects in accordance with Executive Order 13653 and the President's Climate Action Plan.<sup>28</sup> This guidance outlines the purpose and objective for incorporating this consideration into current and future studies as well as provides an example of how to incorporate new science and engineering in hydrologic analyses for new and existing Corps projects. Moreover, the guidance establishes a procedure to perform a qualitative analysis of potential climate threats and impacts to the Corps' hydrology-related projects and operations. The guidance calls for districts to conduct an initial screening-level qualitative analysis to identify whether climate change is relevant to the project goals or design. If climate change is determined to be relevant to the project goals or design, the guidance directs districts to make an evaluation of information about climate change impacts such as changes in processes governing rainfall runoff or snowmelt. The information is intended to be used to help identify opportunities to reduce potential vulnerabilities and increase resilience as a part of the project's authorized operations, as well as identify any limitations or issues associated with the data collected.

The Corps also issued guidance in October 2014 on determining the appropriate use of paleoflood information in its planning and operation of water infrastructure.<sup>29</sup> According to Corps guidance, useful information can be gained from paleohydrology, or the evidence of the movement of water and sediment in stream channels before continuous hydrologic records or direct measurements became available. For example, this information can be derived from high water marks, tree rings, and gravel

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<sup>27</sup>U.S. Army Corps of Engineers, *Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation*, Engineering Technical Letter 1100-2-1 (Washington, D.C.: June 30, 2014).

<sup>28</sup>U.S. Army Corps of Engineers, *Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Design, and Projects*, Engineering and Construction Bulletin 2014-10 (Washington, D.C.: May 2, 2014).

<sup>29</sup>U.S. Army Corps of Engineers, *Appropriate Application of Paleoflood Information for Hydrology and Hydraulics Decisions*, Engineering Technical Letter 1100-2-2 (Washington, D.C.: Oct. 31, 2014).

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deposits, among other things, and can help Corps districts estimate flood peak magnitudes, volumes and durations for flood damage assessments, or evaluate design criteria. This guidance also notes that paleoflood information may not be suitable for all projects such as, watersheds that have been altered through time, either by geologic processes or by human activity.

In addition to updating and developing guidance for planning and operating water infrastructure, Corps headquarters officials told us that they also have taken steps to incorporate uncertainty, such as that associated with extreme weather, into their planning process through the Civil Works Transformation Initiative. According to Corps documents, the Civil Works Transformation Initiative began in 2012 to aid the Corps in meeting current and future challenges and addressing the water resources needs throughout the United States. As part of the Initiative, the Corps updated its planning process in 2012 to help strengthen the incorporation of risk into planning assumptions for feasibility studies on new infrastructure projects. For example, Corps headquarters officials told us that they have adopted a risk-informed approach to help address uncertainty, such as that associated with extreme weather, by defining the levels of risk associated with a variety of project designs. Corps officials said, beginning in 2012, feasibility studies for new projects have used this approach to identify risks, including extreme weather, which may occur throughout the life cycle of a water resources project. Headquarters officials told us that, under this approach, project delivery teams must address risks associated with climate change in their project planning documents. To help ensure that the appropriate weather and climate data are being used in the planning process, since 2012, the Corps' external peer review process has asked experts to review the project plans and note whether appropriate data and information were used to respond to extreme weather risks. Corps officials told us that independent external review questions relating to climate change differ, depending on when they were prepared, as well as the type of input provided by the project delivery team and district officials. Because the Civil Works Transformation Initiative is not yet complete, it may be too early to evaluate the impact of this initiative.

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## The Corps Uses Water Control Manuals and Other Tools to Help Prepare for Extreme Weather

The Corps uses a variety of tools in its operations to help prepare for extreme weather, including water control manuals and an automated information system. Water control manuals, which outline the operation of water storage at individual projects, or a system of projects, are used by the Corps to prepare for extreme weather events. These manuals are to outline the various types of weather-related data the Corps uses in its daily operations, as well as when extreme weather events occur. The manuals are also to describe the automated processes used in a data exchange with USGS and the regional NWS center that provides weather forecasts, rainfall information, and streamflow data, among other information to the Corps to prepare for extreme weather events. In addition, water control manuals include a description of the historical information that is used for purposes of creating models to predict streamflow and reservoir stages. Corps guidance, in the form of engineer regulations, describes what is to be included in water control manuals, such as directing districts to establish and outline special operational practices during emergency situations, as well as a drought contingency plan. According to Corps officials, this Corps guidance ensures that Corps districts' water control manuals are created in a standardized manner so all districts are prepared for extreme weather events. Corps guidance also directs districts to ensure that all authorized purposes of a project are addressed in its operations and notes that operations must strike a balance among those purposes, which often have competing needs. According to the Corps' engineer regulations, any operational priorities among multiple authorized purposes during extreme conditions, such as drought or flooding events, may need to be defined in water control manuals.

According to the Corps guidance, water control manuals also must contain provisions for the Corps to temporarily deviate from operations, when necessary, to alleviate critical situations. According to Corps officials, critical situations may include extreme weather events, such as a flood or drought. For example, in December 2014, the Corps approved a deviation from operations at Prado Dam in southern California, which allowed the Corps to temporarily retain water captured behind the dam following a rainstorm. This deviation, along with other deviations in the southern California region, was in response to the drought that California has experienced since 2011. According to Corps guidance, deviations are meant to be temporary and, if a deviation lasts longer than 3 years, the water control manual must be updated. Corps officials we spoke with were unaware of any deviations that, as of May 2015, have lasted more than 3 years.

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Corps headquarters and district officials we interviewed said that some water control manuals may need to be updated due to changing conditions in the watershed; however, they also said that some manuals in existence for many years may not necessarily need to be updated since, in part, they allow for flexibility with changing weather trends. Specifically, headquarters and district officials we spoke with said projects that have not experienced a change in land use around the basin, a change in climate patterns, or new weather-related information may not need to be revised. Furthermore, headquarters officials said water control manuals, including reservoir rule curves and drought contingency plans, have proved relatively robust to the climate changes already observed in the West.<sup>30</sup> According to these officials, when combined with the ability to temporarily deviate from operations, when necessary, there is flexibility to respond to short-term and long-term needs based on the best available information and science. The Corps is currently working to develop and implement a strategy to update drought contingency plans to account for climate change. According to Corps officials, the agency will complete its strategy for updating these plans by fiscal year 2016.

Corps guidance directs districts to periodically review and revise water control manuals, as necessary, to conform to changing requirements resulting from land development in the project area, improvements in technology, and the availability of new hydrologic data, among other things. Some district officials said water control manuals have not been consistently updated due to changing conditions in the watershed, primarily due to funding constraints. Corps headquarters officials said there is not a Corps-wide process in place to assess whether manuals should be updated; rather, it is up to the discretion of the districts to do so. Some district officials said that they had requested funding to update water control manuals but did not receive the requested funding to conduct such updates. We will continue to assess this issue.<sup>31</sup>

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<sup>30</sup>A reservoir rule curve is the maximum elevation to which the Corps can fill a reservoir during various times during the year, with the exception of real-time flood operations.

<sup>31</sup>Section 1046 of WRRDA 2014 included a provision for GAO to conduct an audit to determine, among other things, if the Corps' reviews of project operations complied with policies and requirements of applicable law and regulations and to submit a report to Congress by June 10, 2016. We are commencing work on the Corps' project operations, which is to be completed in 2016

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The Corps has also established the Corps Water Management System (CWMS), an automated information system supporting the Corps' operations to, among other things, prepare for extreme weather. CWMS contains various data, such as weather conditions, soil moisture, snow accumulation, streamflow, and water level that can be used by the districts to develop models of watershed and channel processes and to forecast future availability of water. For example, CWMS allows the districts to simulate different operational scenarios to determine which one will more likely result in higher downstream water levels due to a large storm. According to Corps documentation, information from the simulation is intended to help the districts assess the economic, environmental, life safety, and other consequences, such as those from an extreme weather event, of different operational scenarios and lead to better-informed operational decisions. For example, Los Angeles district officials told us that CWMS models are being calibrated for expected maximum flood conditions which can allow them to better forecast runoff volumes in areas prone to extreme weather events. According to Corps documents, CWMS also will support rapid flood forecasting by the district and help reduce the potential for flooding in the basin. CWMS has been deployed to 35 of 38 districts since 2009 but has not yet been fully integrated into all Corps districts, and the watershed and channel models have not been fully implemented as of June 2015. The Corps plans to complete integrating CWMS into all districts by the end of 2015, and an effort is under way to have the watershed and channel models fully integrated by 2023 or earlier, depending on funding.

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### The Corps Collaborates with Key Stakeholders to Plan and Operate Water Infrastructure

The Corps has taken steps to prepare for extreme weather through its participation in various collaboration efforts with federal agencies and other stakeholders at both the regional and national levels.

At the regional level, Corps district officials told us that their collaboration with federal agencies and local stakeholders is sufficient for effective planning and operation of water infrastructure. Corps officials told us they regularly collaborate with federal agencies and local stakeholders to help ensure that they have the weather and climate data needed to plan and operate water infrastructure and to address extreme weather in a coordinated manner. For example, Alaska district officials told us their district has a long history of collaborating with NWS and USGS to monitor data across the remote areas of Alaska and now collaborates with these agencies using a geostationary satellite. Little Rock district officials told us they participate with agency officials from USGS and NOAA, as well as other stakeholders, at Tri-Agency Fusion Team meetings to discuss ways

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to improve the accuracy of the data generated by the agencies and improve the accuracy and utility of rainfall observations and river forecasts. Savannah district officials told us they regularly communicate with NWS officials in advance of and during extreme weather events. Within certain regions, Corps district officials told us they regularly interact with state and federal officials through the Silver Jackets program to, among other things, identify gaps among agency programs, leverage information and resources, and provide access to national programs such as the Corps Levee Inventory and Assessment Initiative.<sup>32</sup> The Corps is also conducting regional pilot studies nationwide to test different methods and frameworks for adapting to climate change in which they involve numerous stakeholders. For example, four Corps districts completed an Ohio River Basin pilot study in 2013 in which the districts worked with more than 70 stakeholders, including federal and state agencies, academia, and private entities. The pilot study considered the potential effects of climate change on future management of water resources, including 83 Corps dams, 131 levees and floodwalls, and 63 navigational locks in the 204,000 square miles of the basin. As a result of this pilot study, a consortium of basin interests convened the Ohio River Basin Alliance to address common interests in water resources and basin-wide climate change issues.

Corps district officials told us that they may also interact with state agencies, universities, and private industry to collect data that may not be collected by federal agencies. For example, Little Rock district officials told us they have used the Community Collaborative Rain, Hail, and Snow Network, in which precipitation data are collected by volunteer citizens and published daily on the Internet by Colorado State University. Walla Walla district officials have been participating with the University of Washington since 2012 in support of the Columbia River Treaty analysis that involves information on data collection, modeling, and trends on future weather and climate changes predicted for the region. Some districts told us they also have gained valuable and up-to-date technical information on engineering and design techniques from private industry associations and made key contacts at industry conferences. However, all the districts we spoke with told us they face challenges in attending

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<sup>32</sup>According to the Silver Jackets website, the program provides a formal and consistent strategy for an interagency approach to planning and implementing measures to reduce the risks associated with flooding and other natural hazards. Additional information on the Silver Jackets program is found at <http://www.nfrmp.us/state/>.

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weather-related conferences sponsored by entities other than the federal government due to changes in Department of Defense conference policies.<sup>33</sup>

Corps officials also collaborate with other federal agencies and stakeholders at the national level to identify data gaps that may exist and disseminate critical water resource information and data. For example, Corps headquarters officials have participated in the Climate Change and Water Working Group, a working-level forum established to share information and accelerate the application of climate information in water management, among other things. Through this group, the Corps along with local, state, and federal water management agencies, have examined water user needs for climate and weather information for long- and short-term water resources planning and management and have issued two reports on their findings.<sup>34</sup> We have previously reported the Corps along with NOAA, USGS, and other stakeholders developed the Federal Support Toolbox, a federal Internet portal, to provide current, relevant, and high-quality information on water resources and climate change data applications and tools for assessing the vulnerability of water programs and facilities to climate change.<sup>35</sup> The toolbox is publicly available online through the Integrated Water Resource Science and Services group and is maintained by the Corps with contributions from more than 16 federal agencies and nongovernment partners. According to agency officials, the Integrated Water Resource Science and Services group consists of four core agencies (USACE, NWS, USGS, and the Federal Emergency Management Agency) and is currently focused on improvements of water forecasting and integration of related models and databases.

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<sup>33</sup>See Department of Defense, *Deputy Chief Management Officer, Implementation of Updated Conference Oversight Requirements*, Memorandum (Nov. 6, 2013).

<sup>34</sup>David Raff, Levi Brekke, Kevin Werner, Andy Wood, and Kathleen White, *Short-Term Water Management Decisions: User Needs for Improved Climate, Weather, and Hydrologic Information* (Washington, D.C.: 2012); Levi D. Brekke, Bureau of Reclamation, Technical Service Center, *Addressing Climate Change in Long-Term Water Resources Planning and Management: User Needs for Improving Tools and Information* (Washington, D.C.: 2011).

<sup>35</sup>GAO, *Climate Change: Federal Efforts Under Way to Assess Water Infrastructure Vulnerabilities and Address Adaptation Challenges*, GAO-14-23 (Washington, D.C.: Nov. 14, 2013). The Federal Support Toolbox is available at [www.watertoolbox.us](http://www.watertoolbox.us).

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## The Corps Has Assessed Certain Infrastructure Projects to Prepare for Extreme Weather Events

The Corps has assessed certain water resources infrastructure projects to determine whether they are designed to withstand extreme weather events. Specifically, the Corps has national programs in place to perform risk assessments on dams and levees, as required by law, but, unlike these programs, the Corps is not required to perform systematic, national risk assessments on other types of infrastructure, such as floodwalls and hurricane barriers and has not done so. However, Corps officials said they have been required to assess such infrastructure after an extreme weather event in response to statutory requirements. The Corps has also performed some preliminary vulnerability assessments for sea level rise on its coastal projects and is beginning to conduct vulnerability assessments of inland watersheds to determine how a changing climate is affecting those projects.

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## The Corps Performs Risk Assessments on Dams and Levees but Does Not Assess Other Types of Infrastructure

The Corps performs risk assessments of its dams and levees through two national programs—the Dam Safety Program and the Levee Safety Program—but does not have similar programs in place for other types of infrastructure.<sup>36</sup> As part of its Dam Safety Program, from 2005 to 2009, the Corps performed a screening of 706 of its 707 dams to determine which of its five risk classifications those dams fell under—very high urgency, high urgency, moderate urgency, low urgency, and normal.<sup>37</sup> This risk classification addresses the probability of failure and resulting potential consequences due to failure. Part of the assessment determines whether the dams are designed and operated in such a way that, during a potential flood event, the downstream flooding would not be more severe than flooding if the dam did not exist. The risk assessment also takes into account the likelihood of an extreme weather event. According to Corps officials, all Corps-operated dams will undergo periodic assessments every 10 years because the risk at any given dam may change over time. The Corps has also established the Risk Management Center as a resource to manage and assess risks to dams and levee systems, and the Dam Safety Modification Mandatory Center of Expertise to provide technical advice, oversight, review, and production capability to districts

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<sup>36</sup>The Corps is required by law to carry out a national program of inspection of dams for the purpose of protecting human life and property. 33 U.S.C. § 467a. The Corps is also required to carry out a levee safety initiative. 33 U.S.C. § 3303a. For these programs, the Corps conducted an inventory of dams and levees before carrying out its risk assessments.

<sup>37</sup>One Corps dam that is newly constructed has not yet undergone an initial screening.

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performing any dam modifications in response to the risk assessment. The Dam Safety Modification Mandatory Center of Expertise also maintains a list of subject matter experts in the field of dam safety whose names are accessible via the Internet.

The Corps assesses the risk of its dams through the Dam Safety Program, but not all dam safety modification projects have been funded. More specifically, the Corps' initial screening of dams, completed in 2009, found that 18 dams fell under the very high urgency classification, 83 dams fell under the high urgency classification, 219 dams fell under the moderate urgency classification, and the remaining 386 dams fell under the low urgency classification. For those dams in the very high urgency, high urgency, and moderate urgency classifications, the Corps guidance directs that an Interim Risk Reduction Measures Plan be developed, which is a temporary approach to reduce dam safety risks while long-term solutions are being pursued. The Corps found that completing dam safety modifications on its dams in the three most urgent classifications would cost more than \$23 billion.<sup>38</sup> The cost for dam safety modifications for the very high urgency classification was about \$4.2 billion; the high urgency classification cost was about \$7 billion, and the moderate urgency classification cost was about \$12 billion. According to Corps officials, from fiscal year 2009 through fiscal year 2014, the Corps received about \$2.5 billion in appropriations to begin dam safety modification studies and construction on 15 very high urgency dams. As of June 2015, dam safety modification construction has been completed on seven very high urgency dams, and the Corps was working on the other eight.<sup>39</sup> Corps officials we spoke with in two districts said that they recognize that dams in other districts may fall into the very high urgency classification for modifications, but the dams in their own district, which are in the high urgency classification, are also at a high risk of failure should an extreme weather event occur.

The Corps also operates the Levee Safety Program, which began in 2006. According to the Corps, although the Dam and Levee Safety Programs are similar in their approach to risk assessments, the Levee Safety Program has not progressed as quickly, largely because the Corps

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<sup>38</sup>Dam safety modification costs are presented in fiscal year 2013 dollars.

<sup>39</sup>We have work ongoing on the Dam Safety Program that is continuing to assess these issues and will report the results in 2016.

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owns and operates less than 20 percent of the 14,700 miles of levees that fall under the program.<sup>40</sup> Until 2009, the Corps collected information on 14,700 miles of levees for inclusion in the National Levee Database.<sup>41</sup> Since that time, the Corps has been conducting risk assessments of the 14,700 miles of levees that are included in the Levee Safety Program. The 14,700 miles of levees are divided into 2,887 segments, and risk assessments have been completed for about 43 percent of those segments as of April 2015. The Levee Safety Program risk assessments are to take into account the likelihood of an extreme weather event and how a levee will perform during that event. Based on the risk assessments that have been completed as of April 2015, 1 percent of those levees are classified as very high urgency, 8 percent are classified as high urgency, 27 percent are classified as moderate urgency, and 64 percent are classified as low urgency. Based on the risk assessments completed, as of June 2015, the Corps has not begun making improvements to any of the levees it owns and operates because it is still conducting the risk assessments and will prioritize any improvements once those assessments are complete. Improvements made to the non-Corps levees based on the results of the risk assessment are at the discretion of the local sponsor, with advice from the Corps on risk reduction measures.

Unlike the requirements for the Dam Safety and Levee Safety Programs, the agency is not required to perform risk assessments on other types of existing infrastructure, such as hurricane barriers and floodwalls, and it

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<sup>40</sup>The remaining 80 percent of levee miles are either (1) federally authorized but operated and maintained by local sponsors or (2) in a nonfederal system. Section 3016 of WRRDA 2014 included a provision for GAO to report to Congress on opportunities for alignment of federal programs relating to levees.

<sup>41</sup>Included in the Levee Safety Program are those levees that are: (1) operated and maintained by the Corps, (2) federally authorized but local sponsor operated and maintained, and (3) nonfederal levee systems in the Corps' Rehabilitation and Inspection Program, which implements Pub. L. No. 84-99's authority to repair and rehabilitate flood control projects damaged by floods and coastal storm events. There are also an unknown number of miles of other levees in the United States that are not included in the Corps' Levee Safety Program. The National Levee Database includes, among other items, the Federal Emergency Management Agency region, the name of the local sponsor(s), the length of the levee(s), a link to a map of the levee(s), and the inspection date and rating. We have work ongoing on the Levee Safety Program that is continuing to assess these issues and will report the results in 2016.

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has not yet conducted an inventory of other types of infrastructure.<sup>42</sup> According to Corps officials, the agency has not performed systematic, national risk assessments on other types of existing infrastructure given funding limitations (see table 2). However, the Corps has received appropriations for and has been required to assess such infrastructure after an extreme weather event, such as in the aftermath of Hurricane Katrina in 2005 and Hurricane Sandy in 2012.<sup>43</sup>

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**Table 2: U.S. Army Corps of Engineers' Systematic, National Infrastructure Risk Assessments, 2006-June 2015**

Type of infrastructure	Number of projects	Number of assessments
Dams	707	706
Levees (in segments)	2,887	1,232
Other <sup>a</sup>	b	0

Source: GAO analysis of Corps data. | GAO-15-660

<sup>a</sup>Other includes infrastructure, such as hurricane barriers and floodwalls.

<sup>b</sup>The Corps has not yet completed an inventory of other types of infrastructure.

Subsequent to Hurricane Sandy, for example, the Corps released, in November 2013, an assessment of the performance of specific projects and, in January 2015, a more general assessment of the North Atlantic coastline. The project-specific performance assessment evaluated 75 constructed coastal storm risk management projects in the Corps' North

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<sup>42</sup>The Corps' Civil Works Transformation Initiative states that that the Corps will be developing a master inventory list of its infrastructure assets. Corps officials said they do not yet know when this inventory will be completed.

<sup>43</sup>Appropriation acts for fiscal year 2006 appropriated funds for and required the Corps to conduct a comprehensive hurricane protection analysis and design of flood control, coastal restoration, and hurricane protection measures for the southeastern Louisiana coastal region. Pub. L. No. 109-103, tit. I, 119 Stat. 2247, 2247-48 (2005), *amended by* Pub. L. No. 109-148, § 5009, 119 Stat. 2680, 2814 (2005). In addition, one of the appropriation acts appropriated funds for and required the Corps to conduct an analysis and design for comprehensive improvements or modifications to existing improvements in the coastal area of Mississippi in the interest of hurricane and storm damage reduction, prevention of saltwater intrusion, preservation of fish and wildlife, prevention of erosion and other related water resource purposes. Pub. L. No. 109-148, 119 Stat. 2680, 2761 (2005). The Supplemental Appropriations Act for fiscal year 2013 appropriated funds for and required the Corps to conduct a comprehensive study to address the flood risks of vulnerable coastal populations in areas impacted by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps. Pub. L. No. 113-2, tit. II, 127 Stat. 4, 5 (2013).

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Atlantic Division, which extends from Maine to Virginia, 31 projects in the Great Lakes and Ohio River Division, and 9 projects in the South Atlantic Division. For the more general assessment, the Corps looked at the risk along 31,000 miles of Atlantic Ocean shoreline from Virginia to New Hampshire as a system.<sup>44</sup> The Corps divided the area into multiple areas of coastline that were hydraulically separate from one another, studying the risk of flood, as well as the exposure of the populations, exposure by population density, infrastructure density, vulnerability by socioeconomic factors, and vulnerability of environmental resources and cultural resources. This risk assessment identified, among other things, nine high-risk areas of the North Atlantic Coast that warrant additional analyses to address coastal flood risk. As of June 2015, the Corps has made no improvements to its projects based on the general risk assessment in the Corps' study of Hurricane Sandy, which was made final in January 2015. However, according to Corps officials, many projects identified in the project-specific assessment received funding for and received repair and restoration through the Corps' Flood Control and Coastal Emergencies Program.<sup>45</sup>

The Corps conducted these risk assessments following Hurricanes Katrina and Sandy after receiving an appropriation for and being required by law to conduct them, as the Corps does not generally receive funding for broad program activities, such as risk assessments on infrastructure other than dams and levees. However, the Corps has not worked with Congress to develop a more stable funding approach, as we recommended in September 2010, which could facilitate such risk assessments.<sup>46</sup> That report found that a more stable funding approach could improve the overall efficiency and effectiveness of the Civil Works program. The department partially concurred with our recommendation,

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<sup>44</sup>U.S. Army Corps of Engineers, *Hurricane Sandy Coastal Projects Performance Evaluation Study* (Washington, D.C.: November 2013); *North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk* (Washington, D.C.: January 2015).

<sup>45</sup>The Disaster Relief Appropriations Act, 2013, appropriated just over \$1 billion for the Corps' Flood Control and Coastal Emergencies Program to prepare for flood, hurricane, and other natural disasters and to support emergency operations, repairs, and other activities after Hurricane Sandy. Pub. L. No. 113-2, div. A, tit. X, 127 Stat. 4, 25 (2013).

<sup>46</sup>GAO, *Army Corps of Engineers: Organizational Realignment Could Enhance Effectiveness, but Several Challenges Would Have to Be Overcome*, GAO-10-819 (Washington, D.C.: Sept. 1, 2010).

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stating that it would promote efficient funding. As the frequency and intensity of some extreme weather events are increasing, without performing risk assessments on other types of existing infrastructure, such as hurricane barriers and floodwalls, before an extreme weather event (e.g., using a risk-based model), the Corps will continue to take a piecemeal approach to assessing risk on such infrastructure.<sup>47</sup> For this reason, we continue to believe our recommendation is valid.

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**The Corps Has Conducted Some Vulnerability Assessments of Water Infrastructure Projects to Prepare for Extreme Weather Events**

The Corps has conducted two nationwide screening level assessments to assess its vulnerability to climate change in its management and operation of water infrastructure. According to the Corps' 2014 Climate Adaptation Plan, these vulnerability assessments are necessary so the Corps can address a changing climate and successfully perform its missions, operations, programs, and projects in an increasingly dynamic environment.

In 2013, the Corps began an initial project-level vulnerability assessment for coastal projects relating specifically to sea level change. Teams from 21 Corps districts with coastal projects reviewed more than 1,431 projects to determine the impact of sea level change at the 50- and 100-year planning horizons for coastal projects.<sup>48</sup> These projects were given a score based on science-based parameters to categorize the level of impact that sea level change would have on each project. The Corps completed these initial vulnerability assessments for coastal projects in September 2014 and determined that 944 of the 1,431 projects appear to be able to withstand future changes resulting from sea level rise, 94 projects may experience high or very high impacts as a result of sea level rise, and 393 projects may experience a low or medium impact as a result of sea level rise. As of June 2015, the Corps had begun prioritizing the 94 projects that may experience high or very high impacts as a result of sea

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<sup>47</sup>A federal court recently ruled that the Army Corps' construction, expansion, operation, and failure to maintain a project in Louisiana caused storm surge during several hurricanes and severe storms that flooded properties, which was a temporary taking under the Fifth Amendment of the United States Constitution. The Takings Clause of the Fifth Amendment prohibits the government from taking private property for a public purpose without just compensation. *St. Bernard Parish Gov't v. United States*, No. 05-1119, slip op. at 73 (Fed. Cl. 2015). The court has not yet assessed damages, and its decision may be appealed so it is unclear whether, or how, this decision will impact Corps' operations.

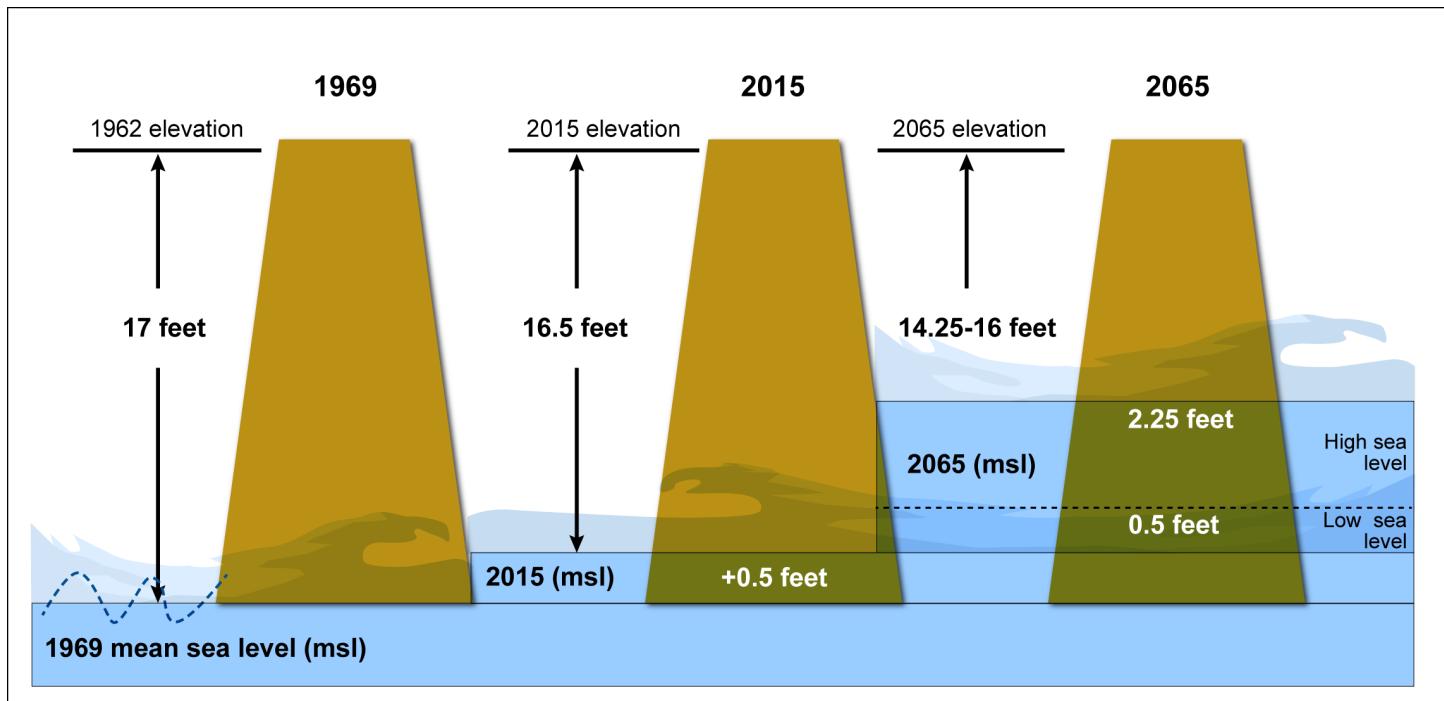
<sup>48</sup>Coastal projects, for the purposes of the vulnerability assessment, are those that are within 40 miles of NOAA's tidally influenced water bodies.

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level rise for a more detailed assessment. Corps officials said they do not yet know when this prioritization will be completed.

As of June 2015, the Corps was piloting methods to conduct the more detailed vulnerability assessment. In one pilot, through a vulnerability assessment of a hurricane barrier in New England that was designed in 1962 to provide navigation and flood risk reduction benefits for the area surrounding a harbor, the Corps found the project had experienced a 6-inch loss from its design elevation due to sea level rise. The hurricane barrier was listed as having potentially high impact from sea level rise in the screening assessment. The more detailed pilot assessment identified a potential future loss of elevation of between 6 inches and 2 feet 3 inches by 2065. Based on Corps data, the change in sea level has resulted in a reduction in the distance between the top of the water and the top of the hurricane barrier from 17 feet at its design to 16.5 feet currently, and potentially down to 14.25 feet within 50 years (see fig. 2). According to Corps officials, these future changes in distance between the top of the sea and the top of the hurricane barrier can result in a greater risk of floods and more operations of the navigation gate, which in turn reduces navigation reliability and increases maintenance costs. The Corps had initially planned to release a draft report on the initial coastal vulnerability assessment in December 2014 but, as of June 2015, the final report had not been released. Corps officials said the final report will likely be released in late summer 2015.

**Figure 2: U.S. Army Corps of Engineers' Hurricane Barrier Design Elevation Changes Due to Sea Level Rise**



Source: GAO representation of U.S. Army Corps of Engineers data. | GAO-15-660

Corps officials acknowledge that the science is not yet available to conduct project-level vulnerability assessments for inland projects. However, the Corps initiated a study in 2012 that focused on how hydrologic changes due to climate change may impact freshwater runoff in some watersheds. As of June 2014, the Corps had identified the top 20 percent of watersheds that were most vulnerable for each business line through this initial watershed study.<sup>49</sup> Corps officials said this is an initial screening level assessment that will lead to more detailed assessments of the most vulnerable water resources infrastructure projects and those with the highest potential impact from extreme weather events. The Corps is working with an expert consortium of federal, academic, nongovernmental organizations, and others to develop the climate and

<sup>49</sup>U.S. Army Corps of Engineers' business lines include: flood risk reduction, navigation, ecosystem restoration, hydropower, recreation, regulatory, water supply, and emergency management.

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hydrology information necessary to conduct project-level assessments. Corps officials said that the consortium will develop the information needed to perform the project assessments and that it is unclear how long developing the necessary science will take.

According to the Corps' 2014 Climate Change Adaptation Plan and Corps headquarters officials, the inland and coastal vulnerability assessments will be merged over the next several years and will be used to determine how the Corps needs to manage and plan for new water resource projects. As of May 2015, Corps officials told us that they did not have a timeline for merging these assessments, in part because the climate and hydrology information is not yet available.

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## Agency Comments and Our Evaluation

We provided a draft of this report for review and comment to the Departments of Agriculture, Commerce, Defense, and the Interior for comment. These agencies did not provide written comments. In an e-mail received on June 29, 2015, the audit liaison for NOAA at the Department of Commerce provided technical comments for our consideration. In addition, in oral comments received on July 2, 2015, the Corps' point of contact on the engagement provided technical comments for our consideration. We incorporated these technical comments as appropriate.

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We are sending copies of this report to the appropriate congressional committees; the Secretaries of Agriculture, Commerce, Defense, and the Interior; and other interested parties. In addition, the report is available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff members have any questions about this report, please contact me at (202) 512-3841 or [fennella@gao.gov](mailto:fennella@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 who made key contributions to this report are listed in appendix I.

A handwritten signature in black ink, appearing to read "Anne-Marie Fennell". The signature is fluid and cursive, with a large, stylized 'A' at the beginning.

Anne-Marie Fennell  
Director, Natural Resources and Environment

# Appendix I: GAO Contact and Staff Acknowledgments

<b>GAO Contact</b>	Anne-Marie Fennell, (202) 512-3841 or <a href="mailto:fennella@gao.gov">fennella@gao.gov</a>
<b>Staff Acknowledgments</b>	In addition to the individual named above, key contributors to this report included Vondalee R. Hunt (Assistant Director), Michael Armes, Cheryl Arvidson, Kendall Childers, Christopher Currie, Cindy Gilbert, Emily Pinto, Holly Sasso, Jeanette Soares, Colleen Taylor, and Patrick Ward.

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