



January 2024

CLIMATE CHANGE

Options to Enhance the Resilience of Federally Funded Flood Risk Management Infrastructure

GAO Highlights

Highlights of [GAO-24-105496](#), a report to congressional requesters

Why GAO Did This Study

More frequent extreme weather events and rising sea levels associated with climate change pose risks to the nation's flood management infrastructure, according to the 2023 *Fifth National Climate Assessment*.

From 2014 through 2023, the Corps dedicated at least \$19 billion in annual appropriations to flood risk management activities, according to GAO's analysis. During that same period, Congress provided at least \$46.1 billion in supplemental appropriations to the Corps for repairs to damaged flood risk management infrastructure, construction of such infrastructure in areas affected by disasters, and other activities.

In 2013, GAO added *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* to its High Risk List. Enhancing climate resilience—by planning for climate hazards and acting to reduce potential losses—can help manage the federal government's fiscal exposure.

GAO was asked to review the climate resilience of the federally funded flood risk management infrastructure. This report examines (1) the Corps' actions in this area and (2) the strengths and limitations of options available to the Corps to further enhance those efforts. GAO reviewed Corps documents, interviewed Corps officials and 21 knowledgeable stakeholders, and used GAO's *Disaster Resilience Framework* to evaluate the Corps' efforts and potential options to further enhance the climate resilience of such infrastructure.

View [GAO-24-105496](#). For more information, contact J. Alfredo Gómez at (202) 512-3841 or gomezj@gao.gov.

January 2024

CLIMATE CHANGE

Options to Enhance the Resilience of Federally Funded Flood Risk Management Infrastructure

What GAO Found

The U.S. Army Corps of Engineers (Corps) is responsible for planning, designing, and constructing much of the nation's federally funded flood risk management infrastructure—for example, levees, dams, floodwalls, floodgates, and hurricane barriers—that help protect communities from coastal storms and floods. Corps' flood risk management infrastructure, such as levees, can be breached by flooding exacerbated by changes in the climate (see fig.).

Breached Levee along the Missouri River, June 2011



Source: U.S. Army Corps of Engineers Omaha District photo by Eileen Williamson. | GAO-24-105496

The Corps has taken, and plans to take, actions to enhance the climate resilience of federally funded flood risk management infrastructure. The Corps has also taken steps to develop climate policies and plans, conduct research, and provide climate-related information and guidance for planning flood risk management infrastructure projects.

On the basis of a review of relevant literature and interviews with knowledgeable stakeholders and Corps officials, GAO identified 14 options to further enhance the climate resilience of federally funded flood risk management infrastructure (see table).

What GAO Recommends

GAO recommends that the Corps (1) analyze the 14 options for enhancing the climate resilience of federally funded flood risk management infrastructure identified in this report; and (2) integrate them, as appropriate, into the Corps' future climate resilience prioritization and planning efforts. Such analysis should also include legislative proposals that identify any additional authorities and resources the Corps would need to implement the options.

Congress should consider—in light of any analyses or proposals submitted by the Corps—providing direction or authority to implement one or more of the 14 options for enhancing the climate resilience of federally funded flood risk management infrastructure identified in this report.

The Corps concurred with GAO's recommendation.

Options to Further Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure

1. Create clear institutional authority to mainstream climate resilience.
2. Research the feasibility of innovative approaches.
3. Expand technical assistance for planning.
4. Update climate information for planning.
5. Update planning guidance.
6. Integrate climate resilience into project-level benefit cost analysis.
7. Expand the use of adaptive management in projects.
8. Update engineering standards and regulations.
9. Conduct climate screening assessment of authorized but unfunded projects.
10. Prioritize projects that incorporate climate resilience.
11. Update manuals for operation and maintenance.
12. Expand technical assistance to nonfederal sponsors for operations and maintenance.
13. Conduct climate vulnerability assessments of existing infrastructure.
14. Establish process for retrofitting existing infrastructure to account for climate change.

Source: GAO analysis of relevant literature and interviews with knowledgeable stakeholders. | GAO-24-105496

Each option has strengths and limitations. For example, updating planning guidance to require that climate resilience be incorporated into all flood risk management infrastructure studies and projects could increase the extent to which projects adopt resilience measures but might require additional capacity or result in additional costs to implement effectively.

Determining which options to implement to enhance the climate resilience of federally funded flood risk management infrastructure requires detailed analyses of complex issues. Making such determinations may also require difficult decisions involving trade-offs related to the costs and benefits of different options. Nevertheless, conducting a comprehensive analysis of the options identified in this report could help the Corps determine which options to prioritize in future climate resilience planning efforts. Such an analysis would also help the Corps seek congressional approval, as appropriate, for statutory authorities and resources necessary to implement the selected options to reduce federal fiscal exposure.

Implementing multiple options could better leverage the strengths and address the limitations of the different options and offers the greatest potential to improve the climate resilience of federally funded flood risk management infrastructure, according to knowledgeable stakeholders and GAO's *Disaster Resilience Framework*. Corps officials told GAO that they likely would need additional direction or authority from Congress to act on some, or a combination of, options.

Congress is expected to pass a new Water Resources Development Act in 2024, thus presenting Congress with an opportunity to seek and consider any analyses or proposals from the Corps and to provide direction or authority to the agency to take additional actions to implement one or more options for enhancing the climate resilience of federally funded flood risk management infrastructure. Doing so would help the Corps better ensure that such infrastructure can withstand and recover from extreme weather events and natural disasters expected to be exacerbated by climate change.

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Abbreviations

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| CHAT | Climate Hydrology Assessment Tool |
| Corps | U.S. Army Corps of Engineers |
| CTX | Coastal Texas Project |
| EIS | Environmental Impact Statement |
| FEMA | Federal Emergency Management Agency |
| HSDRRS | Greater New Orleans Hurricane and Storm Damage Risk Reduction System |
| NEPA | National Environmental Policy Act of 1969 |
| NOAA | National Oceanic and Atmospheric Administration |
| P&G | Principles and Guidelines |
| PR&G | Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies |
| S2G | Sabine Pass to Galveston Bay Coastal Storm Risk Management Program |
| WRDA | Water Resources Development Act |

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January 16, 2024

The Honorable Tom Carper
Chairman
Committee on Environment and Public Works
United States Senate

The Honorable Mark Kelly
Chairman
Subcommittee on Transportation and Infrastructure
Committee on Environment and Public Works
United States Senate

The Honorable Tammy Duckworth
United States Senate

Changes in the climate pose risks to the effectiveness of our nation's flood risk management infrastructure—structures like levees, dams, floodwalls, floodgates, and hurricane barriers—that help protect communities from coastal storms and floods. According to the *2023 Fifth National Climate Assessment*, more frequent and intense extreme weather events and rising sea levels associated with climate change are likely to increase flooding in different regions across the United States.¹ The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) also reported that there have been 153 flooding, severe storm, and tropical cyclone events where overall costs exceeded \$1 billion each from January 2013 through November 2023, with total losses exceeding \$999.5 billion.² More specifically, stronger coastal storms and rising sea levels may increase the frequency of storm surge overtopping coastal levees. Further, many of the nation's levees and dams were built over 50 years ago and, like other aging infrastructure,

¹U.S. Global Change Research Program, *Fifth National Climate Assessment* (Washington, D.C.: 2023).

²NOAA's cost assessments are based on data sources that capture the total direct costs, both insured and uninsured, of weather and climate events. Cost estimates are adjusted for inflation using the 2023 Consumer Price Index. These disaster costs do not account for losses to natural capital or assets, health care-related losses, or values associated with loss of life. NOAA's National Centers for Environmental Information, "*U.S. Billion-Dollar Weather and Climate Disasters (2023)*" (Washington, D.C.: Dec. 8, 2023), accessed Dec. 12, 2023, <https://www.ncei.noaa.gov/access/billions/>.

may be more vulnerable to failure because they were designed to manage the risks from precipitation and flooding events of the past.

The projected impacts of climate change on flood risk management infrastructure constitute a key source of federal fiscal exposure because of the size of the federal government's investment in such infrastructure. The U.S. Army Corps of Engineers (Corps) is responsible for planning, designing, and constructing much of the nation's federal flood risk management infrastructure—including 14,700 miles of levees, 715 dams, and about 150 major coastal storm risk management projects—which may be affected by climate change.³ Congress generally funds the Corps' flood risk management activities through annual appropriations and occasionally provides the Corps with additional funding through supplemental appropriations, often following flood events.

From 2014 through 2023, Congress provided approximately \$63.4 billion in annual appropriations for the Corps' civil works activities, of which at least \$19 billion went to flood risk management activities, according to our analysis of the Corps' Work Plans. During that same period, Congress provided at least \$46.1 billion in supplemental appropriations to the Corps for repairs to damaged flood risk management infrastructure; construction of flood risk reduction projects in areas affected by flood disasters, such as Hurricanes Harvey, Maria, and Ian; and a wide range of other activities.⁴

In recognition of the federal government's significant stake in managing the impacts of climate change, we have included *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* in our High Risk List since 2013.⁵ We and others have recommended that the federal government invest in climate resilience to

³In 2023, the Corps' flood risk management capital stock valued at \$81.5 billion. The Corps estimates its flood risk management "capital stock value" by calculating the cumulative value of investments in such infrastructure since 1936, while adjusting for asset retirements and losses in productive capacity caused by deterioration.

⁴The Corps' supplemental appropriations during this period include \$17.1 billion appropriated in the Infrastructure and Jobs Act, Pub. L. No. 117-58, 135 Stat. 429 (2021), of which at least \$5.8 billion went to flood risk management activities, according to our analysis of the Corps' Work Plans.

⁵The High Risk List identifies federal programs and operations that are vulnerable to fraud, waste, abuse, and mismanagement, or in need of transformation. See GAO, *High-Risk Series: An Update*, GAO-13-283 (Washington, D.C.: Feb. 14, 2013); and *High-Risk Series: Efforts Made to Achieve Progress Need to Be Maintained and Expanded to Fully Address All Areas*, GAO-23-106203 (Washington, D.C.: Apr. 20, 2023).

help limit its fiscal exposure to the impacts from climate change.⁶ Enhancing climate resilience means taking actions to reduce potential future losses by planning and preparing for potential climate hazards, such as extreme rainfall, sea level rise, and drought. Investing in climate resilience can reduce the need for far more costly steps in the decades to come.

You asked us to review the Corps' actions to limit the federal government's fiscal exposure from climate change by enhancing the climate resilience of federally funded flood risk management infrastructure projects. This report examines (1) the Corps' actions to enhance the climate resilience of federally funded flood risk management infrastructure and (2) the strengths and limitations of options available to the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure. The report also includes information in appendix I on how we used GAO's *Disaster Resilience Framework* to evaluate the extent to which each of the options we identified could help enhance the climate resilience of federally funded flood risk management infrastructure.⁷

To examine the Corps' actions to enhance the climate resilience of federally funded flood risk management infrastructure, we reviewed and summarized the Corps' efforts, including its policies, guidance, and tools related to incorporating climate resilience into flood risk management studies and projects. To better understand this topic and the Corps' efforts, we interviewed Corps officials and 16 individuals and groups from academia, industry trade groups, and nongovernmental organizations with experience working with the Corps and researching ways to further enhance the climate resilience of flood risk management infrastructure.⁸

To examine the strengths and limitations of options available to the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, we took several steps, starting with a search and review of relevant literature. We identified 44 relevant peer-reviewed

⁶See, for example GAO, *Climate Change: Opportunities to Reduce Federal Fiscal Exposure*, [GAO-19-625T](#) (Washington, D.C.: June 11, 2019).

⁷GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, [GAO-20-100SP](#) (Washington, D.C.: October 2019).

⁸We identified individuals and groups for our 16 scoping interviews from our preliminary background research, review of relevant literature, and recommendations from Corps' officials and stakeholders we interviewed.

articles, government reports, industry and trade group publications, conference papers, nonprofit and think tank publications, and working papers on flood risk management infrastructure resilience. To identify options from these sources, we recorded and categorized information about potential options and then distilled this information into a list of 14 high-level options grouped by their relevance to the five phases in the Corps' project delivery process.

To describe the options' strengths and limitations, we conducted semistructured interviews with 21 knowledgeable stakeholders we identified from the literature review and preliminary background research. We identified knowledgeable stakeholders with expertise in flood risk management infrastructure, climate resilience, climate change, and the Corps' general processes for developing and delivering such infrastructure.⁹ We asked each knowledgeable stakeholder to give us their views on the strengths and limitations of each option for which they had expertise.¹⁰ We then conducted a content analysis and grouped their insights on each option into overall themes.¹¹ We also interviewed Corps officials about the 14 options and included their statements on the strengths, limitations, and the extent to which the agency believes it could implement these options under its existing authority.

To assess the extent to which each of these options could further enhance the climate resilience of federally funded flood risk management infrastructure, we compared the options with the Corps' current climate resilience efforts using our *Disaster Resilience Framework*.¹² In this report, we used the *Disaster Resilience Framework* to identify the

⁹To select the 21 knowledgeable stakeholders we spoke with, we primarily considered type of expertise, perspectives from different groups involved with flood risk management infrastructure, and relevance of published work as criteria. We also spoke with 12 of the 21 knowledgeable stakeholders during our scoping interviews.

¹⁰The specific areas of expertise varied among the stakeholders we interviewed, so not all stakeholders commented on every interview question we asked. We did not ask stakeholders their views on whether the option would enhance the climate resilience of federally funded flood risk management infrastructure or if they favored or opposed each option. We do not have information about whether stakeholders would recommend one option over another.

¹¹To characterize knowledgeable stakeholders' views throughout this report, we defined modifiers (e.g., "nearly all") to quantify users' views as follows: "some" represents two to five knowledgeable stakeholders, "several" represents six to 10 knowledgeable stakeholders, "most" represents 11 to 15 knowledgeable stakeholders, and "nearly all" represents 16 to 20 stakeholders.

¹²[GAO-20-100SP](#).

potential positive effects achievable by implementing options to further enhance the climate resilience of federally funded flood risk management infrastructure in conjunction with the Corps' current efforts. For additional details on the scope and methodology of our review, see appendix II.

We conducted this performance audit from October 2021 to January 2024 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

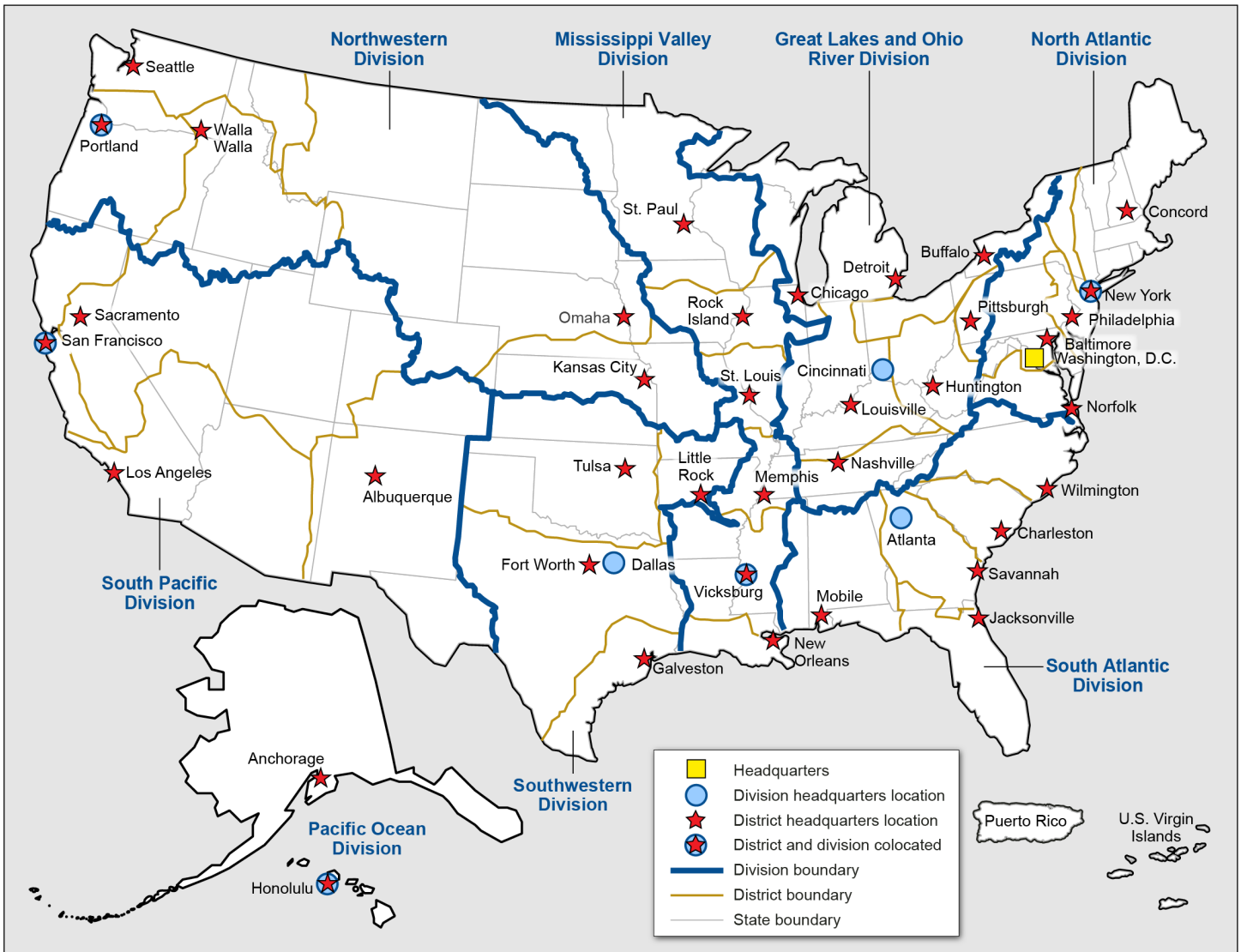
This section describes (1) the Corps' organizational structure and funding, (2) the Corps' flood risk management activities, (3) the Corps' process for developing and delivering water resources projects, (4) climate resilience as a risk management strategy for reducing federal fiscal exposure to climate change, and (5) recent executive orders related to climate resilience.

The Corps' Organizational Structure and Funding

Located within the Department of Defense, the Corps has both military and civilian responsibilities.¹³ Through its Civil Works Program, the Corps plans, designs, constructs, operates, and maintains a wide range of water resources infrastructure projects to reduce the risks of flood and storm damage, improve navigable channels, and restore aquatic ecosystems, among other things. The Assistant Secretary of the Army for Civil Works, appointed by the President, sets the strategic direction for the program and has principal responsibility for the overall supervision of functions relating to the Army's Civil Works Program. The Chief of Engineers, a military officer, is responsible for execution of the civil works and military missions. The Corps' Civil Works Program is organized into three tiers: headquarters in Washington, D.C.; eight regional divisions; and 38 local district offices (see fig. 1).

¹³The Corps' Military program provides, among other things, engineering and construction services to federal agencies and foreign governments. This report discusses the Corps' Civil Works Program.

Figure 1: Locations of the U.S. Army Corps of Engineers' Civil Works Regional Divisions and Local District Offices



Sources: GAO analysis of U.S. Army Corps of Engineers data; Map Resources (map). | GAO-24-105496

Corps headquarters primarily develops policies and guidance to implement the agency's responsibilities and plans the direction of the organization. The eight divisions, which were established generally according to watershed boundaries, primarily coordinate the district's civil works projects and are commanded by military officers. The 38 district offices, also commanded by military officers, are responsible for planning

and implementing feasibility studies and the resulting water resources infrastructure projects that are approved by the divisions and headquarters. District offices are also responsible for coordinating with nonfederal sponsors, including tribal, state, county, and local governments or agencies, on projects. In addition, the Civil Works Program maintains several Centers of Expertise, as well as research laboratories that assist the Corps' regional divisions and local districts in the planning, design, and technical review of civil works projects.¹⁴

Unlike many other federal agencies that have budgets established for broad program activities, Congress appropriates most Corps' civil works funds for specific projects. In general, the Corps receives "no-year" appropriations through annual Energy and Water Development Appropriations Acts. No-year appropriations have no time limits on obligating or expending the funds, meaning that the funds will remain available for their original purposes until expended. Congressional appropriations committees typically outline their priorities for Corps' water resources projects by listing individual projects and specific funding allocations for each project in conference reports or explanatory statements that usually accompany the annual Energy and Water Development Appropriations Acts.




The Corps' Flood Risk Management Activities

Flood risk management is one of the Corps' three core civil works missions, alongside support for commercial navigation and restoration of aquatic ecosystems. The Corps' flood risk management activities seek to reduce the threat to life and property from riverine flooding and coastal storms.¹⁵ Flood risk management infrastructure includes physical structures like dams and levees, as well as coastal storm risk management systems that could include a mix of structural, nonstructural, natural, and nature-based approaches (see fig. 2). The Corps also provides planning guidance and technical assistance; supports partnering and coordination efforts; and participates in direct engineering activities, such as developing flood mitigation measures and repairing infrastructure after floods or coastal storms.

¹⁴For a full list of the Corps' Centers of Expertise, see <https://www.usace.army.mil/About/Centers-of-Expertise/>.

¹⁵For the purposes of this report, we use the term flood risk management to include efforts to address riverine and coastal storm flooding.

Figure 2: Examples of Flood Risk Management Approaches

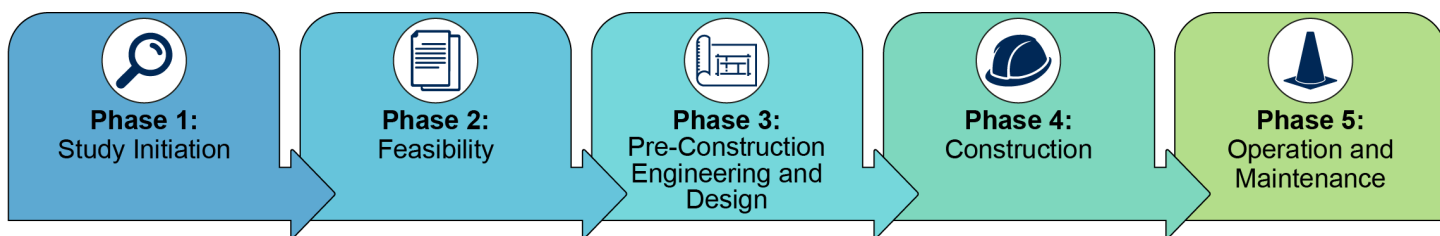
| Structural Flood Approaches | Nonstructural Flood Approaches | Natural and Nature-Based Approaches |
|--|---|--|
|  |  |  |
| <p>Structural approaches to floodproofing seek to prevent flooding by altering the flow of floodwater using infrastructure such as levees, dams, floodgates, and floodwalls.</p> | <p>Nonstructural approaches to floodproofing seek to reduce damage from encroaching floodwater by altering property. These approaches may involve taking measures such as floodproofing structures, elevating structures, and acquiring or relocating structures.</p> | <p>Natural and nature-based approaches to floodproofing seek to reduce flood damage by using landscape elements to mimic natural features or processes. These include things like beaches and dunes; wetlands; living shorelines; and oyster, mussel, and coral reefs.</p> |

Sources: GAO analysis of U.S. Army Corps of Engineers information. Photos: U.S. Army Corps of Engineers New Orleans District (left), Planet Three Elevation (center), and Library of Congress photo by Carol M. Highsmith (right). | GAO-24-105496

The Corps' Process for Developing and Delivering Water Resources Projects

The Corps uses a multistep process for developing and delivering water resources projects that consists of five phases—study initiation, feasibility, pre-construction engineering and design, construction, and operation and maintenance (see fig. 3). The Corps' *Planning Guidance Notebook* provides the overall direction by which the agency formulates; evaluates; and selects civil works projects, including flood risk management infrastructure projects, for implementation.¹⁶

Figure 3: U.S. Army Corps of Engineers' Process for Developing and Delivering Water Resources Projects



Source: GAO analysis of U.S. Army Corps of Engineers information; GAO (icons). | GAO-24-105496

We provide more detailed information about each phase of the Corps' process for developing and delivering water resources projects in appendix III.

Climate Resilience as a Risk-Management Strategy to Reduce Federal Fiscal Exposure

In 2013, we placed *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* on our High Risk List of federal programs and operations vulnerable to waste, fraud, abuse, or mismanagement, or in need of transformation.¹⁷ In related reports, we have found that action is needed to reduce federal fiscal exposure to climate change related to the federal government's roles and responsibilities, including (1) providing property and crop insurance; (2)

¹⁶The U.S. Water Resources Council's Principles, Requirements, and Guidelines (PR&G), published in 2013 and 2014, provide a common framework for how federal agencies, including the Corps, evaluate and select proposed water resources development projects. The PR&G largely replaced the U.S. Water Resources Council's prior Principles and Guidelines (P&G), which had been in place since 1983. See U.S. Water Resources Council, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Mar. 10, 1983). In April 2023, Corps officials said they were updating the agency's 2000 *Planning Guidance Notebook* to reflect changes made in the PR&G. The 2000 *Planning Guidance Notebook* provides detailed guidance on how to implement the general process outlined in the P&G. See U.S. Army Corps of Engineers, *Planning Guidance Notebook*, Engineer Regulation 1105-2-100 (Apr. 22, 2000).

¹⁷We most recently updated our High Risk List in April 2023. See [GAO-23-106203](#).

providing disaster aid; (3) owning or operating infrastructure; (4) developing a national strategic plan to coordinate federal efforts to address the fiscal exposure presented by climate change; and (5) providing data and technical assistance to help tribal, federal, state, local, and private decision makers address climate change.

We have found that enhancing climate resilience can help reduce federal fiscal exposure in these areas. Enhancing climate resilience entails a continuous risk-management process, according to the 2018 *Fourth National Climate Assessment*.¹⁸ Some agencies, like the Corps, have made efforts to address and manage climate change risks within existing programs and operations—a concept known as “mainstreaming.” For example, an agency planning to build a seawall to protect a coastal facility might build it higher to account for projected rising sea levels. According to the 2018 *Fourth National Climate Assessment*, a significant portion of climate risk can be addressed by mainstreaming, which can provide many climate resilience benefits.¹⁹

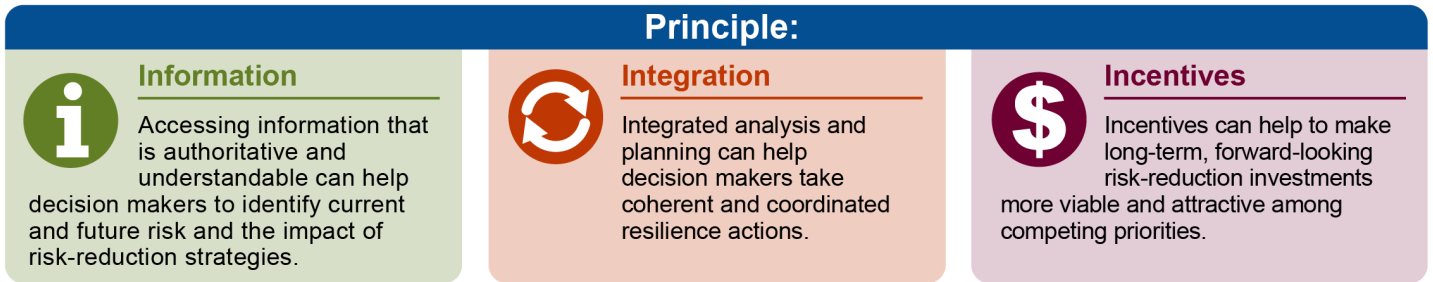
According to GAO’s *Disaster Resilience Framework*, investments in disaster resilience provide a promising means to address federal fiscal exposure because such investments can help limit the overall impacts of disasters.²⁰ GAO’s framework has three guiding principles—information, integration, and incentives—and lists a series of questions that can help identify opportunities to enhance federal efforts to promote disaster resilience (see fig. 4).

¹⁸U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. II (Washington, D.C.: 2018).

¹⁹U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States*.

²⁰[GAO-20-100SP](#).

Figure 4: GAO's *Disaster Resilience Framework* Principles



Source: GAO's *Disaster Resilience Framework* (GAO-21-100SP); GAO (icons). | GAO-24-105496

These principles can apply to any federal effort to help federal agencies and policymakers consider what kinds of actions to take to promote and facilitate disaster risk reduction. Users of the *Disaster Resilience Framework* can apply its principles and use its questions to assess almost any federal effort. Because not all elements of the framework will be relevant to every effort, users can adapt the principles for their specific needs. For more information on how we used GAO's *Disaster Resilience Framework* in this report, see appendix I.

Executive Orders Related to Climate Resilience

In 2021, the Biden administration issued three executive orders that outline key aspects of its approach to climate change and are relevant to the Corps' flood risk management projects:

- **Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad***, directs federal agencies, including the Corps, to submit climate action plans that describe steps the agency can take to bolster adaptation and increase resilience to the impacts of climate change with regard to its facilities and operations. The order also requires agencies to make their climate action plans public and submit annual reports documenting progress on the agency's plans.²¹
- **Executive Order 14030, *Climate Related Financial Risk***, requires agencies to report on the actions they are taking to address climate-related financial risks in their procurement processes as part of their climate action plans.²²

²¹Exec. Order No. 14008, *Tackling the Climate Crisis at Home and Abroad*, 86 Fed. Reg. 7619, 7619-33 (Jan. 27, 2021).

²²Exec. Order No. 14030, *Climate-Related Financial Risk*, 86 Fed. Reg. 27967, 27967-71 (May 20, 2021).

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- **Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs through Federal Sustainability***, requires federal agencies to develop, implement, and update Climate Adaptation and Resilience Plans that build on the climate actions plans required by Executive Order 14008. Executive Order 14057 requires agencies to conduct climate adaptation analyses and planning efforts to support climate-informed financial and management decisions and program implementation.²³ It also requires federal agencies to reform agency policies and funding programs that are maladaptive to climate change and to decrease the vulnerability of communities, natural or built systems, economic sectors, and natural resources to climate impacts and related risks. Implementing instructions for Executive Order 14057 published in August 2022 specify that Climate Adaptation and Resilience Plans are “living documents” that require routine updates to reflect the latest climate science, provide up-to-date information about agencies’ progress toward meeting goals identified in their climate action plans, and update agencies’ strategic priorities.²⁴

The Corps Has Taken or Planned Several Actions to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure

The Corps has taken, and plans to take, actions to enhance the climate resilience of federally funded flood risk management infrastructure by (1) conducting research and developing policies to incorporate climate resilience planning in the agency’s project delivery process; (2) providing climate-related information and guidance to help planners, engineers, and nonfederal sponsors during the agency’s project delivery process; and (3) conducting initial climate vulnerability and risk assessments for Corps’-operated and -maintained flood risk management infrastructure. In addition, three recent Corps’ flood risk management infrastructure projects have begun using the agency’s climate-related information and guidance to incorporate climate resilience features into preliminary project designs.

²³Exec. Order No. 14057, *Catalyzing Clean Energy Industries and Jobs through Federal Sustainability*, 86 Fed. Reg. 70935, 70935-43 (Dec. 8, 2021).

²⁴The implementing instructions specify that agencies must submit an annual Climate Adaptation and Resilience Plan progress report to the Council on Environmental Quality and the Office of Management and Budget. See Council on Environmental Quality, [Implementing Instructions for Executive Order 14057 Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability](#) (Aug. 31, 2022).

The Corps Has Developed Policies and Plans and Conducted Research to Integrate Climate Resilience in All Phases of Its Project Delivery Process

The Corps has developed policies and strategic plans to integrate climate resilience into each phase of the agency's project delivery process. The Corps has also conducted research to improve its knowledge about climate change risks and develop information and adaptation strategies applicable to all its activities.

Developing Climate Resilience Policies and Strategic Plans

The Corps established an overarching climate change adaptation policy and a governance structure to support the policy's implementation in 2011.²⁵ This Corps' policy states that "mainstreaming climate change adaptation means that it will be considered at every step in the project life cycle for all [Corps] projects, both existing and planned ... to reduce vulnerabilities and enhance the resilience of our water resource infrastructure." The policy also established a committee, now called the Climate Preparedness and Resilience Community of Practice, to coordinate and oversee the Corps' climate change adaptation planning and implementation efforts.²⁶

In response to Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, the Acting Assistant Secretary of the Army for Civil Works issued an updated *Climate Preparedness and Resilience Policy Statement* in May 2021.²⁷ The updated policy reaffirms the Corps' commitment to mainstreaming climate change adaptation into the agency's activities.

In October 2021, the Corps released an updated *Climate Action Plan* that identifies actions the agency intends to take to incorporate climate resilience into its decision-making.²⁸ This plan outlines five actions and

²⁵U.S. Army Corps of Engineers, *Climate Change Adaptation Policy Statement* (Washington, D.C.: June 3, 2011).

²⁶The Chief of Engineering and Construction oversees the Climate Preparedness and Resilience Community of Practice and is the senior official responsible for executing climate preparedness and resilience across the Corps.

²⁷The May 2021 policy statement reaffirms and supersedes the adaptation policy statement the Corps issued in 2014. See U.S. Army Corps of Engineers, *Climate Preparedness and Resilience Policy Statement* (Washington, D.C.: May 27, 2021).

²⁸U.S. Army Corps of Engineers, *USACE Climate Action Plan* (Washington, D.C.: October 2021). The 2021 *Climate Action Plan* builds on the Corps' prior climate adaptation plans.

three issue areas that the Corps intends to incorporate in the agency's missions, programs, and management functions, either in anticipation of, or in response to, climate change, and as allowed within relevant authorities.²⁹ In October 2022, the Corps issued a progress report to demonstrate how the agency is meeting the goals of its *Climate Action Plan*.³⁰

Conducting Climate Resilience Research

The Corps has conducted research to better understand climate change risks and the climate resilience measures relevant to Corps activities.³¹ For example, between fiscal years 2010 and 2015, the Corps funded 19 pilot projects to improve the agency's understanding of the effects of climate change and the role and potential effectiveness of adaptation measures. The pilot projects assessed the need for additional climate change information in decision-making, tested new ideas, and generated information necessary to develop policies and guidance. According to a 2017 Corps report, one of the lessons learned from the pilot projects was that establishing policies and guidance can reduce the time and cost of climate adaptation measures because they establish the legal and technical justifications for the actions and narrow the range of potential alternatives.³²

More recently, the Corps has funded studies to better understand existing resilience capacities by developing practical resilience metrics for coastal

²⁹The five priority adaption actions include (1) modernizing Corps programs and policies to support climate-resilient investments; (2) managing Corps lands and waters for climate preparedness and resilience; (3) enabling tribal, state, and local government preparedness; (4) providing actionable climate information, tools, and projections; and (5) planning for climate change-related risks to Corps missions and operations. The three issue areas include (1) updates to the Corps' climate vulnerability assessments; (2) efforts to enhance the Corps' climate literacy in its management workforce; and (3) actions to enhance the climate resilience of Corps sites, facilities, and supply chains.

³⁰U.S. Army Corps of Engineers, *USACE Climate Adaptation Plan: 2022 Progress Report* (Washington, D.C.: Oct. 6, 2022).

³¹The Corps conducts research for flood risk management infrastructure and climate resilience through its [Engineer Research and Development Center](#) and its [Institute for Water Resources](#). For example, the Engineer Research and Development Center's Coastal and Hydraulics Laboratory develops scientific and technical capabilities to help reduce disaster risk, increase resilience, and support sustainable water resources infrastructure. The Institute for Water Resources provides forward-looking analysis, cutting-edge methodologies, and innovative tools to aid the Corps' water resources program, including flood risk management.

³²A. Pinson and K. White, *Report on Lessons Learned from USACE Climate Change Adaptation Pilot Projects Fiscal Years 2010-2015*, Civil Works Technical Series 2017-03 (Washington, D.C.: Aug. 30, 2017).

infrastructure and research more comprehensive ways to evaluate project benefits when conducting benefit cost analyses. For example, a 2019 study developed resilience metrics for coastal infrastructure that will better quantify the ability of a community and its coastal infrastructure to withstand flood and storm damages, rapidly recover, and adapt to future change.³³ A 2022 study examined the agency’s current practice of using benefit cost analyses to formulate and evaluate water resources projects. Future phases of this study will assess different ways to value the environmental and social benefits of various project alternatives, including using natural or nature-based solutions.³⁴

The Corps Has Taken Actions to Provide Information and Guidance on Climate Resilience for Use in the First Four Phases of Its Project Delivery Process

The Corps has taken actions to provide information and guidance on climate resilience to help planners, engineers, and nonfederal sponsors during the first four phases of its project delivery process. These actions include developing climate-related information and web-based tools, developing and updating planning guidance, and providing technical assistance to nonfederal sponsors. Three recent flood risk management projects have begun using the agency’s climate-related information and guidance to incorporate climate resilience features into the primary designs for these projects.

Developing Climate-Related Information and Tools

The Corps has provided climate change projections and information on climate resilience to planners, engineers, and nonfederal sponsors through various efforts and tools.³⁵ For example, in 2015, the Corps published 21 regional climate impact assessments that summarized observed and projected climate and hydrological patterns cited in peer-reviewed literature and authoritative national and regional reports. The regional climate impact assessments characterized climate threats to the Corps’ missions and provided context and linkage to other agency resources for climate resilience planning, such as sea level change calculation and coastal risk reduction resources.

³³B. Ayyub, *Practical Resilience Metrics for Coastal Infrastructure Features*, U.S. Army Engineer Research and Development Center/Coastal Hydraulics Laboratory CR-19-1 (Washington, D.C.: May 2019).

³⁴J.R. Ehrenwerth et al., *Enhancing Benefits Evaluation for Water Resources Projects: Towards a More Comprehensive Approach for Nature-Based Solutions. Evolution of Benefits Evaluation and Prioritization of Water Resources Projects* (Washington, D.C.: July 2022).

³⁵The Corps collaborates with other entities, such as NOAA, academic experts, nongovernmental organizations, and the private sector, to translate climate science into actionable information for decision-making.

The Corps has developed a suite of web-based tools to support climate preparedness and resilience planning and engineering design. To understand sea level change scenarios, the Corps' Sea Level Analysis Tool allows users to compare current sea levels with projected sea level change.³⁶ To understand the effects of climate change on hydrology, the Corps' Climate Hydrology Assessment Tool (CHAT) allows users to visualize downscaled global climate model outputs specific to their study area.³⁷

Developing and Updating Guidance

The Corps has taken steps to integrate climate resilience into its planning process by developing and updating guidance. For example:

- **Incorporating sea level change in Civil Works Programs.** In 2009, the Corps issued guidance for incorporating the direct and indirect physical effects of projected future sea level change in managing, planning, engineering, designing, constructing, operating, and maintaining Corps' projects.³⁸ This guidance, which was most recently updated in 2019, directs Corps districts to consider three scenarios of potential sea level change—low, intermediate, and high—when planning and designing new infrastructure, as well as managing existing water infrastructure.
- **Procedures to evaluate sea level change: impacts, responses, and adaptation.** In 2014, the Corps issued guidance for how to evaluate the effects of projected future sea level change on Corps' projects and what to consider when adapting projects to projected

³⁶Users can generate reports that contain key outputs from the Sea Level Analysis Tool, and the inputs used to create the outputs for feasibility studies. According to Corps officials, the Sea Level Analysis Tool does not predict future sea levels, rather it provides multiple future sea level change scenarios to help users consider the full range of reasonably plausible future conditions.

³⁷Users can generate ranges and trends in modeled historic and future (projected) streamflow, temperature, and precipitation variables from the CHAT. The CHAT also supports the development of defensible and repeatable analytical results, helping to ensure that the Corps can effectively use the information throughout its decision-making processes.

³⁸U.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). This engineer circular expired in 2011 and, in 2013, the Corps transitioned this guidance to an engineering regulation, which was most recently updated in 2019. See U.S. Army Corps of Engineers, *Global Changes Incorporating Sea-Level Change in Civil Works Programs*, Engineering Regulation 1100-2-8162 (Washington, D.C.: June 15, 2019).

change.³⁹ This guidance, which was most recently updated in 2019, is intended to incorporate sea level change in the Corps' planning process, enhance the resilience of projects, and maximize projects' performance over time.

- **Incorporating climate change impacts to inland hydrology in civil works studies, designs, and projects.** In May 2014, the Corps issued guidance for incorporating climate change impacts to inland hydrology in civil works studies, design, and projects.⁴⁰ This guidance, which was most recently updated in 2022, outlines the purpose of incorporating this consideration into current and future studies and provides examples of how to incorporate new science and engineering in hydrologic analyses for new and existing Corps' projects.⁴¹ Moreover, the guidance establishes a procedure to perform a qualitative analysis of potential climate change impacts in the context of hydrologic studies for inland watersheds.
- **Risk assessment for flood risk management studies.** In 2019, the Corps issued an engineering regulation to provide guidance on its risk assessment requirements for flood risk management studies.⁴² This guidance outlines a risk framework for decision-making and variables to include as part of the risk assessment to quantify the performance, resilience, and risks of all alternatives considered in formulating the project recommendation.
- **Civil works sustainable infrastructure practices guidebook.** In 2019, the Corps published guidance on sustainable infrastructure practices to use for its civil works projects, programs, and other

³⁹U.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). The Corps transitioned this guidance to an engineering pamphlet, with the same name, in 2019. See U.S. Army Corps of Engineers, *Procedures to Evaluate Sea-Level Change: Impacts, Responses, and Adaptation*, Engineering Pamphlet 1100-2-1 (Washington, D.C.: June 30, 2019).

⁴⁰U.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).

⁴¹U.S. Army Corps of Engineers, *Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects*, Engineering and Construction Bulletin 2018-14, Rev. 2 (Washington, D.C.: Aug. 19, 2022).

⁴²U.S. Army Corps of Engineers, *Planning Risk Assessment for Flood Risk Management Studies*, Engineering Regulation 1105-2-101 (Washington, D.C.: July 15, 2019).

activities.⁴³ Corps staff are required to check for applicable best practices, including climate resilience, prior to beginning any new project, activity, or service. Some considerations include accounting for the capacity of a project to evolve over time.

- **Guide to Resilience Practices.** In 2020, the Corps issued guidance on resilience practices.⁴⁴ This guidance provides examples of resilience practices used across the agency to help staff consider and incorporate resilience into their decision-making.

Providing Technical Assistance

The Corps provides direct technical assistance and planning support to nonfederal sponsors through its Floodplain Management Services program and Planning Assistance to States program. For example, as part of the Floodplain Management Services program, the Corps has supported 100 studies intended to assist nonfederal sponsors in planning and preparing for climate change in fiscal years 2021 and 2022. According to the Corps' 2022 *Climate Adaptation Plan Progress Report*, when providing technical assistance and planning support, the Corps seeks to leverage the technical resources and expertise of other federal and nonfederal partners to produce effective solutions to mitigating flood risk.⁴⁵ As part of its collaborative efforts, the Corps also provides technical support through interagency, state-led Silver Jackets teams.⁴⁶ For example, in 2018, the Washington State Silver Jackets team hosted a webinar series to increase awareness about and accessibility to climate resilience information and help integrate such information into flood risk management planning throughout the state.

⁴³U.S. Army Corps of Engineers, *Civil Works Sustainable Infrastructure Practices Guidebook*, Engineering Pamphlet 1100-2-2 (Washington D.C.: Dec. 1, 2019).

⁴⁴U.S. Army Corps of Engineers, *USACE Guide to Resilience Practices*, Engineering Pamphlet 1100-1-5 (Washington, D.C.: Dec. 1, 2020).

⁴⁵U.S. Army Corps of Engineers, *USACE Climate Adaptation Plan: 2022 Progress Report*.

⁴⁶Silver Jackets teams are interagency teams that facilitate collaborative solutions to state flood risk priorities. The state-led teams bring together multiple state, federal, and sometimes tribal and local agencies to learn from one another and work together to reduce risk from floods and sometimes other natural disasters. For more information, see <https://www.iwr.usace.army.mil/Silver-Jackets/>.

Three Recent Flood Risk Management Projects Have Begun Implementing the Corps' Climate Resilience Steps and Guidance

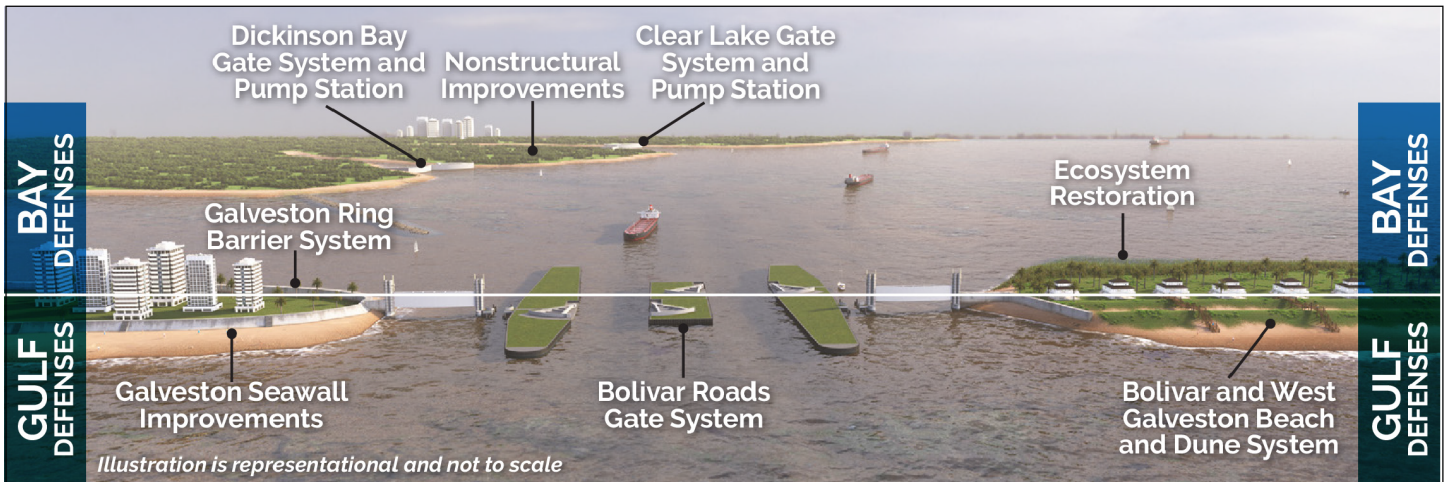
Three recent flood risk management projects—the Coastal Texas Project (Coastal Texas), Sabine Pass to Galveston Bay Coastal Storm Risk Management Program (Brazoria, Jefferson, and Orange Counties, Texas), and Norfolk Coastal Storm Risk Management Project (Norfolk, Virginia)—offer examples of the Corps' flood risk management infrastructure projects that considered future climate projections in their planning.⁴⁷ These projects, developed for coastal areas, used a combination of climate information, modeling tools, guidance, and technical assistance.

For example, the Corps used computerized storm models to (1) simulate and predict future storm surge risks for relevant coastal areas, (2) identify design criteria, and (3) test the effectiveness of potential flood management solutions. Storm surge models simulate a wide variety of hurricanes and tropical storms using different rising sea level change scenarios—low, intermediate, and high—as directed by agency guidance. Corps officials said the storm surge models used for the Coastal Texas Project (Coastal Texas) and Sabine Pass to Galveston Bay Coastal Storm Risk Management Program (Brazoria, Jefferson, and Orange Counties, Texas) generally supported designing flood risk management features using the intermediate sea level change scenario, with the possibility of future adaptability. Corps officials also said they designed some project features, such as large flood gates, using the high sea level change scenario, to ensure they will perform as intended throughout the project life span, as it would be too costly to remove and replace such structures on a recurring basis (see figs. 5 and 6).⁴⁸

⁴⁷We identified Corps' flood risk management infrastructure studies or projects that incorporated climate resilience through our background research and asking individuals and groups during our 16 scoping interviews, Corps officials, and 21 selected knowledgeable stakeholders to provide examples of projects. We developed a list of nine potential flood risk management infrastructure projects, in various stages of development, and asked Corps officials which projects would best illustrate incorporating climate resilience, and they suggested these three examples.

⁴⁸According to Corps officials, flood risk management infrastructure provides some level of protection and reduces risk to a socially tolerable level but does not eliminate all flood risks or deliver total protection to communities.

Figure 5: Coastal Texas (CTX) Project



| | |
|----------------------------------|---|
| Location | Coast of Texas |
| Threat | Coastal flood risks are growing due to rising sea levels and the increased size and intensity of storms. |
| Project plan | The CTX project includes a combination of coastal storm risk management and ecosystem restoration projects that function as a system to reduce the risk of coastal storm surge damage. The CTX project also uses a combination of structural, nonstructural, and natural and nature-based features to provide multiple lines of defense. |
| Project features | <p>Gulf defenses: Include a combination of surge gates at Bolivar Roads, 43 miles of beach and dune segments on Bolivar Peninsula and West Galveston Island, and improvements to the existing 10-mile seawall on Galveston Island. The CTX project also includes beach and dune nourishment along approximately 3 miles of South Padre Island.</p> <p>Bay defenses: Include an 18-mile ring barrier system on Galveston Island; two surge gates (and pumping stations) on the mainland; and complementary nonstructural measures, such as home elevations and floodproofing along Galveston Bay.</p> <p>Aquatic ecosystem restoration: Includes restoring about 6,600 acres of aquatic ecosystems along the coast.</p> |
| Project partners | <p>Federal sponsor: U.S. Army Corps of Engineers Galveston District</p> <p>Nonfederal sponsors: Gulf Coast Protection District and Texas General Land Office</p> |
| Current project phase | Pre-Construction Engineering and Design |
| Project authorization | Congress authorized this project in the Water Resources Development Act of 2022. ^a |
| Estimated completion date | The CTX project could take up to 20 years to build, depending on the pace of funding. |
| Estimated project cost | \$34.38 billion (\$21.38 billion federal, \$13 billion nonfederal) |

Sources: GAO analysis of U.S. Army Corps of Engineers Galveston District project website and documents. Photo: Conceptual rendering of multiple lines of defense on the Texas Coast. | GAO-24-105496

^aWater Resources Development Act of 2022, Pub. L. No. 117-263, div. H, tit. LXXXI, § 8401, 136 Stat. 2395, 3842.

Figure 6: Sabine Pass to Galveston Bay Coastal Storm Risk Management (S2G) Program



| | |
|----------------------------------|--|
| Location | Brazoria, Jefferson, and Orange Counties, Texas |
| Threat | Coastal flood risks are growing due to rising sea levels and the increased size and intensity of storms. |
| Project plan | The S2G Program is comprised of three coastal storm risk management projects in the Freeport, Port Arthur, and Orange County regions. For example, improvements will be made to existing hurricane flood protection systems, such as raising levees, in the Freeport and Port Arthur regions. A new coastal storm risk management system will be constructed in southern Orange County. |
| Project features | <p>Freeport: The project will raise about 13.1 miles of existing earthen levees, construct or reconstruct 5.5 miles of floodwalls, add a navigable sector gate on the Dow Barge Canal, and upgrade an existing pump station and multiple drainage structures.</p> <p>Port Arthur: The project will raise about 16 miles of existing earthen levees, construct or reconstruct 6 miles of floodwalls, build 2 miles of new earthen levees in the Port Neches area, construct or replace 20 road and railroad closures, and add erosion protection for 10 pump stations.</p> <p>Orange County: The project will construct about 20 miles of new earthen levees, 3 miles of concrete floodwalls, 200 gravity drainage structures, 16 pump stations, 40 road and railroad closures, and two navigable sector gates. The project also includes restoring about 450 acres of coastal marsh and 560 acres of forested wetlands.</p> |
| Project partners | <p>Federal sponsor: U.S. Army Corps of Engineers Galveston District</p> <p>Nonfederal sponsors: Velasco Drainage District (Freeport), Jefferson County Drainage District No. 7 (Port Arthur), and the Gulf Coast Protection District (Orange County)</p> |
| Current project phase | <p>Freeport: Pre-Construction Engineering and Design</p> <p>Port Arthur: Construction</p> <p>Orange County: Pre-Construction Engineering and Design</p> |
| Project authorization | Congress authorized this project in the Water Resources Development Act of 2018. ^a |
| Estimated completion date | Freeport: 2028, Port Arthur: 2029, Orange County: 2033 |
| Estimated project cost | <p>Freeport: \$703.4 million (\$457.2 million federal, \$246.2 million nonfederal)</p> <p>Port Arthur: \$863 million (\$561 million federal, \$302 million nonfederal)</p> <p>Orange County: \$2.39 billion (\$1.55 billion federal, \$836.56 million nonfederal)</p> |

Sources: GAO analysis of U.S. Army Corps of Engineers Galveston District project website and documents. Photos: Conceptual renderings of I-wall and T-wall (left) and raising earthen levees (right). | GAO-24-105496

^aWater Resources Development Act of 2018, Pub. L. No. 115-270, tit. I, § 1401, 132 Stat. 3765, 3838.

Designing flood risk management infrastructure project elements that are adaptable to future change can involve actions such as building a levee with a wider base now, so that it is easier for the Corps to increase its height later. According to Corps officials, the Norfolk Coastal Storm Risk Management Project (Norfolk, Virginia) will utilize several types of flood improvement structures specifically designed for reducing coastal flood impacts, such as replacing I-walls with T-walls and using wider bases for levees and floodwalls that allow for future adaptability. Corps officials said it will be easier to raise levees and floodwalls to protect against rising sea levels with these features, if necessary (see fig. 7).

Figure 7: Norfolk Coastal Storm Risk Management Project



| | |
|----------------------------------|---|
| Location | Norfolk, Virginia |
| Threat | The frequency of flooding in Norfolk, Virginia is increasing due to rising sea levels and the increased size and intensification of storms. |
| Project plan | The project will integrate structural, nonstructural, and natural and nature-based features to provide comprehensive flood risk reduction for Norfolk, Virginia. The project has five implementation phases. |
| Project features | The project will include storm surge barriers, nearly 8 miles of floodwalls, nearly 1 mile of levees, 11 tide gates, and 10 pump stations, along with a series of nonstructural projects that include home elevations, basement fills, and commercial floodproofing. The project also includes natural and nature-based features like creating oyster reefs and living shorelines, and wetlands mitigation. |
| Project partners | Federal sponsor: U.S. Army Corps of Engineers Norfolk District Nonfederal sponsor: City of Norfolk, Virginia |
| Current project phase | Pre-Construction Engineering and Design |
| Project authorization | Congress authorized this project in the Water Resources Development Act of 2020. ^a |
| Estimated completion date | 2032 |
| Estimated project cost | \$2.6 billion (\$1.69 billion federal, \$910 million nonfederal) |

Sources: GAO analysis of U.S. Army Corps of Engineers Norfolk District project website and documents. Photos: Conceptual renderings of a T-wall, gated closures, and pump station at Fountain Park (left) and levee at Harbor Park. | GAO-24-105496

^aWater Resources Development Act of 2020, Pub. L. No. 116-620, div. AA, § 401, 134 Stat. 1182, 2738.

The Corps Has Taken Actions to Provide Information on Climate Resilience and Assess Federally Owned Infrastructure in the Final Phase of Its Project Delivery Process

The Corps has taken actions to provide information and assess federally owned and operated infrastructure for climate resilience during the final phase of its project delivery process—the operation and maintenance phase. Such actions include developing and updating manuals for operation and maintenance, inspecting completed infrastructure, and conducting climate vulnerability screenings and risk assessments of federally operated flood risk management infrastructure. One flood risk management project—the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (Southeast Louisiana)—provides an example of a completed Corps project that will be routinely assessed during operation and maintenance to determine if modifications are needed to address rising sea levels.

Manuals for Operation and Maintenance

Various Corps manuals direct the operation and maintenance of flood risk management infrastructure projects owned and operated by the Corps or by nonfederal sponsors. For projects operated or managed by nonfederal sponsors, upon physical completion of the project, the Corps prepares and provides the nonfederal sponsor with an operation and maintenance manual that outlines procedures for the project. For certain projects operated or managed by the Corps, including reservoirs, locks, dams, and major control structures, Corps engineer regulations require preparation of a water control manual, which generally defines rules or provides guidance for the operation and management of the project. According to Corps officials, some, but not all, flood risk management infrastructure projects have both operation and maintenance manuals and water control manuals. The Corps can revise manuals for operation and maintenance in consultation with the nonfederal sponsor if conditions change, but these manuals tend to be updated less frequently than water control manuals. The Corps is required to review water control manuals every 10 years.

Inspecting Completed Flood Risk Management Projects

The Corps performs risk assessments of Corps-owned and -operated dams and levees through two national programs—the Dam Safety Program and the Levee Safety Program—but does not have similar programs to assess other types of infrastructure.⁴⁹ For projects not operated by the Corps, the nonfederal sponsors responsible for operating and maintaining the projects complete semiannual operations reports,

⁴⁹The 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.

and the Corps periodically inspects these projects through its Inspection of Completed Works program. The Inspection of Completed Works program seeks to ensure that nonfederal sponsors of flood risk management infrastructure perform essential activities in accordance with the project's operation and maintenance manuals. According to Corps officials, all Corps' operated dams undergo periodic inspections and assessments every 5 to 10 years because the risks to individual dams may change over time. The Corps also plans to use 10-year risk assessments to revisit data regarding the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (Southeast Louisiana) and to assess whether the system needs modifications, such as raising the height of levees to protect against rising sea levels (see fig. 8).

Figure 8: Greater New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRRS)



| | |
|------------------------------|--|
| Location | Southeast Louisiana |
| Threat | Coastal flood risks are increasing due to rising sea levels and the increased size and intensification of storms. |
| Project plan | The HSDRRS includes five parishes and consists of 350 miles of levees and floodwalls, 73 nonfederal pumping stations, three canal closures with pumps, and four gated outlets. |
| Project features | <p>Pump stations: Repairing 61 pump stations and storm proofing 49 pump stations.</p> <p>Canal closures: Building three permanent canal closures and pumps at the 17th Street Canal, Orleans Avenue Canal, and London Avenue Canal.</p> <p>Inner Harbor Navigation Canal-Lake Borgne Surge Barrier: A 1.8-mile concrete barrier wall, the largest of its kind in the world, which works in tandem with the Seabrook Floodgate Complex. It also includes three gated structures—a bypass barge gate and a flood control sector gate (each 150 feet wide), and a 56-foot-wide vertical lift gate.</p> <p>Seabrook Floodgate Complex: A 95-foot-wide navigable sector and two 50-foot-wide nonnavigable vertical lift gates that work in tandem with the Inner Harbor Navigation Canal-Lake Borgne Surge Barrier.</p> |
| Project partners | <p>Federal sponsor: U.S. Army Corps of Engineers New Orleans District</p> <p>Nonfederal sponsors: Louisiana Coastal Protection and Restoration Authority</p> |
| Current project phase | Operations and Maintenance |
| Project authorization | Aspects of the HSDRRS were authorized as early as 1965 ^a , and Congress has authorized various updates to the system since. Following Hurricane Katrina and the 2005 hurricane season, Congress authorized the restoration, replacement, and reinforcement of the system in a number of laws. These laws include (1) the Department of Defense, Emergency Supplemental Appropriations to Address Hurricanes in the Gulf of Mexico, and Pandemic Influenza Act, 2006 ^b ; (2) the Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Hurricane Recovery, 2006 ^c ; and (3) the U.S. Troop Readiness, Veterans' Care, Katrina Recovery, and Iraq Accountability Appropriations Act, 2007 ^d ; among others. |
| Completed | 2022 |
| Project cost | \$14.45 billion (\$12.8 billion federal, \$1.5 billion nonfederal) |

Sources: GAO analysis of U.S. Army Corps of Engineers New Orleans District project website and documents. Photos: Inner Harbor Navigation Canal-Lake Borgne Surge Barrier gates (left) and Seabrook Floodgate Complex (right) | GAO-24-105496

^aFlood Control Act of 1965, Pub. L. No. 89-298, tit. II, § 204, 79 Stat. 1073, 1086.

Conducting Climate Vulnerability Screening and Risk Assessments

^bDepartment of Defense, Emergency Supplemental Appropriations to Address Hurricanes in the Gulf of Mexico, and Pandemic Influenza Act, 2006, Pub. L. No. 109-148, ch. 3, 119 Stat. 2680, 2762 (2005).

^cEmergency Supplemental Appropriations Act for Defense, the Global War and Terror, and Hurricane Recovery, 2006, Pub. L. No. 109-234, tit. II, ch. 3, 120 Stat. 418, 453-55.

^dU.S. Troop Readiness, Veterans' Care, Katrina Recovery, and Iraq Accountability Appropriations Act, 2007, Pub. L. No. 110-28, tit. IV, ch. 3, 121 Stat. 112, 153-54.

The Corps has conducted two nationwide climate vulnerability assessments to screen its portfolio of operated and maintained projects. According to the Corps' 2021 *Climate Action Plan*, vulnerability assessments are necessary for the Corps' ability to address climate change and successfully perform its missions, operations, programs, and projects in an increasingly dynamic environment.

In September 2014, the Corps completed initial vulnerability assessments of coastal projects that the Corps operates and maintains, using the Comprehensive Evaluation with Respect to Sea Level Change tool.⁵⁰ The Corps determined that 944 of its 1,431 evaluated coastal projects were not vulnerable to sea-level change, 94 projects may experience high or very high impacts from changing sea levels, and 393 projects may experience low or medium impacts from changing sea levels. The Corps began prioritizing the 94 projects that may experience high or very high impacts from changing sea levels for a more detailed assessment but paused this effort when priorities shifted with a new administration. In the Corps' 2022 *Climate Adaptation Plan Progress Report*, the agency reported completing an initial climate vulnerability screening of its portfolio of operated and maintained projects, including coastal and riverine water resources projects, using the Civil Works Vulnerability Assessment tool.⁵¹ The Corps plans to rank projects by vulnerability (e.g., high, moderate,

⁵⁰The Comprehensive Evaluation of Projects with Respect to Sea-Level Change assessed the vulnerability of Corps' coastal projects to the impacts of sea level change, and associated tides and surge, at the 50- and 100-year planning horizons. Coastal projects, for the purpose of the vulnerability assessment, are projects that are within 40 miles of tidally influenced water bodies, as defined by NOAA. See J. Garster, M. Huber, and K. White, *U.S. Army Corps of Engineers Screening-Level Assessment of Projects with Respect to Sea-Level Change* (Washington, D.C.: June 2015).

⁵¹The Civil Works Vulnerability Assessment tool provides a multifaceted analysis of multiple risks. The Corps also used scenario-based evaluations of sea level change impacts (if relevant), a review of peer-reviewed literature describing observed and future trends in hydrology and meteorology, a time series-based statistical assessment of the stationarity assumption, and an evaluation of watershed specific projections of future hydrology and meteorology via the CHAT to determine projects' residual risk from climate change. See U.S. Army Corps of Engineers, *USACE Climate Adaptation Plan: 2022 Progress Report*.

and low risk, or no impact) and prioritize high-risk projects for more detailed assessments to determine the consequences of inaction and appropriate climate adaptation steps.

Options to Further Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Have Strengths and Limitations

Through our analysis of relevant literature and interviews with stakeholders, we identified 14 options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure. Each of these options has strengths and limitations, according to knowledgeable stakeholders and relevant literature.⁵² Corps officials provided comments on the strengths and limitations of each option and the agency's authority to implement each option. According to these officials, the Corps likely would need additional congressional direction or authority to implement some options we identified but could implement aspects of certain options under existing law. We have not evaluated the extent to which the Corps could implement these options without congressional action.

Implementing multiple options could leverage the strengths and address the limitations of the individual options and offer greater possibilities for improving the climate resilience of federally funded flood risk management infrastructure, according to knowledgeable stakeholders we interviewed, literature we reviewed, and our analysis of the 14 options using our *Disaster Resilience Framework* (see app. I). Selecting the appropriate mix of options to best reduce the fiscal risks to the federal government is a policy choice that requires complex trade-offs. These trade-offs should be made with full information about the strengths and limitations of different options.

⁵²We gathered information on knowledgeable stakeholder views on the strengths and limitations of each option and not their views on whether the option would enhance the climate resilience of federally funded flood risk management infrastructure. We did not ask each knowledgeable stakeholder if they favored or opposed each option, and we do not have information about whether stakeholders would recommend one option over another. For additional information about how we identified the options from a literature search and interviewing stakeholders, see appendix II. For additional information about how these options could enhance the climate resilience of federally funded flood risk management infrastructure, see our analysis in appendix I.

Each Option to Further Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Has Strengths and Limitations

Each of the 14 options we identified to further enhance the climate resilience of federally funded flood risk management infrastructure has strengths and limitations, according to the knowledgeable stakeholders we interviewed and our review of relevant literature.⁵³ We organized the 14 options based on the five phases of the Corps’ project delivery process—(1) study initiation, (2) feasibility, (3) pre-construction engineering and design, (4) construction, and (5) operation and maintenance (see table 1).

Table 1: Options for the U.S. Army Corps of Engineers to Further Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure, by Project Delivery Phase

| |
|---|
| Applicable to all five phases of the project delivery process |
| 1. Create clear institutional authority to mainstream climate resilience. |
| 2. Research the feasibility of innovative approaches. |
| Phase 1: Study Initiation |
| 3. Expand technical assistance for planning. |
| Phase 2: Feasibility |
| 4. Update climate information for planning. |
| 5. Update planning guidance. |
| 6. Expand use of adaptive management in projects. ^a |
| 7. Integrate climate resilience into project-level benefit cost analyses. |
| Phase 3: Pre-Construction Engineering and Design |
| 8. Update engineering standards and regulations. |
| 9. Conduct climate screening assessments of authorized but unfunded projects. |
| Phase 4: Construction |
| 10. Prioritize projects that incorporate climate resilience. |
| Phase 5: Operation and Maintenance |
| 11. Update manuals for operation and maintenance. ^b |
| 12. Expand technical assistance to nonfederal sponsors for operation and maintenance. |
| 13. Conduct climate vulnerability assessments of existing infrastructure. |
| 14. Establish process for retrofitting existing infrastructure to account for climate change. |

Source: GAO analysis of literature and interviews with knowledgeable stakeholders. | GAO-24-105496

⁵³We conducted 21 interviews with knowledgeable stakeholders, eight of which included multiple individuals representing a single organization, which we counted as one knowledgeable stakeholder. To characterize knowledgeable stakeholders’ views throughout this report, we defined modifiers (e.g., “nearly all”) to quantify users’ views as follows: “some” represents two to five knowledgeable stakeholders, “several” represents six to 10 knowledgeable stakeholders, “most” represents 11 to 15 knowledgeable stakeholders, and “nearly all” represents 16 to 20 stakeholders.

Strengths and Limitations of
Options Applicable to All Five
Phases of the Project Delivery
Process

Note: We did not evaluate the extent to which the U.S. Army Corps of Engineers could implement these options without congressional action.

^aFor the purposes of this report, the term adaptive management includes both (1) adaptability, which includes designing a project that can be adjusted to future conditions; and (2) adaptive management, a structured management approach for addressing uncertainties by monitoring and assessing project performance or defined triggers and making modifications, as necessary.

^bFor the purposes of this report, we use the term manuals for operation and maintenance to represent a variety of manuals, such as operation and maintenance manuals, water control manuals, and water control plans.

We identified two options available to the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure that are applicable to all five phases of the Corps' project delivery process. Table 2 summarizes knowledgeable stakeholder opinions on the strengths and limitations of the options that are applicable to all phases of the Corps' project delivery process.

Table 2: Strengths and Limitations of Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Applicable to All Five Phases of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process

| Option | Strengths | Limitations |
|---|---|--|
| Option 1: Create Clear Institutional Authority to Mainstream Climate Resilience | | |
| Create clear institutional authority to mainstream the incorporation of climate resilience into federally funded flood risk management infrastructure studies and projects. | <ul style="list-style-type: none"> • Incorporates climate change and resilience into all Corps' decisions and projects. • Clearly communicates the Corps' priorities and expectations. • Could increase oversight and accountability for climate resilience measures. • Could increase Corps' knowledge sharing. • Corps officials believe they can implement this option under current authorities. | <ul style="list-style-type: none"> • Will not be effective without dedicated climate resilience staff with expertise at all agency levels. • May isolate climate resilience work within the agency. • Institutional authority could be subjective. • The effectiveness of this option depends on broader climate policies and goals set by Congress and the administration. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. |
| Option 2: Research the Feasibility of Innovative Approaches | | |
| Research the feasibility of innovative approaches to enhance the climate resilience of flood risk management infrastructure. | <ul style="list-style-type: none"> • Allows for research advances and developments where knowledge gaps exist. • Develops information on how to best build and manage projects in a changing climate. • Reduces subjectivity of decisions. • Long-term research can demonstrate project effectiveness. | <ul style="list-style-type: none"> • Communities may resist innovations that increase costs. • Long-term project monitoring is challenging to maintain, since benefits may not occur for many years. • Different geographic locations have different needs. • May take a long time to develop and implement innovative approaches. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. • Corps officials believe they have some authority to implement this option, but additional research-related authority would be helpful for effective implementation. |

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials. | GAO-24-105496

Note: We identified these options and described their strengths and limitations based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the extent to which the Corps could implement these options without congressional action.

Option 1: Create Clear Institutional Authority to Mainstream Climate Resilience

Creating clear institutional authority to mainstream the incorporation of climate resilience into federally funded flood risk management infrastructure studies and projects would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they believe they could implement this option under current authorities.

Option 2: Research the Feasibility of Innovative Approaches

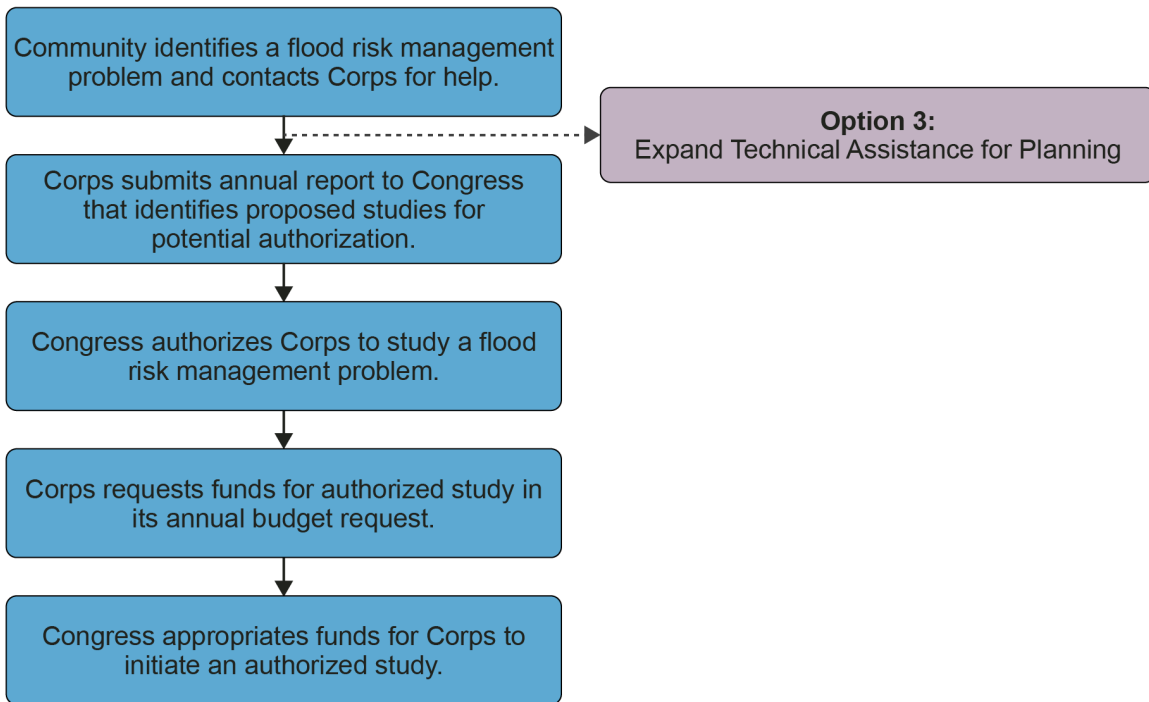
Researching the feasibility of innovative approaches to enhance the climate resilience of federally funded flood risk management infrastructure would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said that while the Corps is not a science agency with broad research authority, they believe they have some authority to implement this option. However, Corps officials we interviewed said that the agency would need additional authority to implement this option effectively.

For additional information about the strengths and limitations of these options and Corps officials' comments on their implementation, see appendix IV.

Strengths and Limitations of Options for Phase 1—Study Initiation

We identified one option available to the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure during phase 1 of the project delivery process—study initiation. Figure 9 shows the typical steps within this phase and where the option to enhance climate resilience could be implemented. For additional information about the Corps' study initiation phase, see appendix III.

Figure 9: Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 1 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Note: We identified 14 options that could further enhance the climate resilience of federally funded flood risk management infrastructure based on a comprehensive review of relevant literature. We assigned numbers to each option, and this figure depicts Option 3 of 14 that applies to phase 1: study initiation of the Corps' project delivery process.

Table 3 summarizes knowledgeable stakeholder opinions on the strengths and limitations of the option for phase 1.

Table 3: Strengths and Limitations of the Option to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 1 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process

| Option | Strengths | Limitations |
|--|---|---|
| Option 3: Expand Technical Assistance for Planning | | |
| Expand technical assistance provided by the Corps to communities to help them access and understand the climate information needed to identify flood risk problems and possible solutions. | <ul style="list-style-type: none"> Helps communities with limited capacity access and to apply climate-related data to projects to make more informed decisions. Helps the Corps build relationships with communities. Could increase use of existing Corps resources. | <ul style="list-style-type: none"> Will require consistent, authoritative information to be useful for communities. Communities may need assistance choosing which tools and data to use and how to use data. Capacity varies by community. Necessitates additional capacity to implement effectively. Well-established Corps processes and procedures will take time to change. Corps officials believe current technical assistance authorities are too limited to implement this option effectively and that additional authority is needed. |

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials. | GAO-24-105496

Note: We identified this option and described its strengths and limitations based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the extent to which the Corps could implement this option without congressional action.

Option 3: Expand Technical Assistance for Planning

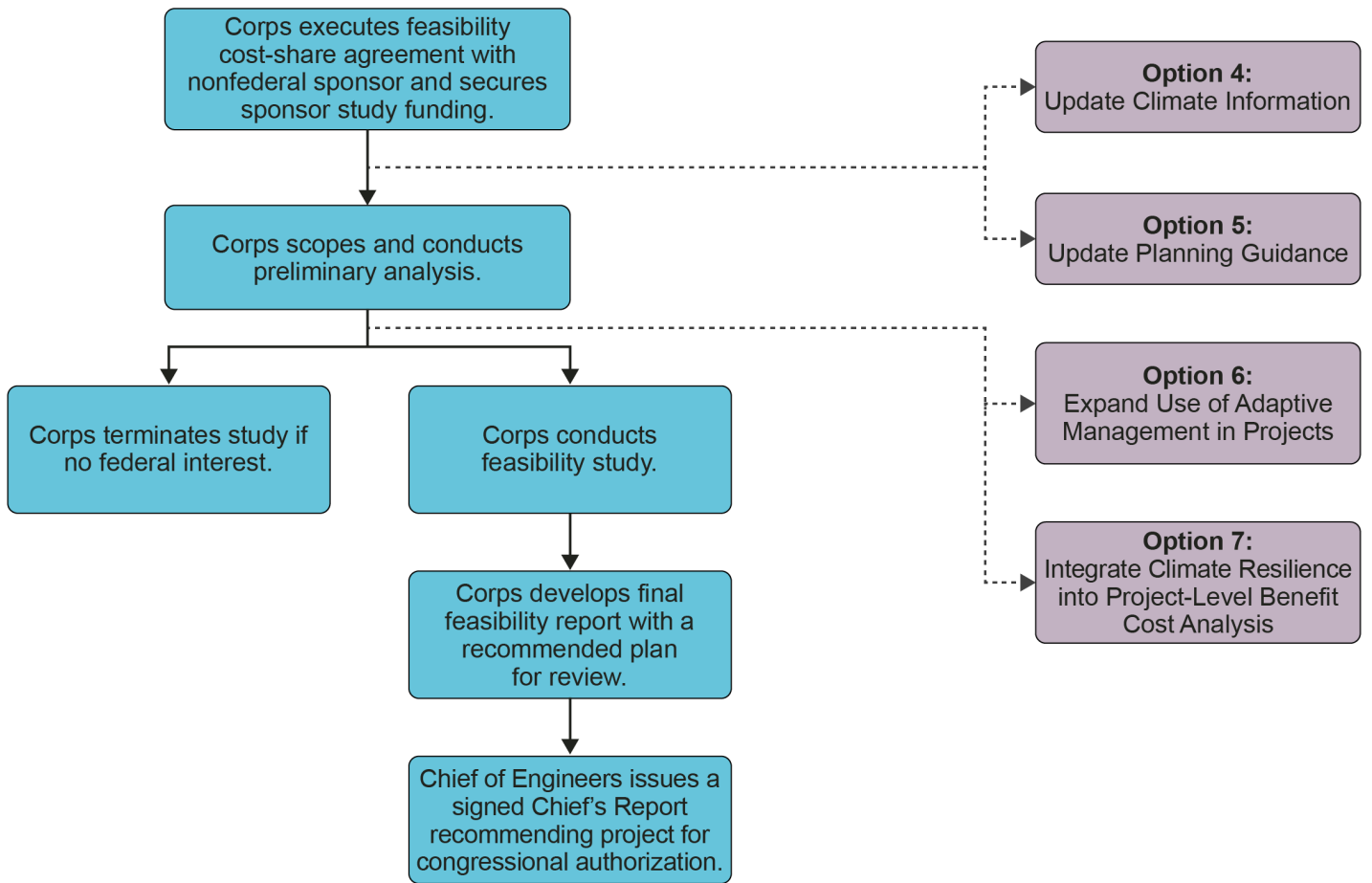
Expanding technical assistance that the Corps provides to communities to help them access and understand the climate information needed to identify flood risk problems and possible solutions would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they need additional authority to implement this option effectively, as current technical assistance authorities are too limited.

For additional information about the strengths and limitations of this option and Corps officials' comments on its implementation, see appendix IV.

Strengths and Limitations of Options for Phase 2—Feasibility

We identified four potential options available to the Corps to enhance the climate resilience of federally funded flood risk management infrastructure during phase 2 of the Corps' project delivery process—feasibility. Figure 10 shows the typical steps within this phase and where the options to enhance resilience could be implemented. For additional information about the Corps' feasibility phase, see appendix III.

Figure 10: Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 2 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Note: We identified 14 options that could further enhance the climate resilience of federally funded flood risk management infrastructure based on a comprehensive review of relevant literature. We assigned numbers to each option, and this figure depicts Options 4 through 7 of 14 that apply to phase 2: feasibility of the Corps' project delivery process.

Table 4 summarizes knowledgeable stakeholder opinions on the strengths and limitations of the options for phase 2.

Table 4: Strengths and Limitations of Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 2 of the U.S. Army Corps of Engineers’ (Corps) Project Delivery Process

| Option | Strengths | Limitations |
|---|--|--|
| Option 4: Update Climate Information for Planning | | |
| Update the Corps’ climate information needed for flood risk management infrastructure feasibility studies to be authoritative, actionable, and forward-looking. | <ul style="list-style-type: none"> • Facilitates consistent, informed decision-making. • Could help make climate-related information more easily accessible. • Consistent, authoritative data help communities explain why modifications or new projects are important. • Corps officials believe they can implement this option under current authorities. | <ul style="list-style-type: none"> • Other agencies may be responsible for collecting climate-related information. • Data availability differ by location. • Challenging to make decisions on what climate-related information to use for planning under uncertainty. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. |
| Option 5: Update Planning Guidance | | |
| Continue updating existing Corps’ guidance, and issue new technical guidance to require that climate resilience be incorporated into all flood risk management infrastructure studies and projects. | <ul style="list-style-type: none"> • Adds climate resilience requirements to all guidance and standards. • Continually updates guidance to include the best available climate-related information. • May increase the incorporation of climate resilience into all projects. • Helps nonfederal sponsors set expectations with communities. • Corps officials believe they can implement this option under current authorities. | <ul style="list-style-type: none"> • Will take time to collaborate with other external groups and professional societies. • Historically a lower priority than studies and projects to fund. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. |
| Option 6: Expand Use of Adaptive Management in Projects | | |
| Expand use of adaptive management in flood risk management infrastructure projects to enable enhanced climate resilience efforts later in project life span. ^a | <ul style="list-style-type: none"> • Helps manage uncertainty associated with future climate change in project design. • May save on long-term costs. • Allows flexibility to modify large, long-lived projects in the future to changing conditions. | <ul style="list-style-type: none"> • Will not be effective without clearly defined triggers that can be monitored and enforced. • Difficult to adapt structural projects or projects with limited space in urban areas. • Projects with future adaptability may not have well-defined future resilience measures. • Relies on future decisions to manage and implement modifications when adaptation triggers are met. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. • Corps officials believe they have some authority to implement this option for beach projects, but additional authority for non-beach projects would be required for effective implementation. |

| Option | Strengths | Limitations |
|--|---|---|
| Option 7: Integrate Climate Resilience into Project-Level Benefit Cost Analysis | | |
| Update the Corps' methods for conducting benefit cost analyses for flood risk management infrastructure to consider climate resilience. ^b | <ul style="list-style-type: none"> • Provides more comprehensive benefits and costs for projects. • Could increase consideration of equity issues in decision-making. • Builds consideration of climate resilience into all processes and design alternatives. | <ul style="list-style-type: none"> • Challenging to quantify all climate resilience benefits and costs. • Challenging to develop methodology that is fair and repeatable. • Corps may not have the authority to change aspects of the benefit cost analysis process. • Will require changing Corps' planning and guidance. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. • Corps officials believe they have some authority to implement this option, but additional authority would be helpful for effective implementation. |

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials. | GAO-24-105496

Note: We identified these options and described their strengths and limitations based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the extent to which the Corps could implement these options without congressional action.

^aFor the purposes of this report, the term adaptive management includes both (1) adaptability, which includes designing a project that can be adjusted to future conditions; and (2) adaptive management, a structured management approach for addressing uncertainties by monitoring and assessing project performance or defined triggers and making modifications, as necessary.

^bIn August 2023, the Office of Management and Budget published draft guidance that describes best practices for analyzing changes in ecosystem services (i.e., contributions of ecosystems to the benefits used in economic and other human activity) in the benefit cost analysis context. See Office of Management and Budget, *Guidance For Assessing Changes in Environmental and Ecosystem Services in Benefit-Cost Analysis* (August 2023).

Option 4: Update Climate Information for Planning

Updating Corps climate information needed for federally funded flood risk management infrastructure feasibility studies to be authoritative, actionable, and forward-looking would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials we interviewed told us they believe they could update climate information for planning under current authorities.

Option 5: Update Planning Guidance

Updating existing Corps' planning guidance and issuing new technical guidance to require that climate resilience be incorporated into all federally funded flood risk management infrastructure feasibility studies and projects would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials we interviewed said they believe the agency has the authority to update planning guidance under current authorities.

Option 6: Expand Use of Adaptive Management in Projects

Expanding project adaptability and the use of adaptive management to enable enhanced climate resilience efforts later in the flood risk management project life span would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they believe they have some authority to implement this option for beach projects, but additional authority for non-beach projects would be required for effective implementation.

Option 7: Integrate Climate Resilience into Project-Level Benefit Cost Analysis

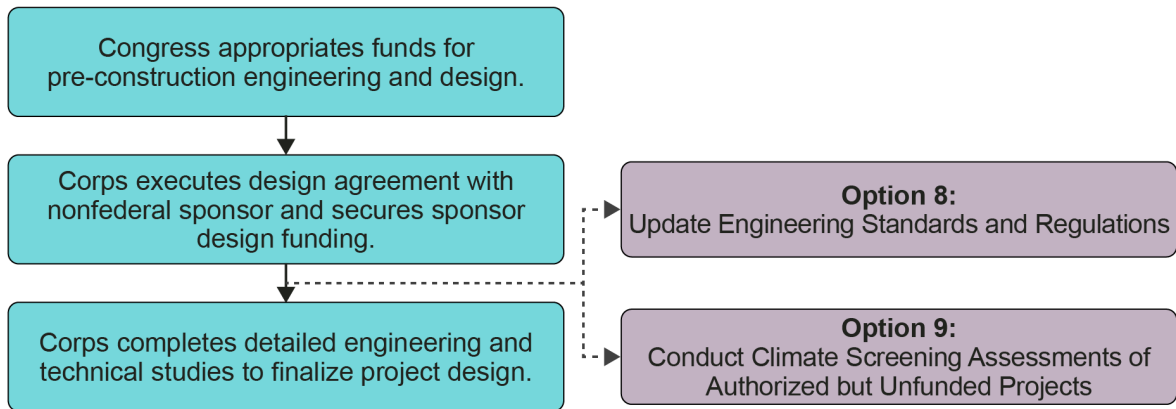
Updating the Corps' methods for conducting benefit cost analysis for federally funded flood risk management infrastructure to consider climate resilience would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they believe they have some authority to implement this option, but additional authority would be helpful to effectively integrate climate resilience into project-level benefit cost analyses.

For additional information about the strengths and limitations of these options and Corps officials' comments on their implementation, see appendix IV.

Strengths and Limitations of Options for Phase 3—Pre-Construction Engineering and Design

We identified two options available to the Corps to enhance the climate resilience of federally funded flood risk management infrastructure during phase 3 of its project delivery process—pre-construction engineering and design. Figure 11 shows the typical steps in this phase of the Corps' process and where the options could be implemented. For additional information about the Corps' pre-construction engineering and design phase, see appendix III.

Figure 11: Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 3 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Note: We identified 14 options that could further enhance the climate resilience of federally funded flood risk management infrastructure based on a comprehensive review of relevant literature. We assigned numbers to each option, and this figure depicts Options 8 and 9 of 14 that apply to phase 3: pre-construction engineering and design of the Corps' project delivery process.

Table 5 summarizes knowledgeable stakeholder opinions on the strengths and limitations of the options for phase 3.

Table 5: Strengths and Limitations of Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 3 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process

| Option | Strengths | Limitations |
|---|---|---|
| Option 8: Update Engineering Standards and Regulations | | |
| Update existing Corps' engineering standards and regulations, and issue new engineering standards and regulations, to require that climate resilience be incorporated into all flood risk management infrastructure projects. | <ul style="list-style-type: none"> Continually update standards and regulations to include the best available climate-related information. Builds Corps expertise and the consideration of climate change into all projects. Corps officials believe they can implement this option under current authorities. | <ul style="list-style-type: none"> Communities may resist new standards that increase costs and change established norms. Challenging to select appropriate future climate scenario to design to. Challenging to update standards if data are outdated or incomplete. Will take time to collaborate with other external groups and professional societies. Historically a lower priority than studies and projects to fund. Necessitates additional capacity to implement effectively. Well-established Corps processes and procedures will take time to change. |
| Option 9: Conduct Climate Screening Assessments of Authorized but Unfunded Projects | | |
| Conduct climate-screening assessments of authorized but unfunded projects prior to construction to determine if the projects incorporate suitable climate resilience measures. | <ul style="list-style-type: none"> Includes latest climate information in project designs. Determines if older project designs still protect communities against flood risks. | <ul style="list-style-type: none"> Lack of guidance to implement and account for future uncertainty, new information, and new climate resilience features. Necessitates additional capacity to implement effectively. Well-established Corps processes and procedures will take time to change. Corps officials believe they have some authority to implement this option, but additional authority would be required for effective implementation. |

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials. | GAO-24-105496

Note: We identified these options and described their strengths and limitations based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the extent to which the Corps could implement these options without congressional action.

Option 8: Update Engineering Standards and Regulations

Updating existing Corps' engineering standards and regulations and issuing new engineering standards and regulations that require climate resilience be incorporated into all federally funded flood risk management infrastructure projects, would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they believe they could implement this option under current authorities.

Option 9: Conduct Climate Screening Assessments of Authorized but Unfunded Projects

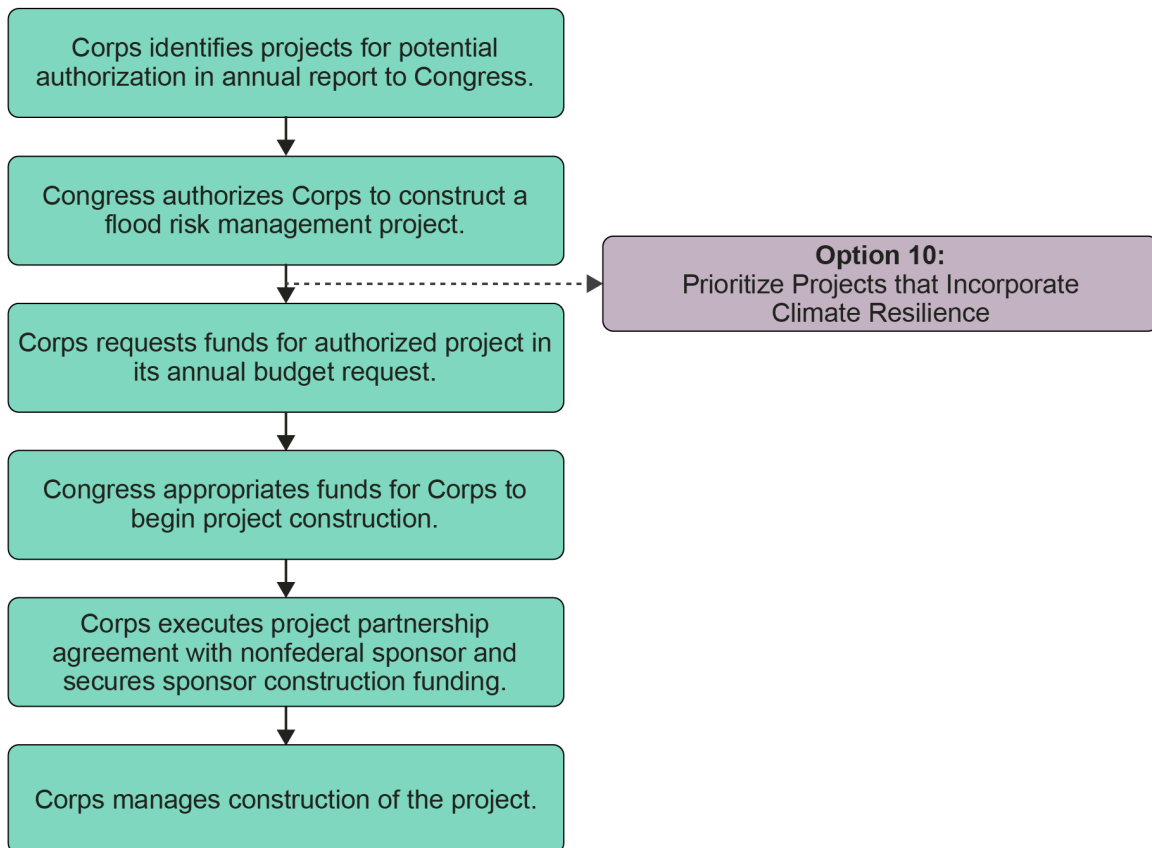
Conducting climate-screening assessments of authorized but unfunded flood risk management infrastructure projects prior to construction to determine if the projects incorporate suitable climate resilience measures would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they believe they have some authority to implement this option, but additional authority would be required for effective implementation.

For additional information about the strengths and limitations of these options and Corps officials' comments on their implementation, see appendix IV.

Strengths and Limitations of Options for Phase 4—Construction

We identified one potential option available to the Corps to enhance the climate resilience of federally funded flood risk management infrastructure during phase 4 of the Corps' project delivery process—construction. Figure 12 shows the typical steps in this phase and where the option could be implemented. For additional information about the Corps' construction phase, see appendix III.

Figure 12: Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 4 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Note: We identified 14 options that could further enhance the climate resilience of federally funded flood risk management infrastructure based on a comprehensive review of relevant literature. We assigned numbers to each option, and this figure depicts Option 10 of 14 that applies to phase 4: construction of the Corps' project delivery process.

Table 6 summarizes knowledgeable stakeholder opinions on the strengths and limitations of the option for phase 4.

Table 6: Strengths and Limitations of Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 4 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process

| Option | Strengths | Limitations |
|--|--|---|
| Option 10: Prioritize Projects That Incorporate Climate Resilience | | |
| Prioritize flood risk infrastructure projects that incorporate climate resilience. | <ul style="list-style-type: none"> • Encourages incorporation of climate resilience into all projects. • Responsive to climate change and community needs. • Could prioritize high-risk areas and vulnerable communities. • Shows that climate resilience is a priority. | <ul style="list-style-type: none"> • Lack of guidance on how to prioritize climate resilience projects. • Other factors may take precedence or be higher priorities than climate resilience. • May disproportionately impact underserved communities. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. • Corps officials believe they are limited in their ability to implement this option based on the priorities of the administration and Congress. |

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials. | GAO-24-105496

Note: We identified this option and described its strengths and limitations based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the extent to which the Corps could implement this option without congressional action.

Option 10: Prioritize Projects That Incorporate Climate Resilience

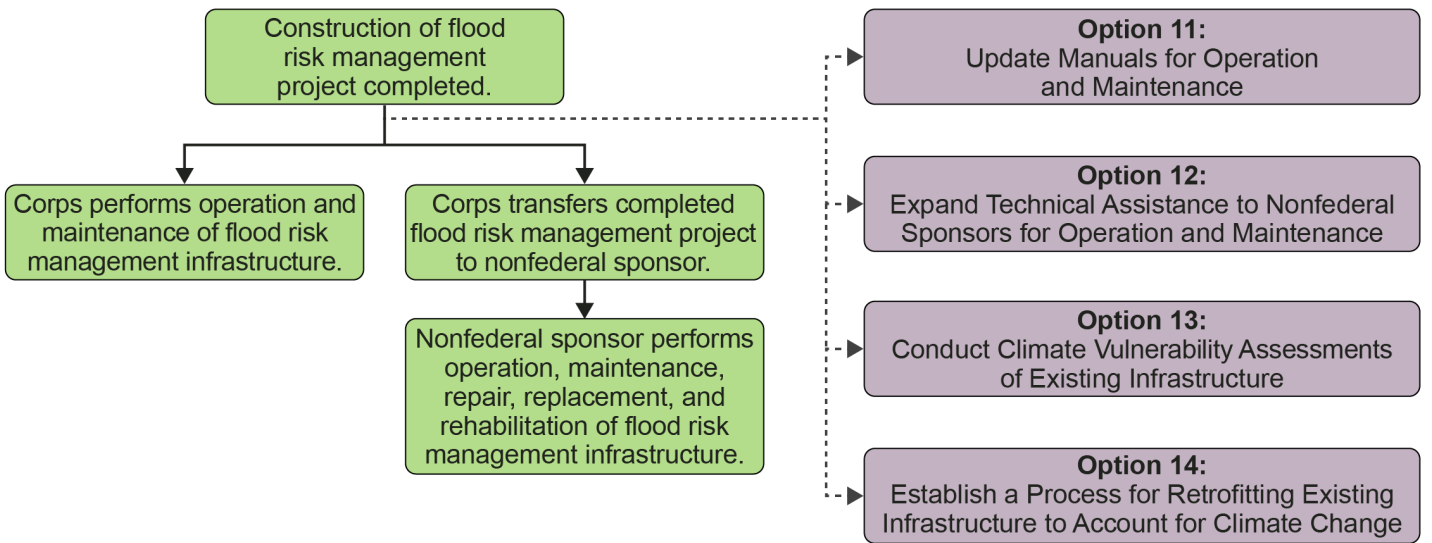
Prioritizing federally funded flood risk management infrastructure projects that incorporate climate resilience would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they may have authority to implement this option, but they are limited in their ability to do so based on the priorities of the administration and Congress.

For additional information about the strengths and limitations of this option and Corps officials' comments on its implementation, see appendix IV.

Strengths and Limitations of Options for Phase 5—Operation and Maintenance

We identified four potential options available to the Corps to enhance the climate resilience of federally funded flood risk management infrastructure during phase 5 of the agency's project delivery process—operation and maintenance. Figure 13 shows the typical steps in this phase of the process and where the options could be implemented. For additional information about the Corps' operation and maintenance phase, see appendix III.

Figure 13: Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 5 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Note: We identified 14 options that could further enhance the climate resilience of federally funded flood risk management infrastructure based on a comprehensive review of relevant literature. We assigned numbers to each option, and this figure depicts Options 11 through 14 of 14 that apply to phase 5: operation and maintenance of the Corps' project delivery process.

Table 7 summarizes knowledgeable stakeholder opinions on the strengths and limitations of the options for phase 5

Table 7: Strengths and Limitations of Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure during Phase 5 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process

| Options | Strengths | Limitations |
|---|---|---|
| Option 11: Update Manuals for Operation and Maintenance | | |
| Update manuals for operation and maintenance to account for climate change and climate resilience best practices. ^a | <ul style="list-style-type: none"> • Helps ensure that the best available science and practices are included in manuals. • Standardizes climate change projections in manuals. • Corps officials believe they can implement this option under current authorities. | <ul style="list-style-type: none"> • The Corps does not have operation and maintenance responsibilities for much of the flood risk management infrastructure it delivers. • Potential increased costs to nonfederal sponsors responsible for operating and maintaining completed project. • Depends on having reliable and updated climate-related information. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. |
| Option 12: Expand Technical Assistance to Nonfederal Sponsors for Operation and Maintenance | | |
| Expand technical assistance provided by the Corps to help nonfederal sponsors maintain, operate, repair, replace, and rehabilitate flood risk management infrastructure. | <ul style="list-style-type: none"> • Considers upgrades to infrastructure based on nonstationarity of climate change. • Can help communities better understand climate-related risks. • Could improve the quality and consistency of information and Corps' assistance to communities. • Can facilitate communication and collaboration among communities to enhance resilience at the watershed or regional level. | <ul style="list-style-type: none"> • May overlap with assistance provided by other programs and the industry. • Climate-related information comes from other agencies. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. • Corps officials believe they cannot implement this option under their current authorities related to providing technical assistance. |
| Option 13: Conduct Climate Vulnerability Assessment of All Existing Infrastructure | | |
| Conduct climate vulnerability assessments on all existing flood risk management infrastructure to identify the most vulnerable infrastructure, infrastructure with the highest consequences from failure, and infrastructure that will require adaptation sooner. | <ul style="list-style-type: none"> • May increase awareness of infrastructure that needs attention. • Could help direct resources toward largest risks. • More efficient than updating individual manuals for operation and maintenance. • Could be considered in existing infrastructure assessment processes. | <ul style="list-style-type: none"> • Lack of guidance on how to conduct vulnerability assessments. • Will not improve climate resilience unless paired with funding to address vulnerabilities identified by the assessments. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. • Corps officials believe they cannot implement this option under existing authorities. |

| Options | Strengths | Limitations |
|---|---|---|
| Option 14: Establish Process for Retrofitting Existing Infrastructure to Account for Climate Change | | |
| Establish a process for modifications to enhance the climate resilience of existing flood risk management infrastructure most vulnerable to climate change. | <ul style="list-style-type: none"> • Would fill a gap in current processes for retrofitting existing infrastructure. • Addresses long-term risks to aging infrastructure that may be more vulnerable to climate change. • Increases flexibility during planning and operation and maintenance. | <ul style="list-style-type: none"> • May overlap or conflict with the Corps' existing project delivery process. • Lack of guidance on how to complete retrofitting process. • Necessitates additional capacity to implement effectively. • Well-established Corps processes and procedures will take time to change. • Corps officials believe they cannot implement this option under existing authorities. |

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials. | GAO-24-105496

Note: We identified these options and described their strengths and limitations based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the extent to which the Corps could implement these options without congressional action.

⁹For the purposes of this report, we use the term manuals for operation and maintenance to represent a variety of manuals, such as operation and maintenance manuals, water control manuals, and water control plans. Strengths and limitations for Option 11 may not apply to all manual types, as the Corps operates and maintains some flood risk management infrastructure and nonfederal sponsors operate and maintain other flood risk management infrastructure.

Option 11: Update Manuals for Operation and Maintenance

Updating manuals for operation and maintenance to account for climate change and climate resilience best practices would have strengths and limitations, according to knowledgeable stakeholders and relevant literature.⁵⁴ Corps officials said they believe they could implement this option under current authorities.

Option 12: Expand Technical Assistance to Nonfederal Sponsors for Operation and Maintenance

Expanding the technical assistance provided by the Corps to help nonfederal sponsors maintain, operate, repair, replace, and rehabilitate federally funded flood risk management infrastructure would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they would need additional authority to implement this option.

Option 13: Conduct Climate Vulnerability Assessment of All Existing Infrastructure

Conducting climate vulnerability assessments on all existing federally funded flood risk management infrastructure to identify the most vulnerable infrastructure, infrastructure with the highest consequences

⁵⁴For the purposes of this report, we use the term manuals for operation and maintenance to represent a variety of manuals, such as operation and maintenance manuals, water control manuals, and water control plans. Strengths and limitations for Option 11 may not apply to all manual types, as the Corps operates and maintains some flood risk management infrastructure, and nonfederal sponsors operate and maintain other flood risk management infrastructure.

from failure, and infrastructure that will require adaptation sooner would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they would need additional authority to implement this option.

Option 14: Establish Process for Retrofitting Existing Infrastructure to Address Climate Change

Establishing a process for modifications to enhance the climate resilience of existing federally funded flood risk management infrastructure most vulnerable to climate change would have strengths and limitations, according to knowledgeable stakeholders and relevant literature. Corps officials said they would need additional authority to implement this option.

For additional information about the strengths and limitations of these options and Corps officials' comments on their implementation, see appendix IV.

Implementing Multiple Options Provides the Greatest Potential to Further Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure

Implementing multiple options could better leverage the strengths, as well as address the limitations, of the different options. A multi-option approach would also offer the greatest potential to improve the climate resilience of federally funded flood risk management infrastructure, according to the knowledgeable stakeholders we interviewed and our analysis of the 14 options, using our *Disaster Resilience Framework*. Our *Disaster Resilience Framework* states that integrating strategic resilience goals can help decision makers work toward a common vision and help ensure focus on a wide variety of opportunities to reduce risk.

Most of the knowledgeable stakeholders we interviewed said that, given their relative strengths and limitations, some of the options to further enhance the climate resilience of federally funded flood risk management infrastructure are mutually reinforcing, and that these options would work best if more than one was implemented. Similarly, Corps officials said that a combination of the options would be the most helpful for continuing to incorporate climate resilience into the project delivery process for federally funded flood risk management infrastructure. For example, several knowledgeable stakeholders said it would be difficult to update guidance without using the latest climate information. Another stakeholder said it would be difficult to update guidance without providing technical assistance to help planners and nonfederal sponsors understand changes in the guidance. Corps officials also said that the options we identified to provide additional technical assistance, for planning and operation and maintenance, would require having updated climate information.

Several knowledgeable stakeholders also suggested that some of the options may be most effective when implemented sequentially. For example, some knowledgeable stakeholders said that if the Corps were to conduct climate vulnerability assessments on all existing flood risk management, then it would need a plan or process to modify vulnerable infrastructure.

Recent executive orders direct federal agencies to take steps related to enhancing our nation's resilience to climate change. Executive Order 14008 states that the administration's policy is to deploy the full capacity of federal agencies to, among other things, combat climate change and implement a government-wide approach that increases climate resilience.⁵⁵ The order directs agencies to submit a climate action plan that describes steps the agency can take with regard to its facilities and operations to bolster adaptation and increase resilience to the impacts of climate change, submit annual progress reports, and make action plans publicly available. In addition, Executive Order 14030 requires agencies to report on actions they are taking to integrate climate-related financial risk into their procurement process.⁵⁶ Furthermore, Executive Order 14057 and its implementing instructions require agencies to develop, implement, and update their climate action plans and to conduct climate adaptation analyses and planning for climate-informed financial and management decisions and program implementation.⁵⁷ Finally, Executive Order 14057 also requires federal agencies to reform agency policies and funding programs that are maladaptive to climate change and that increase the vulnerability of communities, natural or built systems, economic sectors, and natural resources to climate impacts or related risks.

The Corps has taken, and plans to take, actions to enhance the climate resilience of federally funded flood risk management infrastructure. For example, in May 2021, the Acting Assistant Secretary of the Army for Civil Works updated the Corps' overarching climate policy, reaffirming that it is the Corps' policy to integrate climate change preparedness and resilience planning and actions in all Corps activities to help enhance community

⁵⁵Exec. Order No. 14008, *Tackling the Climate Crisis at Home and Abroad*, 86 Fed. Reg. 7619, 7922 (Jan. 27, 2021).

⁵⁶Exec. Order No. 14030, *Climate-Related Financial Risk*, 86 Fed. Reg. 27967, 26969 (May 20, 2021).

⁵⁷Exec. Order No. 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, 86 Fed. Reg. 70935, 70937 (Dec. 8, 2021).

resilience and reduce potential vulnerability to the effects of climate change and variability. Further, in October 2021, the Corps issued an updated Climate Action Plan for integrating climate adaptation and resilience into its missions and programs. This included actions the Corps plans to take, such as issuing new technical design guidance, updating existing guidance, requiring climate change be considered in project planning and design, updating climate information, and providing technical assistance to help nonfederal sponsors better plan for climate change. Given the value of the nation's flood risk management infrastructure and the potential cost of future infrastructure, it is important that the Corps continues to work to enhance climate resilience in its efforts.

Our comparison of the 14 options available to the Corps' current efforts, using the principles of our *Disaster Resilience Framework*, shows how implementing each option could further enhance the climate resilience of federally funded flood risk management infrastructure (see app. 1). For example, the framework states that integrating missions and resources that support disaster risk reduction can help build national resilience to natural hazards. Using the framework's integration principle, we compared the option of the Corps updating its planning guidance to require that climate resilience measures be incorporated in projects with the Corps' efforts to provide planning guidance on how to implement climate resilience. We found that new and updated planning guidance could help further enhance the climate resilience of federally funded flood risk management infrastructure projects.

Determining the appropriate mix of options for enhancing the climate resilience of federally funded flood risk management infrastructure is a policy choice that requires complex trade-off decisions. These trade-off decisions should be made with full information about the strengths and limitations of the different options. Corps officials told us that their ongoing efforts, and planned efforts, to enhance climate resilience are consistent with some of the 14 options we identified in this report.⁵⁸ Specifically, Corps officials said they could likely implement some of the options under their existing authorities. For example, officials said they believe the Corps has authority to create an institutional entity for mainstreaming

⁵⁸For additional information on the 14 options we identified and our comparison of them with the Corps' ongoing and planned efforts to enhance the climate resilience of federally funded flood risk management infrastructure, see our *Disaster Resilience Framework* analysis in appendix I. We determined that the Corps still has opportunities to enhance climate resilience by implementing the 14 options we identified.

climate resilience into flood risk management infrastructure studies and projects. However, Corps officials said they likely would need additional direction or authority from Congress to act on some of the options or to implement a combination of options. For example, officials said they would need additional authority to provide technical assistance that is not requested by a nonfederal sponsor or tied to a specific project. Corps officials also stated that some of the options would have limited effectiveness without additional appropriations to implement them.

Congress is expected to pass a new Water Resources Development Act authorizing Corps' civil works activities in 2024. The forthcoming Water Resources Development Act presents Congress with an opportunity to provide the Corps with clear direction and authority to implement certain options for enhancing the climate resilience of federally funded flood risk management infrastructure. The 14 options we identified in this report represent opportunities to improve resilience in the nation's flood risk management infrastructure and help ensure that federally funded structures, such as levees, dams, floodwalls, floodgates, and hurricane barriers, can better withstand or more easily recover from changes in the climate.

Moreover, providing the Corps with additional direction or authority to implement one or more of the options could further enhance the climate resilience of more or all federally funded flood risk management infrastructure, depending on the options exercised. Doing so would also provide an important avenue for addressing the federal government's fiscal exposure to the impacts of climate change, as the options offer the opportunity to reduce the overall impact of disasters.⁵⁹ Finally, considering how to implement a variety of options to enhance the climate resilience of federally funded flood risk management infrastructure, such as the options identified in this report, could help the Corps meet its responsibilities under Executive Orders 14008, 14030, and 14057.

Conclusions

The Corps has taken several important steps to enhance the climate resilience of federally funded flood risk management infrastructure. Nevertheless, opportunities exist for the Corps to take additional actions that limit the federal government's fiscal exposure from damage to such infrastructure. We identified 14 options that the Corps could take to

⁵⁹This conclusion is based on our analysis using our *Disaster Resilience Framework*. See appendix I for more information on how we used the framework to evaluate the extent to which each of the options we identified could help enhance the climate resilience of federally funded flood risk management infrastructure.

further enhance the climate resilience of federally funded flood risk management infrastructure, each of which has strengths and limitations. More specifically, we concluded that implementing multiple options could leverage their strengths and address their limitations and offers the greatest potential to enhance the climate resilience of federally funded flood risk management infrastructure. Our conclusion is based on an extensive analysis using our *Disaster Resilience Framework*, our review of relevant literature, and interviews with knowledgeable stakeholders. However, Corps officials we interviewed said the agency is completing actions related to some of the options but would need additional direction or authority from Congress to implement some, or a combination of, the options. The officials also said that some options could not be implemented, or would have limited effectiveness, without additional funding.

Determining which options to implement to enhance the climate resilience of federally funded flood risk management infrastructure requires detailed analyses of complex issues and may require difficult decisions involving trade-offs related to the costs and benefits of different options. Nevertheless, conducting a comprehensive analysis of the options identified in this report could help the Corps determine which options to prioritize in future climate resilience planning efforts and seek congressional approval, as appropriate, for statutory authorities and resources necessary to implement those options. Furthermore, conducting a comprehensive analysis of the available options can help the Corps better ensure that federally funded flood risk management infrastructure can withstand and more readily recover from climate-related damages, and thereby reduce the need for federal disaster assistance and limit the federal government's fiscal exposure.

Finally, a new Water Resources Development Act authorizing the Corps' civil works activities offers an opportunity for Congress to seek and consider any analyses or proposals from the Corps and provide direction or authority to the agency to take additional actions to implement one or more options for enhancing the climate resilience of federally funded flood risk management infrastructure. Doing so would help the Corps ensure that flood risk management infrastructure can better withstand, and recover from, extreme weather events and natural disasters that are expected to be exacerbated by climate change.

Recommendation for Executive Action

The Assistant Secretary of the Army for Civil Works should direct the Chief of Engineers and Commanding General of the U.S. Army Corps of Engineers to (1) analyze the 14 options for enhancing the climate resilience of federally funded flood risk management infrastructure identified in this report; and (2) integrate them, as appropriate, into the Corps' future climate resilience prioritization and planning efforts. Such analysis should include an explanation of the Corps' decision to prioritize or not prioritize the options, as well as legislative proposals, as appropriate, that identify any additional authorities and resources the Corps would need to implement the options. (Recommendation 1)

Matter for Congressional Consideration

As Congress considers authorizing legislation for the U.S. Army Corps of Engineers' civil works activities, Congress should consider—in light of any analyses or proposals submitted by the U.S. Army Corps of Engineers—providing direction or authority to implement one or more of the 14 options for enhancing the climate resilience of federally funded flood risk management infrastructure identified in this report. (Matter for Consideration 1)

Agency Comments

We provided a draft of this report to the Corps for review and comment. In its comments, reproduced in appendix V, the Corps concurred with our recommendation, stating that it will analyze the 14 options in the report and integrate them, as appropriate, into the Corps' future climate resilience prioritization and planning efforts to include explanations of their decisions as well as legislative proposals, as appropriate for additional authorities and resources needed to implement the options. The Corps also provided technical comments, which we incorporated as appropriate.

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 appropriate congressional committees, the Secretary of Defense, the Assistant Secretary of the Army for Civil Works, the Chief of Engineers and Commanding General of the U.S. Army Corps of Engineers, and other interested parties. In addition, the report will be available at no charge on the GAO website at <https://www.gao.gov>.

If you or your staff members 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 major contributions to this report are listed in appendix VI.

A handwritten signature in black ink that reads "Alfredo Gómez". The signature is written in a cursive style with a large, stylized initial 'A' and 'G'.

J. Alfredo Gómez
Director, Natural Resources and Environment

Appendix I: Using the *Disaster Resilience Framework* to Analyze Options to Further Enhance Climate Resilience

The U.S. Army Corps of Engineers (Corps) can reduce federal fiscal exposure by pursuing additional climate resilience options, according to our analysis using GAO's *Disaster Resilience Framework*.¹ GAO has identified the rising number of natural disasters and increasing reliance on federal assistance as a significant source of federal fiscal exposure. Investments in disaster resilience are a promising avenue to address the federal fiscal exposure because such investments offer the opportunity to reduce the overall impact of disasters.

We compared the options available for further enhancing the climate resilience of federally funded flood risk management infrastructure—for example levees, dams, floodwalls, floodgates, and hurricane barriers—with the Corps' current climate resilience efforts, using the principles and subprinciples in GAO's *Disaster Resilience Framework*. As stated in the framework, some principles and concepts are likely to be more relevant in the analysis of certain federal efforts than others. It is appropriate to apply portions of the framework to improve the resilience of federal programs, depending upon the specific circumstances. Users of the framework should exercise their professional judgment when determining how best to make the principles and concepts meet their needs. This appendix documents the professional judgment we applied to our analysis of options available to the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure.

We organized our analysis around the framework's three broad overlapping principles—information, integration, and incentives—and a series of questions that those responsible for overseeing or managing federal efforts can consider when analyzing opportunities to enhance their contribution to national disaster resilience and reduce federal fiscal exposure (see fig. 14).

¹GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, [GAO-20-100SP](#) (Washington, D.C.: October 2019).

Figure 14: GAO's Disaster Resilience Framework Principles



Source: GAO's Disaster Resilience Framework (GAO-21-100SP); GAO (icons). | GAO-24-105496

For each option, an analyst decided which Corps' efforts and *Disaster Resilience Framework* principles, subprinciples, and analysis questions were relevant. The analyst then assessed and documented whether each option could further enhance the climate resilience of federally funded flood risk management infrastructure based on a qualitative assessment of each option and the Corps' current climate resilience efforts. A second analyst reviewed the first analyst's work to ensure that the conclusions drawn were sound. If the second analyst did not concur with the conclusions drawn, the second analyst documented the rationale. The team also documented in its workpapers how any differences of opinion were resolved before presenting the final analyses in figures 15 through 21.

Information. Six of the 14 options to further enhance the climate resilience of federally funded flood risk management infrastructure and the Corps' current efforts align with the information principle of GAO's *Disaster Resilience Framework*. Comparing these options and efforts with the most relevant subprinciples and questions in the framework illustrates opportunities for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure and limit federal fiscal exposure (see figs. 15, 16, and 17).

Appendix I: Using the Disaster Resilience Framework to Analyze Options to Further Enhance Climate Resilience

Figure 15: Opportunities to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Related to the Information Principle in GAO's *Disaster Resilience Framework*

| | | | |
|---|--|---|--|
| <p>Principle:</p> <p>Information</p> <p>Accessing information that is authoritative and understandable can help decision makers to identify current and future risk and the impact of risk-reduction strategies.</p> <p>Provide reliable and authoritative information about current and future risk</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> Enhance the validity and reliability of the disaster risk information produced? <ul style="list-style-type: none"> generate and share additional information that would help decision makers understand their disaster risk reduce the complexity of and translate risk information for non-technical audiences? <p>* Help leverage and synthesize disaster risk information from other partners across agencies, governments, and sectors?</p> <p>* Promote consensus around the reliability of the sources and methods that produce disaster risk information?</p> <p>Improve the ability to assess alternatives to address risk</p> <p>To what extent could federal efforts</p> <ul style="list-style-type: none"> help decision makers identify and select among disaster risk-reduction alternatives? provide technical assistance to help build capacity of nonfederal partners? Contribute to an understanding of approaches for estimating returns on investment? Help decision makers identify and combine available funding sources and innovative methods for meeting disaster risk-reduction needs? <p>Strengthen the ability to assess status and report progress</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> Advance methodologies or processes to measure the current state of nationwide resilience? Promote monitoring of progress toward resilience on a programmatic basis? | <p>Information subprinciple: Provide reliable and authoritative information about current and future risk</p> | | |
| | <p>Option to enhance the climate resilience of federally funded flood risk management infrastructure</p> | <p>Corps' climate resilience effort</p> | <p>Question for consideration: Could the option generate and share additional information that would help decision makers understand their disaster risk?</p> |
| | <p>Option 2: Research the Feasibility of Innovative Approaches^a</p> | <p>Conducting and funding climate resilience research</p> | <p>Yes. The Corps conducts climate resilience and adaptation research through its different programs and centers of expertise. The Corps also funds research studies with external experts.</p> <p>Opportunities exist for the Corps to continue researching the feasibility of innovative approaches to help planners, engineers, and nonfederal sponsors better understand future climate change risks and identify potential solutions.</p> |
| | | | <p>Question for consideration: Could the option help reduce the complexity of and translate risk information for non-technical audiences?</p> |
| | | | <p>Question for consideration: Could the option help reduce the complexity of and translate risk information for non-technical audiences?</p> |
| <p>Option 4: Update Climate Information for Planning^b</p> | <p>Updating some existing climate information</p> | <p>Yes. The Corps recently updated some of its existing web-based tools, including the Sea Level Analysis Tool and the Climate Hydrology Assessment tool.</p> <p>Opportunities exist for the Corps to enhance the validity and reliability of the disaster risk information produced by web-based tools by providing updated climate information.</p> | |

Sources: GAO's *Disaster Resilience Framework* (GAO-20-100SP) and GAO analysis of the U.S. Army Corps of Engineers (Corps) documents, relevant literature, and interviews with knowledgeable stakeholders and Corps officials; GAO (icons). | GAO-24-105496

^aOption 2 is applicable to all five phases of the Corp's project delivery process—study initiation, feasibility, pre-construction engineering and design, construction, and operation and maintenance.

^bOption 4 is applicable to phase 2 of the Corps' project delivery process—feasibility

Appendix I: Using the Disaster Resilience Framework to Analyze Options to Further Enhance Climate Resilience

Figure 16: Opportunities to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Related to the Information Principle in GAO's *Disaster Resilience Framework*

| | | | |
|---|--|--|--|
| <p>Information</p> <p>Accessing information that is authoritative and understandable can help decision makers to identify current and future risk and the impact of risk-reduction strategies.</p> <p>Provide reliable and authoritative information about current and future risk</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> Enhance the validity and reliability of the disaster risk information produced? generate and share additional information that would help decision makers understand their disaster risk reduce the complexity of and translate risk information for non-technical audiences? Help leverage and synthesize disaster risk information from other partners across agencies, governments, and sectors? Promote consensus around the reliability of the sources and methods that produce disaster risk information? <p>Improve the ability to assess alternatives to address risk</p> <p>To what extent could federal efforts</p> <ul style="list-style-type: none"> help decision makers identify and select among disaster risk-reduction alternatives? provide technical assistance to help build capacity of nonfederal partners? Contribute to an understanding of approaches for estimating returns on investment? Help decision makers identify and combine available funding sources and innovative methods for meeting disaster risk-reduction needs? <p>Strengthen the ability to assess status and report progress</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> Advance methodologies or processes to measure the current state of nationwide resilience? Promote monitoring of progress toward resilience on a programmatic basis? | Information subprinciple: Improve the ability to assess alternatives to address risk | | |
| | Option to enhance the climate resilience of federally funded flood risk management infrastructure | Corps' climate resilience effort | Question for consideration: Could the option provide technical assistance to help build capacity of nonfederal partners? |
| | Option 3: Expand Technical Assistance for Planning^a | Providing technical assistance | Yes. The Corps provides direct technical and planning support to communities when requested through various existing programs. Some of the Corps' programs and tools may help communities enhance the climate resilience of federally funded flood risk management projects. Opportunities exist for the Corps to provide technical assistance without specific community requests or study authorizations that could help build capacity of communities when designing climate resilient flood risk management infrastructure projects. |
| | Option 9: Conduct Climate Screening Assessments of Authorized but Unfunded Projects^b | Deauthorization of some projects | Yes. The Corps restudies some flood risk management infrastructure projects if those projects are not constructed and initial feasibility studies are outdated, but climate resilience is not a factor that triggers a restudy. The Corps can also remove certain backlogged flood risk management infrastructure projects during technical reviews if those projects have not begun pre-construction engineering and design. Opportunities exist for the Corps to assess all authorized but not constructed federally funded flood risk management infrastructure projects for climate resilience. |
| Option 12: Expand Technical Assistance to Sponsors for Operations and Maintenance^c | No action taken | Yes. Opportunities exist for the Corps to provide technical assistance for operation and maintenance to help build capacity of nonfederal sponsors and enhance the climate resilience of federally funded flood risk management infrastructure during operation and maintenance. | |

Sources: GAO's *Disaster Resilience Framework* (GAO-20-100SP) and GAO analysis of the U.S. Army Corps of Engineers (Corps) documents, relevant literature, and interviews with knowledgeable stakeholders and Corps officials; GAO (icons). | GAO-24-105496

^aOption 3 is applicable to phase 1 of the Corps' project delivery process—study initiation.

^bOption 9 is applicable to phase 3 of the Corps' project delivery process—pre-construction engineering and design.

^cOption 12 is applicable to phase 5 of the Corps' project delivery process—operation and maintenance.

Appendix I: Using the Disaster Resilience Framework to Analyze Options to Further Enhance Climate Resilience

Figure 17: Opportunities to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Related to the Information Principle in GAO's *Disaster Resilience Framework*

| <p>Information</p> <p>Accessing information that is authoritative and understandable can help decision makers to identify current and future risk and the impact of risk-reduction strategies.</p> <p>Provide reliable and authoritative information about current and future risk</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> Enhance the validity and reliability of the disaster risk information produced? generate and share additional information that would help decision makers understand their disaster risk reduce the complexity of and translate risk information for non-technical audiences? Help leverage and synthesize disaster risk information from other partners across agencies, governments, and sectors? Promote consensus around the reliability of the sources and methods that produce disaster risk information? <p>Improve the ability to assess alternatives to address risk</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> help decision makers identify and select among disaster risk-reduction alternatives? provide technical assistance to help build capacity of nonfederal partners? Contribute to an understanding of approaches for estimating returns on investment? Help decision makers identify and combine available funding sources and innovative methods for meeting disaster risk-reduction needs? <p>Strengthen the ability to assess status and report progress</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> Advance methodologies or processes to measure the current state of nationwide resilience? Promote monitoring of progress toward resilience on a programmatic basis? | Information subprinciple: Strengthen the ability to assess status and report progress | | |
|--|---|--|---|
| | Option to enhance the climate resilience of federally funded flood risk management infrastructure | Corps' climate resilience effort | Question for consideration: Could the option help advance methodologies or processes to measure the current state of nationwide resilience? |
| Option 13: Conduct Climate Vulnerability Assessment of Existing Infrastructure ^a | Vulnerability assessments of some infrastructure | <p>Yes. The Corps has conducted initial climate vulnerability assessments of Corps'-operated and -maintained projects, including coastal and riverine flood risk management infrastructure projects.</p> <p>Opportunities exist for the Corps to conduct climate vulnerability screening assessments of all existing federally funded flood risk management infrastructure to measure the state of resilience for such infrastructure.</p> | |

Sources: GAO's *Disaster Resilience Framework* (GAO-20-100SP) and GAO analysis of the U.S. Army Corps of Engineers (Corps) documents, relevant literature, and interviews with knowledgeable stakeholders and Corps officials; GAO (icons). | GAO-24-105496

^aOption 13 is applicable to phase 5 of the Corps' project delivery process—operation and maintenance.

Integration. Six of the 14 options to further enhance the climate resilience of federally funded flood risk management infrastructure and the Corps' current efforts align with the integration principle of GAO's *Disaster Resilience Framework*. Comparing the options and efforts with the most relevant subprinciples and questions in the framework illustrates opportunities for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure and limit federal fiscal exposure (see figs. 18 and 19).

Appendix I: Using the Disaster Resilience Framework to Analyze Options to Further Enhance Climate Resilience

Figure 18: Opportunities to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Related to the Integration Principle in GAO’s *Disaster Resilience Framework*

| | | | |
|---|---|--|--|
| <p>Integration Integrated analysis and planning can help decision makers take coherent and coordinated resilience actions.</p> <p>Build an overarching strategic vision and goals To what extent could federal efforts:</p> <ul style="list-style-type: none"> • Help to establish overarching strategies that guide national resilience efforts? • Ensure that resilience goals are incorporated into relevant national strategies? • Prioritize resilience goals that reflect the most pressing resilience challenges? <p>Promote coordination across missions and sectors To what extent could federal efforts:</p> <ul style="list-style-type: none"> • Ensure consistent and complementary policies, procedures, and timing across relevant federal funding mechanisms? • Convene stakeholders with different perspectives and interests to create whole systems solutions? • Encourage governance mechanisms that foster coordination and integrated decision-making within and across levels of government? • Engage non-government partners in disaster risk reduction? <p>Recognize relationships among infrastructure and ecosystems To what extent could federal efforts:</p> <ul style="list-style-type: none"> • Promote better understanding and awareness of the interactions among infrastructure components and ecosystems in disaster resilience actions? | <p align="center">Integration subprinciple: Promote coordination across missions and sectors</p> | | |
| | <p>Option to enhance the climate resilience of federally funded flood risk management infrastructure</p> | <p>Corps’ climate resilience effort</p> | <p>Question for consideration: Does the option ensure consistent and complementary policies, procedures, and timing across relevant federal funding mechanisms?</p> |
| | <p>Option 5: Update Planning Guidance^a</p> | <p>Developing and updating guidance</p> | <p>Yes. The Corps has developed and updated some planning guidance to consider climate resilience when planning water resources projects. For example, in 2019, the Corps updated its guidance for incorporating sea level change and directed Districts to consider three scenarios of potential sea level change when planning flood risk management infrastructure projects.</p> <p>Opportunities exist for the Corps to continue updating and developing planning guidance to integrate its broader climate policies and goals, making it easier for planners and engineers to incorporate climate resilience measures into flood risk management infrastructure projects.</p> |
| | <p>Option 6: Expand Use of Adaptive Management in Projects^a</p> | <p>Incorporating adaptive management into various flood risk management feasibility studies</p> | <p>Yes. The Corps has incorporated adaptive management into some flood risk management feasibility studies by creating adaptable features. Using adaptive management in all federally funded flood risk management infrastructure projects could help the Corps reduce overall project costs when future modifications are needed to reduce risk from a changing climate.</p> <p>Opportunities exist for the Corps to consistently integrate adaptable features into federally funded flood risk management infrastructure projects.</p> |
| <p>Option 8: Update Engineering Standards and Regulations^b</p> | <p>Updating some existing standards and regulations</p> | <p>Yes. The Corps has regulation, policy, and guidance in place and under review regarding incorporating climate resilience into its engineering standards and regulations.</p> <p>Opportunities exist for the Corps to continue to update its engineering standards and regulations to require climate resilience and therefore disaster risk-reduction measures.</p> | |

Continues on next page



Appendix I: Using the Disaster Resilience Framework to Analyze Options to Further Enhance Climate Resilience

Continued from previous page

Integration

Integrated analysis and planning can help decision makers take coherent and coordinated resilience actions.

Build an overarching strategic vision and goals

To what extent could federal efforts:

- Help to establish overarching strategies that guide national resilience efforts?
- Ensure that resilience goals are incorporated into relevant national strategies?
- Prioritize resilience goals that reflect the most pressing resilience challenges?

Promote coordination across missions and sectors

To what extent could federal efforts:

- Ensure consistent and complementary policies, procedures, and timing across relevant federal funding mechanisms?
- Convene stakeholders with different perspectives and interests to create whole systems solutions?
- Encourage governance mechanisms that foster coordination and integrated decision-making within and across levels of government?
- Engage non-government partners in disaster risk reduction?

Recognize relationships among infrastructure and ecosystems

To what extent could federal efforts:

- Promote better understanding and awareness of the interactions among infrastructure components and ecosystems in disaster resilience actions?

| Integration subprinciple: Promote coordination across missions and sectors | | |
|---|--|--|
| Option to enhance the climate resilience of federally funded flood risk management infrastructure | Corps' climate resilience effort | Question for consideration: Does the option ensure consistent and complementary policies, procedures, and timing across relevant federal funding mechanisms? |
| Option 11: Update Manuals for Operations and Maintenance ^e | Updating some manuals and inspecting some flood risk management infrastructure | <p>Yes. Nonfederal sponsors operating and maintaining federally funded flood risk management projects follow manuals for operation and maintenance, which they can update, and are subject to Corps' inspections. The Corps is required to review certain manuals for operation and maintenance every 10-years.</p> <p>Opportunities exist for the Corps to work with nonfederal sponsors to regularly update manuals for operation and maintenance to incorporate climate resilience.</p> |
| | | <p>Question for consideration: Does the option encourage governance mechanisms that foster coordination and integrated decision making within and across levels of government?</p> |
| Option 1: Create Clear Institutional Authority to Mainstream Climate Resilience ^d | Strategic planning and policies | <p>Yes. The Corps released its overarching policy regarding climate change adaptation and a governance structure to support the policy's implementation in June 2011. The policy, which was most recently updated in May 2021, states that "mainstreaming climate change adaptation means that it will be considered at every step in the project life cycle for all [Corps] projects, both existing and planned...to reduce vulnerabilities and enhance the resilience of... water resource infrastructure." The Corps also has a Climate Preparedness and Resilience lead position through a community of practice to coordinate climate adaptation efforts.</p> <p>Opportunities exist for the Corps to further coordinate across all levels of the agency to integrate climate resilience policy and goals into flood risk management infrastructure studies and projects.</p> |

Sources: GAO's *Disaster Resilience Framework* (GAO-20-100SP) and GAO analysis of the U.S. Army Corps of Engineers (Corps) documents, relevant literature, and interviews with knowledgeable stakeholders and Corps officials; GAO (icons). | GAO-24-105496

^eOptions 5 and 6 are applicable to phase 2 of the Corps' project delivery process—feasibility.

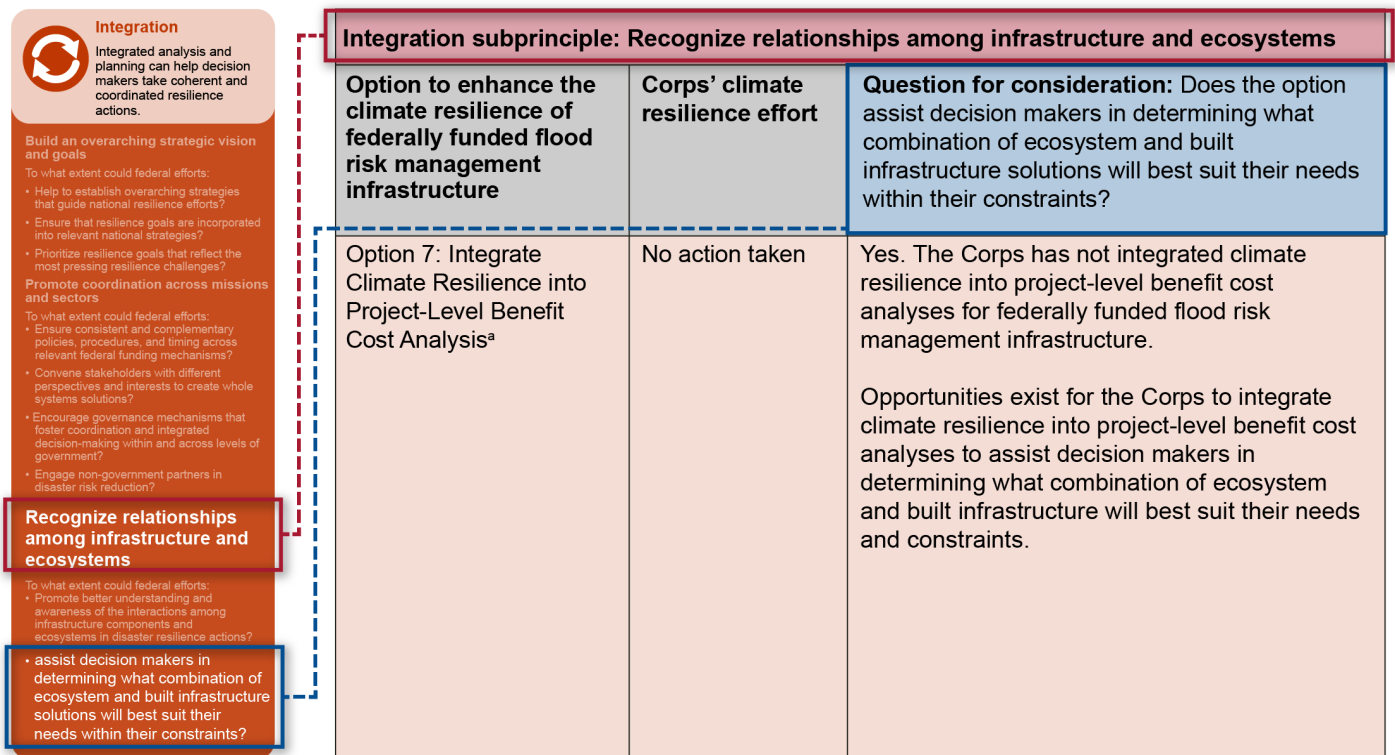
Appendix I: Using the Disaster Resilience Framework to Analyze Options to Further Enhance Climate Resilience

^bOption 8 is applicable to phase 3 of the Corps' project delivery process—pre-construction engineering and design.

^cOption 11 is applicable to phase 5 of the Corps' project delivery process—operation and maintenance.

^dOption 1 is applicable to all five phases of the Corp's project delivery process—study initiation, feasibility, pre-construction engineering and design, construction, and operation and maintenance.

Figure 19: Opportunities to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Related to the Integration Principle in GAO's *Disaster Resilience Framework*



Sources: GAO's *Disaster Resilience Framework* (GAO-20-100SP) and GAO analysis of the U.S. Army Corps of Engineers (Corps) documents, relevant literature, and interviews with knowledgeable stakeholders and Corps officials; GAO (icons). | GAO-24-105496

^aOption 7 is applicable to phase 2 of the Corps' project delivery process—feasibility.

Incentives. Two of the 14 options to further enhance the climate resilience of federally funded flood risk management infrastructure and the Corps' current efforts align with the incentives principle of GAO's *Disaster Resilience Framework*. Comparing the options and efforts with the most relevant subprinciples and questions in the framework illustrates opportunities for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure and limit federal fiscal exposure (see figs. 20 and 21).

Appendix I: Using the Disaster Resilience Framework to Analyze Options to Further Enhance Climate Resilience

Figure 20: Opportunities to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Related to the Incentives Principle in GAO’s *Disaster Resilience Framework*

| | | | |
|---|---|--|---|
| <p>Principle: Incentives</p> <p>Incentives can help to make long-term, forward-looking risk-reduction investments more viable and attractive among competing priorities.</p> <p>Provide financial and nonfinancial incentives</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> • Make risk-reduction measures more viable and attractive? • Incorporate disaster risk-reduction measures in infrastructure and ecosystem management financial assistance? <p>• Require disaster risk-reduction measures for government-owned or –operated infrastructure and for federally funded projects?</p> <p>Reduce disincentives</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> • Alleviate unnecessary administrative burden? • Streamline review processes? • Improve program design to motivate risk-reduction actions? | <p>Incentives subprinciple: Provide financial and nonfinancial incentives</p> | | |
| | <p>Option to enhance the climate resilience of federally funded flood risk management infrastructure</p> | <p>Corps’ climate resilience effort</p> | <p>Question for Consideration: Does the option require disaster risk-reduction measures for government-owned or –operated infrastructure and for federally funded projects?</p> |
| | <p>Option 10: Prioritize Projects that Incorporate Climate Resilience^a</p> | <p>Strategic planning and policies</p> | <p>Yes. The Corps has an existing policy to mainstream climate resilience and adaptation but has not historically used climate resilience to prioritize federally funded flood risk management infrastructure projects for construction.</p> <p>Opportunities exist for the Corps to require disaster risk reduction measures by using climate resilience as a metric when ranking federally funded flood risk management infrastructure projects for construction.</p> |

Sources: GAO’s *Disaster Resilience Framework* (GAO-20-100SP) and GAO analysis of the U.S. Army Corps of Engineers (Corps) documents, relevant literature, and interviews with knowledgeable stakeholders and Corps officials; GAO (icons). | GAO-24-105496

^aOption 10 is applicable to phase 4 of the Corps’ project delivery process—Construction.

Figure 21: Opportunities to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure Related to the Incentives Principle in GAO’s *Disaster Resilience Framework*

| | | | |
|--|--|--|--|
| <p>Principle: Incentives</p> <p>Incentives can help to make long-term, forward-looking risk-reduction investments more viable and attractive among competing priorities.</p> <p>Provide financial and nonfinancial incentives</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> • Make risk-reduction measures more viable and attractive? • Incorporate disaster risk-reduction measures in infrastructure and ecosystem management financial assistance? • Require disaster risk-reduction measures for government-owned or –operated infrastructure and for federally funded projects? <p>Reduce disincentives</p> <p>To what extent could federal efforts:</p> <ul style="list-style-type: none"> • Alleviate unnecessary administrative burden? • Streamline review processes? • Improve program design to motivate risk-reduction actions? | <p>Incentives subprinciple: Reduce disincentives</p> | | |
| | <p>Option to enhance the climate resilience of federally funded flood risk management infrastructure</p> | <p>Corps’ climate resilience effort</p> | <p>Question for Consideration: Could the option streamline review processes?</p> |
| | <p>Option 14: Establish Process for Retrofitting Existing Infrastructure to Account for Climate Change^a</p> | <p>No action taken</p> | <p>Yes. Opportunities exist for the Corps to follow a streamlined process to repair and maintain federally funded flood risk management infrastructure for climate resilience.</p> |

Sources: GAO’s *Disaster Resilience Framework* (GAO-20-100SP) and GAO analysis of the U.S. Army Corps of Engineers (Corps) documents, relevant literature, and interviews with knowledgeable stakeholders and Corps officials; GAO (icons). | GAO-24-105496

^aOption 14 is applicable to phase 5 of the Corps’ project delivery process—Operation and Maintenance.

Appendix II: Objectives, Scope, and Methodology

This report examines (1) the U.S. Army Corps of Engineers' (Corps) actions to enhance the climate resilience of federally funded flood risk management infrastructure (e.g., levees, dams, floodwalls, floodgates, and hurricane barriers); and (2) the strengths and limitations of options available to the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure. To address these objectives, we reviewed agency documents, reviewed relevant literature, and interviewed agency officials and knowledgeable stakeholders. The report also includes information in appendix I on how we used GAO's *Disaster Resilience Framework* to evaluate the extent to which each of the options we identified could help enhance the climate resilience of federally funded flood risk management infrastructure.¹

Describing the Corps' Climate Resilience Efforts

To examine the Corps' actions to enhance the climate resilience of federally funded flood risk management infrastructure, we reviewed and summarized the Corps' efforts, including its policies, guidance, and tools related to incorporating climate resilience into flood risk management feasibility studies and projects. For example, we reviewed the Corps' *Climate Preparedness and Resilience Policy Statements* and *Climate Action Plans* as well as planning guidance like *Incorporating Sea-Level Change in Civil Works Programs* and *Civil Works Sustainable Infrastructure Practices Guidebook*. We also reviewed three executive orders issued in 2021, which outline key aspects of the administration's approach to climate change and are relevant to the Corps: Executive Order 14008 on *Tackling the Climate Crisis at Home and Abroad*, Executive Order 14030 on *Climate-Related Financial Risk*, and Executive Order 14057 on *Catalyzing Clean Energy Industries and Jobs through Federal Sustainability*.

To better understand the Corps' efforts, we interviewed Corps officials from headquarters, divisions, and districts, and individuals from academia, industry trade groups, and nongovernmental organizations with experience working with the Corps and researching ways to further enhance the climate resilience of flood risk management infrastructure. We identified actions the Corps has taken, and plans to take, to enhance the climate resilience of federally funded flood risk management infrastructure across the five phases of the agency's project delivery process—(1) study initiation, (2) feasibility, (3) pre-construction engineering and design, (4) construction, and (5) operation and

¹GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, [GAO-20-100SP](#) (Washington, D.C.: October 2019).

maintenance. In addition, these actions to enhance climate resilience correspond to the principles of our *Disaster Resilience Framework*—information, integration, and incentives.

Describing the Strengths and Limitations of Options

To examine the strengths and limitations of options available to the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, we took several steps, starting with a search and review of relevant literature, to identify options. To describe the options' strengths and limitations, we conducted semistructured interviews with knowledgeable stakeholders we identified from the literature review and preliminary background research.

Review of relevant literature and preliminary background research.

First, we used multiple strategies to search for and review potentially relevant literature to find examples of options that could enhance the climate resilience of federally funded flood risk infrastructure.²

- To conduct the literature search, we searched databases (e.g., Elsevier SCOPUS, ProQuest, and EBSCO) for peer-reviewed articles, government reports, industry and trade group publications, conference papers, nonprofit and think tank publications, and working papers published from January 2011 through December 2021. We searched titles, abstracts, and key words for “Army Corps of Engineers,” “climate change,” and “flood risk management infrastructure” in close proximity to terms such as “adaptation,” and “resilience.”
- To conduct preliminary background research, we searched the Congressional Research Service’s report database, the Congressional Budget Office’s website, GAO’s product page, the Corps’ website, and more general internet searches using relevant key words. To better understand the issue area and potential options, we conducted scoping interviews with 16 individuals and groups from academia, industry and trade groups, and nongovernmental organizations, and Corps officials familiar with flood risk management

²We used a “snowball” approach to identify potentially relevant reports about enhancing the climate resilience of federally funded flood risk management infrastructure. For example, we used citations from identified reports to find additional reports. We also asked the stakeholders and Corps officials we interviewed for report recommendations.

infrastructure, the Corps' project delivery process, and climate resilience.³

- The literature and background search identified 114 potentially relevant peer-reviewed articles, government reports, industry and trade group publications, conference papers, nonprofit and think tank publications, and working papers. After a more detailed review of these relevant sources from the literature review and background research, we determined that 44 sources had relevant examples of options that could enhance the climate resilience of federally funded flood risk management infrastructure.

Identify options. Second, we distilled examples from the relevant literature into a preliminary list of options that the Corps could use in its existing project delivery process to enhance the climate resilience of federally funded flood risk infrastructure. Specifically, we analyzed the content of the 44 sources with relevant examples in greater detail, recorded and categorized information about the examples of options, and then distilled the examples into a list of 14 high-level options grouped by phase in the Corps' project delivery process. GAO's subject matter experts, Corps officials, and the 21 knowledgeable stakeholders we interviewed confirmed that we were not missing any options and that we had accurately categorized the options within the Corps' project delivery process. We discuss this process below, including how we selected the 21 stakeholders.

Identify knowledgeable stakeholders. Following our literature review, we selected a group of external knowledgeable stakeholders to interview about the strengths and limitations of the 14 options we identified from the literature search. To identify potential knowledgeable stakeholders, we identified the authors of our selected literature, and we conducted scoping interviews and utilized a "snowballing" method. First, we used the results of the literature search and preliminary background research to identify potential individuals with knowledge of the Corps' general process for developing and delivering flood risk management infrastructure and climate resilience. We initially identified 96 potential individuals from the 44 selected sources. We then conducted 16 scoping interviews with these individuals to gain a better understanding of the topic. In these scoping interviews, we also asked each individual to recommend other

³We identified the individuals and groups for our 16 scoping interviews from our preliminary background research, review of relevant literature, and recommendations from the Corps officials and stakeholders we interviewed.

stakeholders who might meet our criteria and be able to discuss the strengths and limitations of options we identified from literature.

As a result, we identified a total of 146 potential knowledgeable stakeholders to interview about the strengths and limitations of the 14 options we identified from the literature search. To select the knowledgeable stakeholders we spoke with about the strengths and limitations of the 14 options, we primarily considered three factors. First, we considered the type of expertise that the knowledgeable stakeholder had regarding enhancing flood risk management infrastructure, climate resilience, climate change, and the Corps' project delivery processes. Second, we considered perspectives from different groups involved with flood risk management infrastructure, ensuring that we were selecting a variety of knowledgeable stakeholders with backgrounds in academia, industry and trade groups, nonprofits and think tanks, and engineering and consulting firms, among other things. Finally, we considered the relevance of the knowledgeable stakeholders' published work, specifically, if they had contributed to the literature we selected.

The final list included 28 knowledgeable stakeholders. Seven knowledgeable stakeholders declined to participate in semistructured interviews with GAO, which resulted in us interviewing 21 knowledgeable stakeholders.⁴ Because we selected a nongeneralizable sample of stakeholders to interview, findings from our analysis of their views cannot be generalized to all stakeholders who might have relevant knowledge and expertise. Rather, these interviews provided us with a range of perspectives from a group of stakeholders on the strengths and limitations of options available to the Corps to enhance the climate resilience of federally funded flood risk management infrastructure. In addition, the specific areas of expertise varied among the stakeholders we interviewed, so not all the stakeholders commented on all the interview questions we asked.

Interview knowledgeable stakeholders. Third, we asked the knowledgeable stakeholders we selected for their perspectives on the strengths and limitations of each of the 14 options identified, any other options to consider, and other knowledgeable stakeholders to interview

⁴Eight of the 21 interviews included multiple individuals representing a single organization, which we counted as one knowledgeable stakeholder. The 21 knowledgeable stakeholders included 12 individuals we spoke with during our scoping interviews. These 12 individuals met our criteria for selecting knowledgeable stakeholders to interview about the strengths and limitations of the 14 options we identified from the literature search.

for this purpose. When interviewing the stakeholders, we asked them to consider the options at a high level and to describe their strengths and limitations as they relate to limiting the federal government's fiscal exposure to climate change risks. We did not ask each knowledgeable stakeholder if they favored or opposed each option, and we do not have information about whether stakeholders would recommend one option over another.

Describe the options' strengths and limitations. Finally, to describe the options' strengths and limitations, we conducted a content analysis and synthesized information from the semistructured interviews with 21 knowledgeable stakeholders and grouped individual insights into overall themes. Multiple analysts reviewed the determination of overall themes of the strengths and limitations for each option. In general, we reported the full range of strengths and limitations identified by the 21 knowledgeable stakeholders. However, we did not include strengths and limitations for options if they were outside of the scope of the engagement, such as changing the Corps' existing project delivery process or the agency's overarching mission. We also included the Corps' statements on the strengths, limitations, and the extent to which it could implement these options under its existing authority.⁵ Throughout this report, we use modifiers to characterize the views of the 21 knowledgeable stakeholders as follows:

- "Some" knowledgeable stakeholders represents two to five stakeholders.
- "Several" knowledgeable stakeholders represents six to 10 stakeholders.
- "Most" knowledgeable stakeholders represents 11 to 15 stakeholders.
- "Nearly all" knowledgeable stakeholders represents 16 to 20 stakeholders.

Although our methodology was based on a comprehensive literature search and supplemented with information from interviews with knowledgeable stakeholders and Corps officials, it was not intended to result in an exhaustive list of options but rather an informed menu of potential options with insights on their strengths and limitations. We believe the scope and methodology we used is sufficient for the purpose

⁵In cases where knowledgeable stakeholders or Corps officials commented on whether the agency had authority to implement an option, we summarized those comments but did not do our own assessment of the Corps' authority to implement any of the options.

of providing relevant and useful information to decision makers on the range of options available to the Corps for enhancing the climate resilience of federally funded flood risk management infrastructure and to inform their choices about an appropriate mix of options, if any, to pursue.

Identifying Opportunities Using the *Disaster Resilience Framework*

To assess the extent to which each of the options we identified in this report could further enhance the climate resilience of federally funded flood risk management infrastructure, we compared the identified options with the Corps' current climate resilience efforts and the principles and subprinciples in GAO's *Disaster Resilience Framework*.⁶ For each option, Corps' effort, and principle and subprinciple included in our analysis, an analyst made a determination about whether each option could further enhance the climate resilience of federally funded flood risk management infrastructure, using questions for consideration from the framework.⁷ A second analyst then reviewed the first analyst's work to ensure that the conclusions drawn were sound. See appendix I for additional information about how we conducted this analysis.

We conducted this performance audit from October 2021 to January 2024 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.

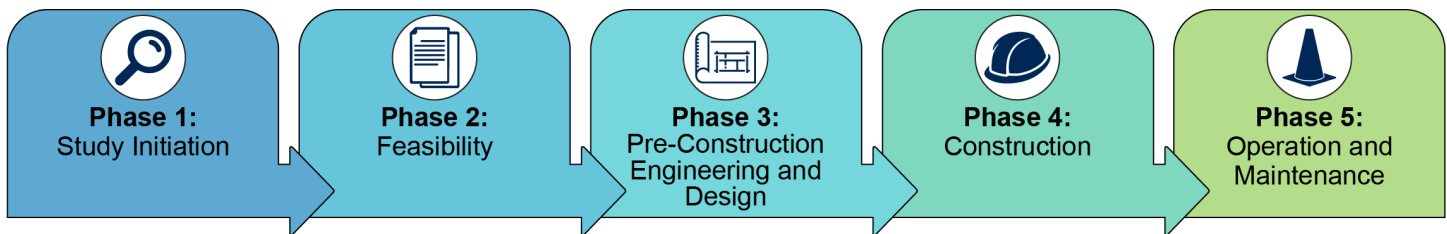
⁶[GAO-20-100SP](#).

⁷Implementation of the options we identified may provide climate resilience benefits across principles outlined in GAO's *Disaster Resilience Framework*. For the purposes of this report, we categorized the options under the principle where they have the most direct link to the Corps' five-phased project delivery process.

Appendix III: Steps in the U.S. Army Corps of Engineers Project Delivery Process

The U.S. Army Corps of Engineers (Corps) generally develops and delivers water resources projects with a multistep process consisting of five phases—(1) study initiation, (2) feasibility, (3) pre-construction engineering and design, (4) construction, and (5) operation and maintenance—involving internal and external stakeholders (see fig. 22).

Figure 22: U.S. Army Corps of Engineers' Process for Developing and Delivering Water Resources Project



Source: GAO analysis of U.S. Army Corps of Engineers information; GAO (icons). | GAO-24-105496

Phase 1: Study Initiation

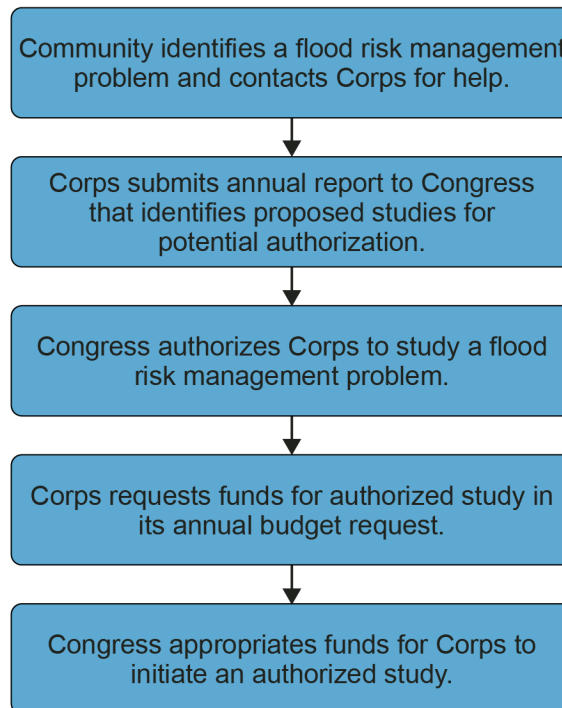
The Corps usually becomes involved in water resources infrastructure projects, including flood risk management infrastructure projects, when a community perceives a need or experiences a problem that is beyond its ability to solve and asks the Corps for assistance. If the Corps does not have the statutory authority required for studying the problem, it must obtain authorization from Congress before proceeding.¹ Congress authorizes Corps' studies through legislation, typically a Water Resources Development Act, or, in some circumstances, through a committee resolution by an authorizing committee.² Next, the Corps must receive an appropriation to study the problem, which it seeks through its annual

¹Specifically, Section 7001 of the Water Resources Reform and Development Act of 2014, Pub. L. No. 113-121, 128 Stat. 1193, 1360-64, as amended, requires the Secretary of the Army to annually submit to Congress a report (e.g., *Report to Congress on Future Water Resources and Development*) that identifies completed feasibility reports, proposed feasibility studies submitted by nonfederal interests, and proposed modification to authorized water resources development projects or feasibility studies that meet five criteria established by Congress. Congressional authorizing committees can use these annual reports to help identify Corps' studies, projects, and project modifications for authorization. The Water Resources Development Act of 2022 drew upon Section 7001 reports to select Corps studies and projects to authorize.

²In recent years, Water Resources Development Acts (WRDA) have generally included three broad categories of water resources project authorizations: project studies and reports, deauthorizations and modifications, and water resources infrastructure (typically, construction activities). Congress enacted the Water Resources Development Act of 2022 as Title LXXXI of Division H of the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023, Pub. L. No. 117-263, 136 Stat. 2395 (2022).

budget request to Congress, and typically receives through Energy and Water Development Appropriations Acts (see fig. 23).

Figure 23: Typical Steps Within Phase 1 of the U.S. Army Corps of Engineers (Corps) Project Delivery Process: Study Initiation



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Phase 2: Feasibility

After Congress authorizes and appropriates funds to study the water resources problem, the Corps conducts a feasibility study. The Corps develops feasibility studies to inform Congress, the Office of Management and Budget, and others whether the water resources development project warrants federal investment and how the problem should be addressed.³

³According to U.S. Water Resources Council's 2013 *Principles and Requirements for Federal Investments in Water Resources*, the federal objective of federal water resources investments is to reflect national priorities, encourage economic development, and protect the environment by: (1) seeking to maximize sustainable economic development; (2) seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used; and (3) protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems.

After congressional authorization, the Corps and nonfederal sponsor typically establish an agreement to conduct the feasibility study and generally share the cost of the study.⁴

Feasibility studies are generally prepared by the Corps' district offices and developed in collaboration with nonfederal sponsors. When conducting the studies, Corps planners typically follow the six-step planning process outlined in its *Planning Guidance Notebook* to identify and evaluate the beneficial and adverse effects of alternative plans for flood risk management projects and select a recommended plan.⁵ The six steps are: (1) identifying objectives, problems, opportunities, and constraints for the project; (2) inventorying and forecasting water and related land resources conditions within the planning area; (3) formulating alternative plans for further consideration; (4) evaluating and analyzing each alternative plan for its economic, environmental, and other effects; (5) comparing the alternative plans to each other; and (6) selecting a recommended plan. The recommended plan is typically the alternative that provides the greatest net economic benefit consistent with protecting

⁴A nonfederal sponsor can be a Tribe, state, county, city, town, or any other political subpart of a state or group of states that has the legal and financial authority and capability to provide the funding and real property requirements needed for a feasibility study and a project.

⁵The U.S. Water Resources Council's Principles, Requirements, and Guidelines (PR&G), published in 2013 and 2014, provide a common framework for how federal agencies, including the Corps, evaluate and select proposed water resources development projects. The PR&G largely replaced the U.S. Water Resources Council's prior Principles and Guidelines (P&G), which had been in place since 1983. See U.S. Water Resources Council, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Mar. 10, 1983). In April 2013, Corps officials said they were updating the agency's 2000 *Planning Guidance Notebook* to reflect changes made in the PR&G. The 2000 *Planning Guidance Notebook* provides detailed guidance on how to implement the general process outlined in the P&G. See U.S. Army Corps of Engineers, *Planning Guidance Notebook*, Engineer Regulation 1105-2-100 (Apr. 22, 2000).

the nation's environment—referred to as the National Economic Development plan.⁶

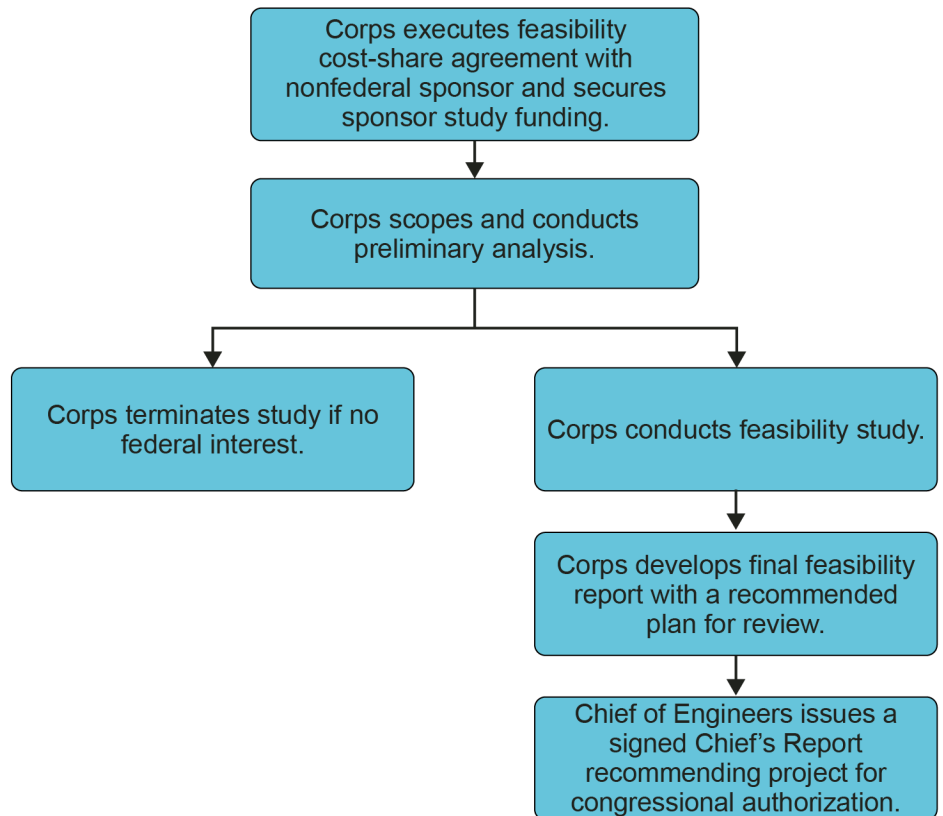
The feasibility study process also generally includes the work the Corps undertakes to satisfy the requirements of the National Environmental Policy Act of 1969, as amended (NEPA) and its implementing regulations, as well as other environmental statutes. NEPA requires federal agencies to consider and disclose the potential environmental impacts of a proposed major federal action before making a final decision. When the Corps determines that a water resources development project could have significant environmental effects, it must prepare an Environmental Impact Statement (EIS). The Corps issues a draft EIS as part of the overall draft feasibility report for public and stakeholder review and issues a final EIS when it issues its final feasibility report. Feasibility studies that require an EIS typically represent larger and more complex studies than those that do not require an EIS.

After going through various levels of review at the Corps division level and headquarters, the results of the feasibility study and recommended plan are documented in a final feasibility report. The Chief of Engineers then reviews the final feasibility report and decides whether to sign a decision document, known as the Chief's Report, recommending the project for construction. The Chief of Engineers transmits the Chief's Report to the Assistant Secretary of the Army for Civil Works for approval. As directed by executive order, the Corps then submits its reports to the Office of Management and Budget before submitting them to Congress. Congress may then authorize the project's construction in a Water Resources Development Act or other legislation (see fig. 24).⁷

⁶The Water Resources Development Act of 2022 includes a new provision that requires the Corps to expand the scope of feasibility studies for flood risk management and hurricane and storm damage risk reduction projects at the request of the nonfederal sponsor. At the request of the nonfederal sponsor, the Corps must formulate alternatives to maximize the net benefits of reduced flood risk within the geographic scope of the study from a range of flood risks, including sea level rise, coastal storm surge, rainfall events, tides, and any other driver of flood risk in the study area. Water Resources Development Act of 2022, Pub. L. No. 117-263, div. H, tit. LXXXI, § 8106, 136 Stat. 2395, 3699–3700 (2022).

⁷For additional information regarding the Corps' feasibility studies, see GAO, *Water Resources Projects: Army Corps of Engineers Can Further Enhance Acceleration of Feasibility Studies*, [GAO-19-561](#) (Washington, D.C.: July 29, 2019) and GAO, *Army Corps of Engineers: Evaluations of Flood Risk Management Projects Could Benefit from Increased Transparency*, [GAO-20-43](#) (Washington, D.C.: Nov. 26, 2019).

Figure 24: Typical Steps Within Phase 2 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process: Feasibility

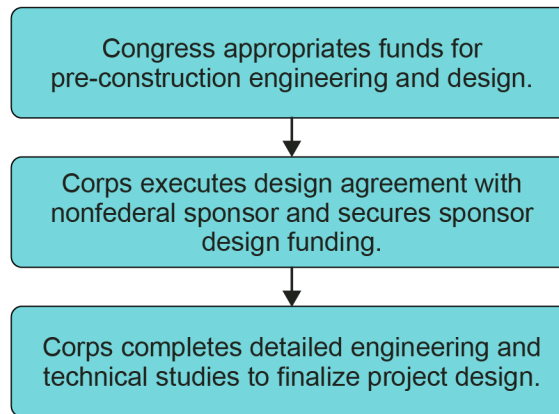


Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Phase 3: Pre-Construction Engineering and Design

Most water resources projects are authorized during the pre-construction 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 the detailed engineering and technical studies and designs needed to begin construction. The Corps can conduct some initial pre-construction engineering and design activities prior to receiving congressional authorization for construction, but the Corps completes this work after receiving authorization. The Corps' pre-construction engineering and design work is subject to the availability of appropriations from Congress (see fig. 25).

Figure 25: Typical Steps Within Phase 3 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process: Pre-Construction Engineering and Design



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

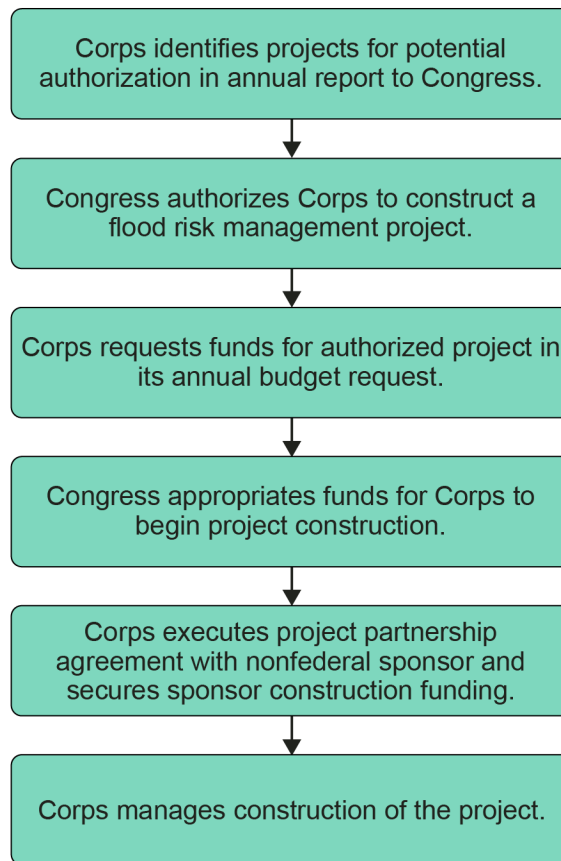
Phase 4: Construction

After Congress authorizes the construction of a water resources project, the Corps seeks construction funds through its annual budget process.⁸ Once the project has been authorized for construction and funds have been appropriated, the Corps district enters into a cost-sharing agreement with the nonfederal sponsor, referred to as a project partnership agreement. After Congress appropriates funds, the construction phase can begin. Construction is generally managed by the Corps but performed by private contractors (see fig. 26). In addition to authorizing construction of Corps programs, Congress has also acted to deauthorize projects and enacted various deauthorization processes for unconstructed projects. For example, the Water Resources Development Act of 2022 created a one-time process to deauthorize projects that are “no longer viable for construction” that applies to projects authorized for construction prior to November 8, 2007.⁹

⁸In fiscal year 2006, the Corps introduced what it refers to as performance-based budgeting. The agency uses performance metrics to evaluate projects' estimated future outcomes and gives priority to projects it determines have the highest expected returns for the national economy and the environment, and those that reduce risk to human life.

⁹Water Resources Development Act of 2022, Pub. L. No. 117-263, div. H, tit. LXXXI, § 8301, 136 Stat. 2395, 3775–76.

Figure 26: Typical Steps Within Phase 4 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process: Construction



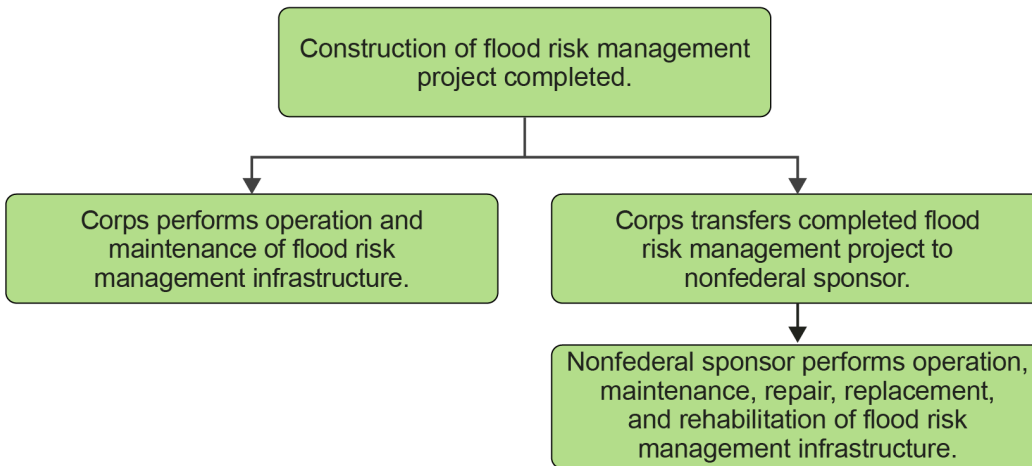
Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Phase 5: Operation and Maintenance

Once construction is completed, the Corps may turn over operation and maintenance of the project to the nonfederal sponsor, which then bears the full cost of operation and maintenance, or the Corps may operate and maintain the project itself. For certain projects operated or maintained by the Corps, including locks, dams, and major control structures, Corps engineering regulations require preparation of a water control manual, which generally defines the rules or provides guidance for the operation and management of the project. The Corps also develops water control plans to ensure that project operations conform to the objectives and specific provisions of authorizing legislation. If the Corps will not operate and maintain the project, it may also develop operational guidance for

nonfederal sponsors in the form of operation and maintenance manuals, which detail when and how to do certain maintenance (see fig. 27).

Figure 27: Typical Steps Within Phase 5 of the U.S. Army Corps of Engineers' (Corps) Project Delivery Process: Operation and Maintenance



Source: GAO analysis of U.S. Army Corps of Engineers information. | GAO-24-105496

Appendix IV: Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure

Through our analysis of relevant literature and interviews with stakeholders, we identified 14 options for the U.S. Army Corps of Engineers (Corps) to further enhance the climate resilience of federally funded flood risk management infrastructure, such as levees, dams, floodwalls, and hurricane barriers (see table 8). These 14 options are organized by the Corps' five-phase project delivery process—(1) study initiation, (2) feasibility, (3) pre-construction engineering and design, (4) construction, and (5) operation and maintenance.

The following appendix includes a description of each option including a summary of strengths and limitations according to knowledgeable stakeholders and relevant literature (see table 8).¹ Corps officials provided comments on the strengths and limitations of each option and the Corps' authority to implement each option. We did not evaluate the accuracy of the Corps' statements regarding their authority to implement the options or the extent to which the Corps could implement any particular option without congressional action. We do not endorse any particular option; rather, the appropriate mix of options to best reduce the fiscal risks to the federal government is a policy choice that requires complex trade-offs. These trade-offs should be made with full information about the strengths and limitations of different options.

¹We conducted 21 interviews with knowledgeable stakeholders, eight of which included multiple individuals representing a single organization, which we counted as one knowledgeable stakeholder. To characterize knowledgeable stakeholders' views throughout this report, we defined modifiers (e.g., "nearly all") to quantify users' views as follows: "some" represents two to five knowledgeable stakeholders, "several" represents six to 10 knowledgeable stakeholders, "most" represents 11 to 15 knowledgeable stakeholders, and "nearly all" represents 16 to 20 stakeholders.

Appendix IV: Options to Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure

Table 8: Options for the U.S. Army Corps of Engineers to Further Enhance the Climate Resilience of Federally Funded Flood Risk Management Infrastructure, by Project Delivery Phase

Applicable to all five phases of the project delivery process

1. Create clear institutional authority to mainstream climate resilience
2. Research the feasibility of innovative approaches

Phase 1: Study Initiation

3. Expand technical assistance for planning

Phase 2: Feasibility

4. Update climate information for planning
5. Update planning guidance
6. Expand use of adaptive management in projects^a
7. Integrate climate resilience into project-level benefit cost analyses

Phase 3: Pre-Construction Engineering and Design

8. Update engineering standards and regulations
9. Conduct climate screening assessments of authorized but unfunded projects

Phase 4: Construction

10. Prioritize projects that incorporate climate resilience

Phase 5: Operation and Maintenance

11. Update manuals for operation and maintenance^b
 12. Expand technical assistance to nonfederal sponsors for operation and maintenance
 13. Conduct climate vulnerability assessments of all existing infrastructure
 14. Establish process for retrofitting existing infrastructure to account for climate change
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Source: GAO analysis of literature and interviews with knowledgeable stakeholders. | GAO-24-105496

Note: We identified these options and described their strengths and limitations based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the extent to which the Corps could implement these options without congressional action.

^aFor the purposes of this report, the term adaptive management includes both (1) adaptability, which includes designing a project that can be adjusted to future conditions and (2) adaptive management, a structured management approach for addressing uncertainties by monitoring and assessing project performance or defined triggers and making modifications, as necessary.

^bFor the purposes of this report, we use the term manuals for operation and maintenance to represent a variety of manuals, such as operation and maintenance manuals, water control manuals, and water control plans.

Option 1: Create Clear Institutional Authority to Mainstream Climate Resilience

Create clear institutional authority to mainstream the incorporation of climate resilience into federally funded flood risk management infrastructure studies and projects. For example:

- Give a high-level U.S. Army Corps of Engineers (Corps) official, and staff, as appropriate, authority and budgetary resources to coordinate climate resilience efforts across Corps mission areas, business lines, and districts, and prioritize climate resilience studies and projects for the most at-risk communities.



All phases

Strengths

- Some stakeholders said an institutional authority would allow the Corps to better incorporate climate change and resilience into all agency decisions and projects. Some stakeholders said it is important to isolate this authority from political considerations regarding climate change. Several stakeholders said this authority should have leadership with the right set of skills to be successful.
- Several stakeholders said an institutional authority would clearly communicate the Corps' priorities and expectations.
- Some stakeholders said this authority could increase oversight and accountability of the agency's climate resilience efforts.
- One stakeholder said if implemented, this option could increase knowledge sharing by bringing together climate resilience officers from Corps' districts to discuss climate resilience problems and solutions.

Limitations

- Nearly all stakeholders said this institutional authority would be ineffective without dedicated climate resilience staff with different and relevant expertise across all levels of the agency (e.g., headquarters, divisions, and districts). Several stakeholders said the institutional authority should be throughout different Corps' operations. Further, one stakeholder said staff with resilience authority must be embedded at the senior level within the agency.
- Some stakeholders said this authority may isolate climate resilience work within the Corps. For example, one stakeholder said implementing climate resilience should be the responsibility of all Corps officials, rather than a specific individual or group. Another stakeholder said the Corps should avoid creating additional bureaucracy when implementing this option.
- Some stakeholders said this authority could be subjective. Some stakeholders said it is important to define what resilience is for this option.
- Some stakeholders said the authority depends on broader climate policies and goals set by Congress and the administration. Some stakeholders said the Corps must consider the economic value of projects, rather than issues like equity or social justice.
- Several stakeholders said the authority necessitates additional capacity to implement effectively. For example, some stakeholders said districts might not have available staff, funding, or expertise to work on climate resilience. Another stakeholder said this option may also require training for Corps staff to consider new factors when evaluating flood risk management infrastructure projects.
- Several stakeholders said it would take time to change well-established Corps processes and procedures. For example, one stakeholder said mainstreaming climate resilience into all Corps flood risk management infrastructure studies and projects requires full buy-in from agency officials. Further, one stakeholder said changes in the organization could create friction within the agency.

Corps Comments on Implementation of Option 1

According to Corps officials, Option 1 encompasses an existing position—the Climate Preparedness and Resilience Lead at Corps headquarters—and its counterparts within the district offices. These staff have varied experience at the district level. For example, the staff in Hawaii is a coastal engineer, and the staff in Arkansas is not. In addition, Corps officials said that some divisions have regional technical specialists, and this position could be replicated across all divisions to provide expertise across the agency. Corps officials said teams have the authority to consider climate resilience and are also required to consider climate resilience across all activities. Further, clear authority that allows the agency to recommend the most resilient plan for flood risk management infrastructure projects would be beneficial. However, Corps officials said this option could isolate climate resilience work. In addition, this option would require additional resources, including dependable long-term funding and time, and would require updates to planning policy and procedures to make application of resilience considerations consistent across the country. Finally, Corps officials said they believe they could implement this option under current authorities.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 2: Research the Feasibility of Innovative Approaches

Research the feasibility of innovative approaches to enhance the climate resilience of federally funded flood risk management infrastructure. For example:

- Fund competitive grants for research, development, and deployment of new technologies to modernize and extend the life of flood risk management infrastructure, expedite repairs or replacements, and enhance resilience to changing climates.
- Fund pilot flood risk management infrastructure projects that demonstrate the long-term benefits of climate resilience.



Strengths

- Several stakeholders said researching the feasibility of innovative approaches would allow for research advances and developments that could address existing knowledge gaps. For example, some stakeholders said this option could help translating climate science into action for flood risk management infrastructure projects. Another stakeholder said if the U.S. Army Corps of Engineers (Corps) conducted pilot projects, then they could test the suitability of innovative approaches prior to large-scale flood risk management infrastructure project implementation.
- Some stakeholders said this option could provide information on how to best build and manage projects in a changing climate.
- One stakeholder said this option could provide objective information that will reduce the subjectivity of decisions if research findings are communicated appropriately.
- One stakeholder said long-term research can demonstrate project effectiveness but that the Corps does not currently conduct long-term research and rarely reevaluates projects after construction.

Limitations

- One stakeholder said communities might resist innovations that increase costs, such as relocating structures out of a high flood risk zone.
- Some stakeholders said long-term project monitoring is challenging, specifically because the benefits of a project may occur years in the future.
- Some stakeholders said different geographic locations have different needs, and some approaches may be site-specific. Some stakeholders also noted that innovative approaches should be holistic. Some stakeholders said innovative approaches should focus on the system of infrastructure.
- Some stakeholders said it might take a long time to develop and implement innovative approaches. For example, one stakeholder said new technologies or research developments require vetting for broad application within the Corps.
- Most stakeholders said this option necessitates additional capacity to implement effectively. For example, one stakeholder said that current research efforts through the Corps' Engineer Research and Development Center are making good progress, but research funding tends to be very specific.
- Several stakeholders said it will take time to change well-established Corps processes and procedures. For example, one stakeholder said outside researchers may be helpful for innovation and that the Corps could increase engagement with both communities and engineering firms.

Corps Comments on Implementation of Option 2

While the Corps is not a science agency with broad research authority, the Corps conducts research on climate adaptation and is always interested in expanding internal efforts and collaboration with other agencies, national labs, universities, and external experts. Corps officials also noted the importance of interacting with experts and peers around the world and the need to reduce the administrative burden for engaging with these groups. Corps officials said the agency has issues with “technology transfer,” which includes moving research through the pilot phase to implementation, such as an engineering manual or training. Corps officials also said having additional authority would allow them to conduct research that connects directly to a type of existing infrastructure. The Corps must consider local governments when implementing research. For example, local governments may be a nonfederal project sponsor, may have certain procedures in place, and may be resistant to changes occurring from implementing research. Additional resources, including adequate and dependable long-term funding, are necessary to implement Option 2 effectively. For example, it is important to have research and development funding that is separate from project-specific funding. Finally, Corps officials stated they believe the agency has some existing authority to implement Option 2.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 3: Expand Technical Assistance for Planning

Expand technical assistance provided by the U.S. Army Corps of Engineers (Corps) to communities to help them access and understand the climate information needed to identify flood risk problems and possible solutions. For example:

- Update the Corps' website to make climate information and tools easier to find and use.
- Host awareness-building activities to help communities understand types of assistance the Corps can provide to help support flood mitigation planning.



Phase 1:
Study Initiation

Strengths

- Most stakeholders said this option could help communities with limited capacity access and apply climate-related data to projects to make more informed decisions about project planning or use of funds. For example, several stakeholders suggested that Corps- provided technical assistance through websites, tools, workshops, or webinars could be useful. One stakeholder said the Corps should identify where to provide technical assistance to help those communities that are more vulnerable or underserved.
- One stakeholder said that by interpreting information and making it understandable and accessible to people local to a flood risk management project, this option could help the Corps build relationships with communities.
- Some stakeholders said this option could increase use of existing Corps resources. For example, one stakeholder said Corps resources are underutilized because states and local communities do not know how to apply them.

Limitations

- Several stakeholders said this option would require consistent, authoritative information to be useful for communities. For example, one stakeholder said some existing Corps projects use flawed models or do not consider the system-wide effects of flood risk management infrastructure.
- Several stakeholders said communities might need assistance in choosing which tools and data to use and understanding how to use the data. For example, one stakeholder said it takes time to build trust between the Corps and communities. Some stakeholders said two-way feedback mechanisms are important for the Corps to understand community needs.
- Some stakeholders said capacity varies by community. For example, one stakeholder said smaller, nonfederal sponsors might not know how to complete technical documents or environmental reviews.
- Most stakeholders said this option necessitates additional capacity to implement effectively. Several stakeholders said this option requires additional staff to provide technical assistance at the district level and additional funding for new Corps responsibilities.
- Some stakeholders said it will take time to change well-established Corps processes and procedures. For example, one stakeholder said that the Corps' decision-making processes pose a constraint to incorporating climate resilience into projects.

Corps Comments on Implementation of Option 3

Corps officials said Option 3 would allow the Corps to collect national data that is not project-specific or related to a community request, which would reduce gaps in information and create more up-to-date information to use within existing technical assistance programs. For example, while some nonfederal sponsors have resources, such as advanced modeling departments, other nonfederal sponsors, such as those in rural areas, could greatly benefit from additional technical assistance because they do not have expertise. In addition, some nonfederal sponsors cannot keep up with flood risk management infrastructure maintenance. Corps officials said providing proactive technical assistance would require additional resources, such as more staff and dependable funding that is not reliant on nonfederal sponsor requests. Finally, Corps officials said they would need additional authority to implement Option 3 effectively, as current technical assistance authorities are too limited. For example, current technical assistance programs work well, but the agency believes it lacks the authority to provide assistance that is not requested by a nonfederal sponsor or tied to a specific project. Further, Corps officials said other agencies have the authority to proactively provide information and assistance to the public in a way that the Corps cannot.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 4: Update Climate Information for Planning

Update U.S. Army Corps of Engineers (Corps) climate information needed for feasibility studies to be authoritative, actionable, and forward-looking. For example:

- Expand regional or location-specific datasets and forecasting models to help guide decision-making and investments in studies and projects that incorporate climate resilience.
- Update web-based tools with the latest forward-looking climate data.



**Phase 2:
Feasibility**

Strengths

- Several stakeholders said this option would help facilitate consistent, informed decision-making. For example, one stakeholder said the Corps would have a better understanding of where climate information comes from. They said climate information could be more standardized and coordinated across agencies including the Corps, National Oceanic and Atmospheric Organization (NOAA), Federal Emergency Management Agency (FEMA), and U.S. Department of Housing and Urban Development. Another stakeholder said having standardized climate information for Corps projects across the country would also help develop a standardized approach for project planning because requirements vary by state.
- Some stakeholders said this option could help make climate information more easily accessible. For example, one stakeholder said web-based tools make information easier to access.
- Some stakeholders said consistent, authoritative climate-related information helps communities explain why modifications or new approaches are important to include in projects.

Limitations

- Most stakeholders said other agencies, such as NOAA, FEMA, or the U.S. Geological Survey, may be responsible for collecting climate-related information. Specifically, one stakeholder said the Corps uses climate data that currently exist but does not help develop or produce climate data. Another stakeholder said it is important to build public awareness and share existing information rather than expand information.
- Some stakeholders said data availability differs by location. For example, one stakeholder said certain types of hazard information are available in some locations but not others.
- Some stakeholders said it is challenging to make decisions on what climate-related information to use for planning under uncertainty.
- Several stakeholders said this option necessitates additional capacity to implement effectively. For example, several stakeholders said updating data is expensive and takes time. One stakeholder said it is important to ensure that the Corps is collecting quality information. Another stakeholder said the Corps should work with academia and other agencies on this option because they do not have sufficient staff.
- One stakeholder said it will take time to change well-established Corps processes and procedures. Specifically, they said that the Corps has a strict process for changing guidance with new information.

Corps Comments on Implementation of Option 4

Corps officials said the agency is updating climate information for planning. Corps officials said that they support federal agency alignment on climate information, but the methods and tools must depend on the needs of the agency. For example, officials said the Corps waits to use actionable information because the most recently published climate projections may have uncertainties too big to justify general design decisions for long-lived projects like flood risk management infrastructure. Officials said, for example, that precipitation, drought, and flooding projections are not as reliable as sea-level change projections. Corps officials also said Option 4 would require additional resources, including dependable funding. Finally, Corps officials believe the agency has the authority to implement Option 4 and is already using the most current and actionable climate information. For example, agency guidance directs districts to consider three scenarios of potential sea-level change (e.g., low, intermediate, and high) when planning, designing, and managing infrastructure.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 5: Update Planning Guidance

Continue updating existing U.S. Army Corps of Engineers (Corps) guidance and issue new technical guidance to require that climate resilience be incorporated into all flood risk management infrastructure studies and projects. For example:

- Consistently use forward-looking climate information and future projections in Corps guidance.
- Improve methodologies to consider multihazard flood events and holistic approaches for reducing flooding for all projects.



**Phase 2:
Feasibility**

Strengths

- Some stakeholders said this option could add climate resilience requirements to all guidance and standards. One stakeholder said this option would help justify the costs of keeping climate resilience features in flood risk management infrastructure designs because those features have longer-term benefits that are not accounted for in current analyses.
- Some stakeholders said this option would help ensure that the Corps continually updates guidance to include the best available climate information. For example, one stakeholder said that science has progressed since some Corps planning guidance was updated decades ago. Another stakeholder said the Corps should look for gaps in its guidance and fill in missing or new information.
- One stakeholder said this option might increase the incorporation of climate resilience into all projects by making resilience a requirement, which will make it a primary concern.
- One stakeholder said this option helps nonfederal sponsors set expectations with communities about what level of protection is needed for a flood risk management project.

Limitations

- Some stakeholders said this option will take time to collaborate with other external groups and professional societies, such as the American Society of Civil Engineers. Specifically, one stakeholder said the Corps does not always successfully develop objectives with people local to flood risk management projects based on planning guidance.
- Some stakeholders said updating planning guidance is historically a lower priority for funding, as opposed to new Corps flood risk management studies and projects.
- Most stakeholders said this option necessitates additional capacity to implement effectively. For example, one stakeholder said the Corps needs a dedicated source of funding to update planning guidance.
- Some stakeholders said it takes time to change well-established Corps processes and procedures. For example, one stakeholder said the Corps generally updates only portions of guidance at a time.

Corps Comments on Implementation of Option 5

Corps officials said they may address aspects of Option 5 when they implement their updated *Planning Guidance Notebook*—which is expected to provide detailed guidance on how to implement the general process outlined in the *Principles, Requirements, and Guidelines* for evaluating and selecting projects.^a The Corps is also working with the Assistant Secretary of the Army to develop policy and guidance for flood resilience, which will include climate resilience. Corps officials said the agency needs to update a lot of planning guidance. However, Corps officials said the agency is not making poorly informed decisions as a result of outdated planning guidance. In addition, agency officials said updating and developing guidance makes planning and designing projects easier. For example, Corps officials said updated guidance on climate resilience, nature-based solutions, and multihazard events would be useful. In addition, Corps officials said Option 5 would require additional resources, including consistent funding and staff. Corps officials said most of their funding is project-based and cannot be used for updating planning guidance. Finally, Corps officials believe the agency can update planning guidance under current authorities.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

^aThe U.S. Water Resources Council's *Principles, Requirements, and Guidelines* (PR&G), published in 2013 and 2014, provide a common framework for how federal agencies, including the Corps, evaluate and select proposed water resources development projects. The PR&G largely replaced the U.S. Water Resources Council's prior *Principles and Guidelines* (P&G), which had been in place since 1983. U.S. Water Resources Council, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Mar. 10, 1983). In April 2023, Corps officials said they were updating the agency's 2000 *Planning Guidance Notebook* to reflect changes made in the PR&G. The 2000 *Planning Guidance Notebook* provides detailed guidance on how to implement the general process outlined in the P&G. See U.S. Army Corps of Engineers, *Planning Guidance Notebook*, Engineer Regulation 1105-2-100 (Apr. 22, 2000).

Option 6: Expand Use of Adaptive Management in Projects

Expand use of adaptive management in flood risk management infrastructure projects to enable enhanced climate resilience efforts later in project life spans.^a For example:

- Use adaptive management, a process for addressing risk and uncertainty by being flexible and adjusting decisions to reflect improved knowledge over time, for projects.
- Incorporate and clearly outline future “triggers” where, if met, additional assessment or adaptation for the flood risk management infrastructure project is required.



**Phase 2:
Feasibility**

Strengths

- Several stakeholders said this option would help manage uncertainty associated with future climate change in project design. Specifically, adaptive management creates options for future infrastructure adaptation in response to climate change.
- One stakeholder said this option might save costs in the long term, as the climate is constantly changing and large structures are inflexible.
- Some stakeholders said this option allows flexibility to modify large, long-lived projects in the future to changing conditions. For example, a stakeholder said this option would allow for project redesign if circumstances change, without the U.S. Army Corps of Engineers (Corps) or the nonfederal sponsor needing to seek additional authorities. In addition, one stakeholder said that outlining triggers for adaptive management within a project partnership agreement would allow the nonfederal sponsor to cost share with the Corps for project updates in the future.

Limitations

- Most stakeholders said this option would not be effective without clearly defined triggers that can be monitored and enforced.
- Some stakeholders said it is difficult to adapt structural projects or projects with limited space in urban areas. For example, one stakeholder said it is difficult to get preemptive land easements to prevent future impacts near a flood risk management project.
- Some stakeholders said projects with future adaptability may not have well-defined future resilience measures.
- Several stakeholders said this option relies on future decisions to manage and implement modifications when adaptation triggers are met. One stakeholder said that as a result, adaptive management practices will be difficult to implement, expensive upfront, and may take decades to show benefits.
- Most stakeholders said this option necessitates additional capacity to implement effectively. For example, one stakeholder said building adaptive projects may lead to higher up-front costs and another said that it is important to consider who is responsible for funding future project modifications.
- Several stakeholders said it will take time to change well-established Corps processes and procedures, such as the Corps' planning framework.

Corps Comments on Implementation of Option 6

Corps officials said having expanded authority to include adaptable features in projects would be helpful to enhancing climate resilience. Currently, future adaptation activities would be the responsibility of the nonfederal sponsor, which may have limited resources or knowledge to conduct monitoring and adaptation activities. In addition, Corps officials said the agency is working to develop procedures that may allow for more of an ecosystem-services approach to designing projects. An ecosystem-services approach might make it easier to implement adaptable projects and projects with nonstructural solutions. Corps officials said additional resources would be needed to implement Option 6, including funding. In addition, Corps officials said current processes to value costs and benefits would show up-front costs to build adaptable projects but not the future benefits from the adaptation. Finally, Corps officials believe they are limited in their authority to consider adaptive management in projects, with the exception of beach renourishment projects, which can be adapted with continuing construction funds.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

^aFor the purposes of this report, the term adaptive management includes both (1) adaptability, which includes designing a project that can be adjusted to future conditions; and (2) adaptive management, a structured management approach for addressing uncertainties by monitoring and assessing project performance or defined triggers and making modifications, as necessary.

Option 7: Integrate Climate Resilience into Project-Level Benefit Cost Analysis

Update U.S. Army Corps of Engineers (Corps) methods for conducting benefit cost analyses for flood risk management infrastructure to consider climate resilience. For example:

- Incorporate social and environmental costs with economic costs in benefit cost analyses to better understand the full impacts of different solutions and allow for broader considerations of climate resilience.
- Value all adaptation benefits (e.g., reduction in loss of life) when conducting benefit cost analyses, which may incentivize the Corps to build more resilient flood risk management infrastructure, rather than build such infrastructure to current conditions.



Phase 2: Feasibility

Strengths

- Most stakeholders said integrating climate resilience into project-level benefit cost analysis would help ensure a more comprehensive analysis. For example, most stakeholders said these analyses could include more information on a project's benefits and costs—including economic, environmental, and social—and one stakeholder said that analyzed benefits and costs could extend beyond the standard 50-year analysis period. In addition, one stakeholder said benefit cost analysis should be revised to include more future benefits and costs.
- Some stakeholders said this option could increase consideration of equity issues in decision-making.
- One stakeholder said this option would build the consideration of climate resilience into all Corps planning processes and design alternatives because project selection is driven by benefit cost analysis.

Limitations

- Most stakeholders said it is challenging to quantify all climate resilience benefits and costs, such as nontraditional environmental and social benefits and costs.
- Several stakeholders said it is challenging to develop a methodology that is fair and repeatable. For example, some stakeholders said that some benefit cost analysis approaches could be subjective. One stakeholder said that the current approach could lead to an overestimate of costs.
- Several stakeholders said the Corps may not have the authority to change aspects of the benefit cost analysis process, such as the discount rate (i.e., a rate that is applied to future benefits and costs to express their value in present terms for comparisons). Several stakeholders noted that other agencies, like the Office of Management and Budget, are also involved in setting aspects of the benefit cost analysis process. Further, some stakeholders said it would be helpful if agencies responsible for benefit cost analyses agree on how to account for climate change benefits and costs for consistency.
- One stakeholder said this option will require changing Corps' planning and guidance as it relates to considering trade-offs.
- Some stakeholders said this option would require having additional capacity to implement effectively, such as time to engage with professional societies and economists.
- Some stakeholders said it will take time to change well-established Corps processes and procedures, including training staff at different levels on new methodologies.

Corps Comments on Implementation of Option 7

Corps officials said they are currently considering developing guidance or a policy on the use of comprehensive benefits, which could include climate resilience, in benefit cost analysis. Corps officials said Option 7 could improve environmental justice outcomes. However, Corps officials said this option risks double counting some benefits if climate resilience is an independent benefit. In addition, Corps officials said changes to their benefit cost analysis process would take time to go through federal rulemaking. Finally, Corps officials believe the agency has some authority to implement Option 7, but additional authority would be helpful for effective implementation.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Notes: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

In August 2023, the Office of Management and Budget published draft guidance that describes best practices for analyzing changes in ecosystem services (i.e., contributions of ecosystems to the benefits used in economic and other human activity) in the benefit cost analysis context. See Office of Management and Budget, *Guidance For Assessing Changes in Environmental and Ecosystem Services in Benefit-Cost Analysis* (August 2023).

Option 8: Update Engineering Standards and Regulations

Update existing U.S. Army Corps of Engineers (Corps) engineering standards and regulations, and issue new engineering standards and regulations, to require that climate resilience be incorporated into all flood risk management infrastructure projects. For example:

- Incorporate current climate science and future climate projections into engineering standards and regulations.



Phase 3:
Pre-Construction
Engineering and
Design

Strengths

- Several stakeholders said this option would help the Corps continually update its standards and regulations to include the best available climate-related information. One stakeholder said that climate change is likely affecting all work that the Corps is doing, and the climate will continue to evolve, so this option is important.
- Some stakeholders said this option would enhance the Corps' climate expertise and incorporate the consideration of climate change into all federally funded flood risk management infrastructure projects. One stakeholder said federal agencies, like the Corps, have the most knowledge and experience on how to incorporate risk into engineering standards.

Limitations

- One stakeholder said communities might resist new standards, which could require modifying infrastructure, that increase costs and change established norms.
- One stakeholder said it is challenging to select an appropriate future climate scenario to design a flood risk management project to. They said that some climate scenarios might not be feasible for the Corps to design flood risk management infrastructure to.
- Some stakeholders said it is challenging to update standards if data are outdated or incomplete. For example, one stakeholder noted that precipitation frequency data are outdated, and another stakeholder said research is needed to better understand compound flooding.
- One stakeholder said it will take time to collaborate with external groups and professional societies to update engineering standards and regulations, and the Corps cannot package this information alone.
- One stakeholder said updating engineering standards and regulations is historically a lower priority than funding new flood risk studies and projects.
- Several stakeholders said this option necessitates additional capacity to implement effectively, such as dedicated funding and staff.
- One stakeholder said it will take time to change well-established Corps processes and procedures.

Corps Comments on Implementation of Option 8

Corps officials said the agency's engineering guidance is outdated and, as a result, they sometimes pursue design exceptions to incorporate the latest science, which creates uncertainty and additional work. In addition, Corps officials said updated engineering standards and regulations would ensure that flood risk management infrastructure projects are delivered based on the climate resilience needs of the nonfederal sponsor. Corps officials said guidance related to climate change would need to be regionally specific and not nationwide, as climate change affects parts of the country differently. Corps officials said additional resources would be needed to implement Option 8, including funding. Finally, Corps officials said they believe the agency has the authority to implement Option 8.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 9: Conduct Climate Screening Assessments of Authorized but Unfunded Projects

Conduct climate-screening assessments of authorized but unfunded projects prior to construction to determine if the projects incorporate suitable climate resilience measures. For example:

- Determine whether changes in the climate affect the long-term viability of the flood risk management infrastructure project.
- Incorporate current climate projections for flood risk management infrastructure projects with older authorizations.



Phase 3:
Pre-Construction
Engineering and
Design

Strengths

- Several stakeholders said this option would help ensure that the latest climate-related information is included in flood risk management infrastructure project designs. One stakeholder noted that climate change projections change every couple of years.
- Several stakeholders said this option would help determine if older project designs still protect communities against flood risks. For example, one stakeholder said there are older U.S. Army Corps of Engineers (Corps) flood risk management infrastructure projects that did not consider climate change.

Limitations

- Some stakeholders said there is a lack of guidance to implement and account for future uncertainty, new information, and new climate resilience features. One stakeholder said the Corps would need to determine the maximum age of studies before it requires a screening assessment.
- Most stakeholders said this option necessitates additional capacity to implement effectively. For example, one stakeholder said conducting climate screening assessments on flood risk management infrastructure projects could create a larger project backlog and increase time between project approval and completion.
- Some stakeholders said it will take time to change well-established Corps processes and procedures. Most stakeholders said the Corps may face resistance for longer project times or costly assessments at the local level.

Corps Comments on Implementation of Option 9

According to Corps officials, the agency currently restudies some flood risk management projects if those projects are not constructed and initial studies are outdated. However, the Corps does not have a hard-and-fast rule on projects it restudies or how old a feasibility study must be to prompt an additional study. Corps officials said they would need new authority to conduct new feasibility studies to consider climate change risks for projects in limbo—for example, those projects that have completed the pre-construction engineering and design phase but have not started construction. Corps officials also said they have some authority, depending on the language of authorizing acts, to catch and remove certain backlogged flood risk management infrastructure projects during technical reviews—for example, those projects that have a completed the feasibility study but have not begun pre-construction engineering and design. Corps officials said Option 9 is only necessary for projects authorized prior to the issuance of the agency's 2014 climate policy that requires the consideration of climate change in all decisions. In addition, Corps officials said Option 9 would require an additional study cost share by nonfederal sponsors for climate screening assessments. Finally, Corps officials said they believe the agency has some authority to implement this option, but additional authority would be required for effective implementation.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (i)con. | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 10: Prioritize Projects that Incorporate Climate Resilience

Prioritize federally funded flood risk management infrastructure projects that incorporate climate resilience. For example:

- Prioritize flood risk management infrastructure projects that incorporate climate resilience into their designs.



Phase 4:
Construction

Strengths

- Some stakeholders said this option would encourage incorporating climate resilience into all U.S. Army Corps of Engineers (Corps) flood risk management infrastructure projects. Further, some stakeholders said climate resilience should be a component of all Corps work.
- One stakeholder said this option is responsive to climate change and community needs.
- Some stakeholders said this option could prioritize high-risk areas and vulnerable communities.
- Some stakeholders said this option would demonstrate that climate resilience is a Corps priority. For example, one stakeholder said this option requires that climate resilience is incorporated before flood risk management infrastructure projects are funded.

Limitations

- Some stakeholders said there is a lack of guidance on how to measure resilience to prioritize climate resilience projects.
- Most stakeholders said other factors might take precedence or be higher priorities than climate resilience. For example, one stakeholder said other important factors the Corps must consider include national security.
- Some stakeholders said this option might disproportionately affect disadvantaged communities. For example, one stakeholder said prioritizing projects that incorporate climate resilience might reduce the consideration of social vulnerability and that communities with higher property values may get priority, rather than communities that need protection.
- Several stakeholders said this option necessitates additional capacity to implement effectively.
- One stakeholder said it will take time to change well-established Corps processes and procedures, such as benefit cost analyses. In addition, one stakeholder said dedicated Corps leadership is required for this option to be successful.

Corps Comments on Implementation of Option 10

Corps officials said they currently follow budgeting guidelines for flood risk management projects that prioritize life safety, project benefits, and economically disadvantaged communities. In addition, Corps officials said it would be challenging to develop criteria for prioritizing projects and metrics for rating projects for climate resilience. Option 10 would also require having dialog on how to make climate resilience impactful alongside other project considerations, such as life safety and critical infrastructure. In addition, projects would provide benefits to communities at different times, making it difficult to rank an entire project. Finally, Corps officials said they believe the agency may have authority to implement Option 10 but is limited in its ability to do so based on the priorities of the administration and Congress. For example, Congress prioritizes projects for the Corps to construct through Water Resources Development Acts and annual appropriations acts.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 11: Update Manuals for Operation and Maintenance

Update manuals for operation and maintenance to account for climate change and climate resilience best practices.^a For example:

- Update manuals for operation and maintenance on a regular basis with the most up-to-date climate science.



Phase 5:
Operation and
Maintenance

Strengths

- Some stakeholders said this option would help ensure that the best available science and practices are included in manuals for operation and maintenance of flood risk management infrastructure.
- One stakeholder said this option would help standardize climate change projections in manuals for operation and maintenance.

Limitations

- Some stakeholders said the U.S. Army Corps of Engineers (Corps) does not have operation and maintenance responsibilities for much of the flood risk management infrastructure it constructs. One stakeholder said nonfederal sponsors might not have funding set aside to update manuals during operation and maintenance.
- Some stakeholders said this option could result in potential increased costs to nonfederal sponsors. For example, a stakeholder said flood risk management infrastructure operators or managers might resist this option because they would not want to be subject to future uncertainty.
- Some stakeholders said this option depends on having reliable and updated climate-related information. One stakeholder said climate information is nonstationary and will change over time.
- Several stakeholders said that this option necessitates additional capacity to implement effectively, including dedicated funding for the Corps.
- One stakeholder said it will take time to change well-established Corps processes and procedures and that many manuals are outdated and not web based. They also said updating manuals is historically an underfunded area.

Corps Comments on Implementation of Option 11

Corps officials said routine updates to manuals for operation and maintenance could also include climate change risks and flood risk management project monitoring for adaptive management. However, Corps officials said nonfederal sponsors responsible for operation and maintenance of completed flood risk management infrastructure projects do not always follow the manuals. The Corps lacks the authority to enforce following these manuals when projects are completed and turned over to the nonfederal sponsor after construction. Corps officials said Option 11 may be effective for simpler flood risk management projects where all operational guidelines are contained in a single manual. However, Corps officials said more complex projects would require changes to multiple manuals. Finally, Corps officials said they believe the agency could update manuals for operation and maintenance under current authorities. For example, the Corps currently updates manuals for operation and maintenance, mostly for dams, when new information is available or there are critical changes to the infrastructure.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

^aFor the purposes of this report, we use the term manuals for operation and maintenance to represent a variety of manuals, such as operation and maintenance manuals, water control manuals, and water control plans. Strengths and limitations for Option 11 may not apply to all manual types, as the Corps operates and maintains some flood risk management infrastructure, and nonfederal sponsors operate and maintain other flood risk management infrastructure.

Option 12: Expand Technical Assistance to Nonfederal Sponsors for Operation and Maintenance

Expand the technical assistance provided by the U.S. Army Corps of Engineers (Corps) to help nonfederal sponsors operate, maintain, repair, replace, and rehabilitate flood risk management infrastructure. For example:

- Help nonfederal sponsors understand and address potential climate risks to make better-informed operating and maintenance decisions.
- Expand support for real-time flood monitoring and options for triaging floods.



Phase 5:
Operation and
Maintenance

Strengths

- One stakeholder said this option considers upgrades to infrastructure based on the fact that climate change is not static.
- Some stakeholders said this option could help communities better understand climate-related risks. For example, one stakeholder said the Corps has a lot of information and could develop its relationships with communities with more proactive technical assistance.
- Some stakeholders said this option could improve the quality and consistency of climate-related information and assistance to communities. For example, one stakeholder said nonfederal sponsors who agreed to conduct operation and maintenance decades ago may not have knowledge of what to do now.
- Some stakeholders said this option could facilitate communication and collaboration among communities to enhance resilience at a watershed or regional level. For example, one stakeholder said some flood risk management infrastructure systems have multiple owners that do not communicate with each other.

Limitations

- One stakeholder said this option might overlap with technical assistance provided by other programs and industry groups.
- One stakeholder said this option would depend on climate-related information from other federal agencies, such as the National Oceanic and Atmospheric Administration.
- Several stakeholders said this option necessitates additional capacity to implement effectively. For example, a stakeholder said the Corps would need to provide technical assistance at the division level, and those staff would require training.
- One stakeholder said it will take time to change well-established Corps processes and procedures, for example, by better considering operation and maintenance when planning projects.

Corps Comments on Implementation of Option 12

Corps officials said their current capability to provide technical assistance for operation and maintenance is within the agency's Dam and Levee Safety programs. Through these programs, the agency conducts inspections of federally authorized dam and levee projects. Corps officials said nonfederal sponsors might not have the knowledge to conduct operation and maintenance, including specialized monitoring or modeling, so Option 12 may be helpful. However, Corps officials said technical assistance alone may not compel nonfederal sponsors to maintain flood risk management infrastructure if they lack the funding to do so, and the Corps cannot provide such funding. In addition, Corps officials said Option 12 could result in the identification of additional problems for nonfederal sponsors to solve, and the Corps lacks mechanisms to compel nonfederal sponsors responsible for operation and maintenance to fix these problems. Finally, Corps officials believe they do not have the authority under current technical assistance programs to provide technical assistance to nonfederal sponsor for operation and maintenance that is not requested by the community.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 13: Conduct Climate Vulnerability Assessments of All Existing Infrastructure

Conduct climate vulnerability assessments on all existing flood risk management infrastructure to identify the most vulnerable infrastructure, infrastructure with the highest consequences from failure, and infrastructure that will require adaptation sooner. For example:

- Conduct climate vulnerability assessments or climate stress tests on a regular basis to help the U.S. Army Corps of Engineers (Corps) and Congress prioritize which existing flood risk management infrastructure projects to modify (e.g., focus on infrastructure prone to repeated failure).



Phase 5:
Operation and
Maintenance

Strengths

- Some stakeholders said this option might increase awareness of infrastructure that needs attention, for example, due to safety concerns. One stakeholder said the Corps should evaluate the vulnerabilities of existing infrastructure and make modifications, rather than focusing on building new projects.
- Some stakeholders said this option could help direct resources toward infrastructure or projects facing the largest risks.
- One stakeholder said this option is more efficient than updating individual manuals for operation and maintenance.
- Some stakeholders said the Corps could consider this option in an existing infrastructure assessment process. For example, one stakeholder said the Corps could incorporate climate vulnerability into its annual or biannual infrastructure inspections.

Limitations

- Some stakeholders said there is a lack of guidance on how to conduct climate vulnerability assessments. For example, one stakeholder said the Corps must consider the scale of climate vulnerability assessments.
- Some stakeholders said this option would not improve climate resilience unless paired with funding to address vulnerabilities identified by assessment.
- Several stakeholders said this option necessitates additional capacity, such as additional personnel to perform the assessment, to implement effectively. One stakeholder said the federal government has competing needs and a high volume of infrastructure and facilities to maintain.
- One stakeholder said it will take time to change well-established Corps processes and procedures.

Corps Comments on Implementation of Option 13

Corps officials said climate vulnerability assessments of Corps-owned and -operated infrastructure, including flood risk management infrastructure, is underway to better understand how such infrastructure will respond to climate change. The current risk screenings and assessments for federal levees also supports improved risk and consequence understanding on existing levee systems. Corps officials said conducting climate vulnerability assessments of all existing flood risk management infrastructure would require additional resources, including agreement from nonfederal sponsors responsible for operation and maintenance and funding to study and implement retrofitting actions. In addition, Corps officials said they would need to develop a new process to complete improvements to infrastructure based on problems identified in the vulnerability assessments. Finally, Corps officials said they would need additional authority to implement Option 13 effectively, as they believe current authority is limited to Corps-owned and -operated infrastructure. Further, Corps officials said it is challenging to define which flood risk management infrastructure would be included in the climate vulnerability assessments, as the Corps turns many projects over to the nonfederal sponsor to operate and maintain.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (iicon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Option 14: Establish a Process for Retrofitting Existing Infrastructure to Account for Climate Change

Establish a process for modifications to enhance the climate resilience of existing flood risk management infrastructure most vulnerable to climate change. For example:

- Retrofit existing infrastructure before it fails, or it is damaged by a disaster.



Phase 5:
Operation and
Maintenance

Strengths

- Some stakeholders said this option would help address a gap in current processes for modifying existing flood risk management infrastructure. In addition, some stakeholders said this option could increase efficiency.
- Some stakeholders said this option would help address long-term risks to aging flood risk management infrastructure that may be more vulnerable to climate change.
- One stakeholder said this option could increase flexibility during planning and operation and maintenance of flood risk management infrastructure. Another stakeholder said this option could help the U.S. Army Corps of Engineers (Corps) avoid the catastrophic impacts of floods.

Limitations

- Some stakeholders said this option might overlap or conflict with the Corps' existing project delivery process. Specifically, one stakeholder said this option would add another layer of review to the existing project development and delivery process.
- Most stakeholders said there is a lack of guidance on how to complete retrofitting. For example, one stakeholder identified competing needs when retrofitting flood risk management infrastructure, such as climate and social goals.
- Several stakeholders said this option necessitates additional capacity to implement effectively. For example, some stakeholders said too much infrastructure across the country requires retrofitting and some stakeholders said there is a limited budget available.
- One stakeholder said it will take time to change well-established Corps processes and procedures. Further, this option might alter the Corps' list of priority flood risk management projects. This stakeholder also said the Corps might need Congress to prioritize which projects to retrofit.

Corps Comments on Implementation of Option 14

Corps officials said Option 14 would be helpful to move the agency's climate resilience effort forward. This option is also necessary if the administration and Congress want to prioritize climate resilience flood risk management infrastructure projects. Corps officials said it would be beneficial to group flood risk management infrastructure projects into categories to indicate the level of resources needed to enhance climate resilience. For example, some infrastructure will need full reformulation and new alternative solutions, and other infrastructure will require simpler changes that are faster and cheaper to implement. However, Corps officials said Option 14 would require significant effort and additional resources, including funding to complete the work and agreement from nonfederal sponsors. The agency would also need a process to prioritize which flood risk management infrastructure projects need retrofitting after climate screening assessments. Finally, Corps officials said they believe the agency has some authority to study some existing flood risk management infrastructure, but Option 14 would require additional project studies and authorization to implement retrofitting actions.

Source: GAO analysis of information from literature and interviews with knowledgeable stakeholders and Corps officials; GAO (icon). | GAO-24-105496

Note: We identified this and other options for the Corps to further enhance the climate resilience of federally funded flood risk management infrastructure, and described their strengths and limitations, based on a comprehensive review of relevant literature and 21 semistructured interviews with knowledgeable stakeholders. We did not evaluate the accuracy of the Corps' statements about its authorities or the extent to which the Corps could implement this option without congressional action.

Appendix V: Comments from the U.S. Army Corps of Engineers



DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
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108 ARMY PENTAGON
WASHINGTON, DC 20310-0108

December 6, 2023

Mr. J. Alfredo Gomez
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Gomez:

The Army has received the GAO Draft Report, GAO-24-105496, "CLIMATE CHANGE: Options to Enhance the Resilience of Federally Funded Flood Risk Management Infrastructure," dated November 03, 2023 (GAO Code 105496).

The Army appreciates this opportunity to review the draft report and values the GAO staff's professionalism, collaboration, and insights during this project. The Army's comments on the Draft Report (Enclosure 1) and technical comments (Enclosure 2) are included with this response.

Thank you again for the opportunity to comment. My point of contact for this action is Ms. Sharron DaCosta-Chisley, Sharron.H.DaCosta-Chisley.civ@army.mil, (571) 278-6547.

Sincerely,

A handwritten signature in black ink, appearing to read "Michael L. Connor", is positioned above the typed name.

Michael L. Connor
Assistant Secretary of the Army
(Civil Works)

Enclosures

**Appendix V: Comments from the U.S. Army
Corps of Engineers**



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ENCLOSURE 1

GAO Draft Report Dated November 3, 2023
GAO-21-105496 (GAO CODE 105496)

**“CLIMATE CHANGE: OPTIONS TO ENHANCE THE RESILIENCE OF FEDERALLY
FUNDED FLOOD RISK MANAGEMENT INFRASTRUCTURE”**

**ARMY COMMENTS
TO THE GAO RECOMMENDATION**

RECOMMENDATION 1: The Assistant Secretary of the Army for Civil Works should direct the Chief of Engineers and the Commanding General of the U.S. Army Corps of Engineers to (1) analyze the 14 options for enhancing the climate resilience of federally funded flood risk management infrastructure identified in this report, and (2) integrate them, as appropriate, into the Corps’ future climate resilience prioritization and planning efforts. Such analysis should include an explanation of the Corps’ decision to prioritize or not prioritize the options as well as legislative proposals, as appropriate, that identify any additional authorities and resources the Corps would need to implement the options.

OASA(CW) RESPONSE: Army concurs.

The U.S. Army Corps of Engineers (Corps) will analyze the 14 options in the report and integrate, as appropriate, into the Corps’ future climate resilience prioritization and planning efforts to include explanations of their decisions as well as legislative proposals, as appropriate for additional authorities and resources needed to implement the options.

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

J. Alfredo Gómez, (202) 512-3841 or gomezj@gao.gov

Staff Acknowledgments

In addition to the individual named above, Joe Thompson (Assistant Director), Holly Halifax (Analyst-in-Charge), Zoe Need, Curtis Birch Synnott, Gillian Wolfe, John Delicath, and Adrian Apodaca made key contributions to this report. Also contributing to this report were Claudia Becker, Kyle Browning, Colleen Candrl, Lilia Chaidez, Brad Dobbins, William Gerard, Cindy Gilbert, Claudia Hadjigeorgiou, Vondalee Hunt, Susan Irving, Adriane Kline, Edward “Jim” Rice, PhD, Rebecca Sero, Lisa Vojta, and Patrick Ward.

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