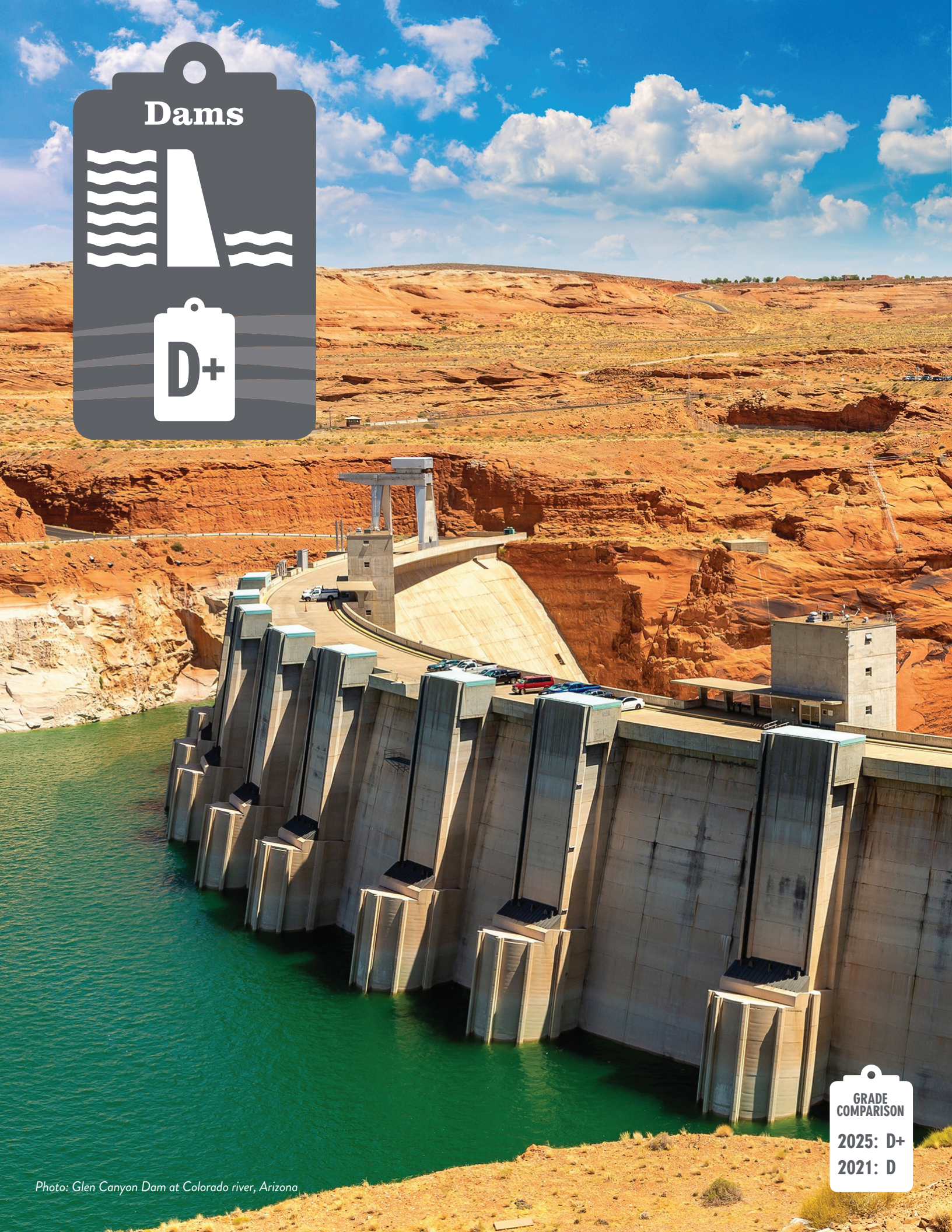


Photo: Glen Canyon Dam at Colorado river, Arizona

DAMS

EXECUTIVE SUMMARY

There are more than 92,000[1] dams in the U.S. that generate electricity, supply drinking water, and protect communities and critical infrastructure. Nearly 17,000 of these dams are considered high hazard potential, meaning there is likelihood of deadly harm to residents and property in the case of a dam failure. The cost of maintaining, upgrading, and repairing these structures has increased significantly since the beginning of the 21st century because of an increase in extreme weather events, growing populations downstream, and the outdated design challenges of aging structures. The average age of our nation's dams is over 60 years, while 7 of 10 dams nationwide are expected to reach 50 years by 2025. The Infrastructure Investment and Jobs Act (IIJA) provided approximately $3 billion to improve dam safety, although Congress redirected $364 million of that funding for other purposes. Furthermore, federal dam safety programs continue to receive annual appropriations below their authorized funding levels. Despite these challenges, IIJA funding, combined with other Congressional actions, provided a needed boost to overall dam safety and rehabilitation. However, without a more significant commitment to dam safety through increased annual investment in inspection, monitoring, planning, and necessary dam repairs, the cost to bring the nation's dams into a state of good repair will continue to rise and downstream communities will face a greater risk of danger from potential dam failure.

BACKGROUND

The U.S. is home to more than 92,000 dams, which are responsible for flood control, irrigation, water supply and conservation, river navigation, hydropower generation, mine waste storage, and recreation. Of those, only 4% are owned by the federal government, with the remaining 95% owned by state or local government, a public utility, or a private owner. More than 16,800 dams are classified as high hazard potentia, meaning that loss of life and significant property destruction is likely in the event of a dam failure. More than 38,000 of the nation's dams support recreational activities and therefore experience significant public access. On average, the nation's dams are 64 years old and need significant repair and upgrades. The structural integrity and performance of many of the nation's dams are increasingly affected by extreme weather, with frequent and intense rain events placing a significant strain on dams and their ability to hold water, threatening the safety of downstream communities.

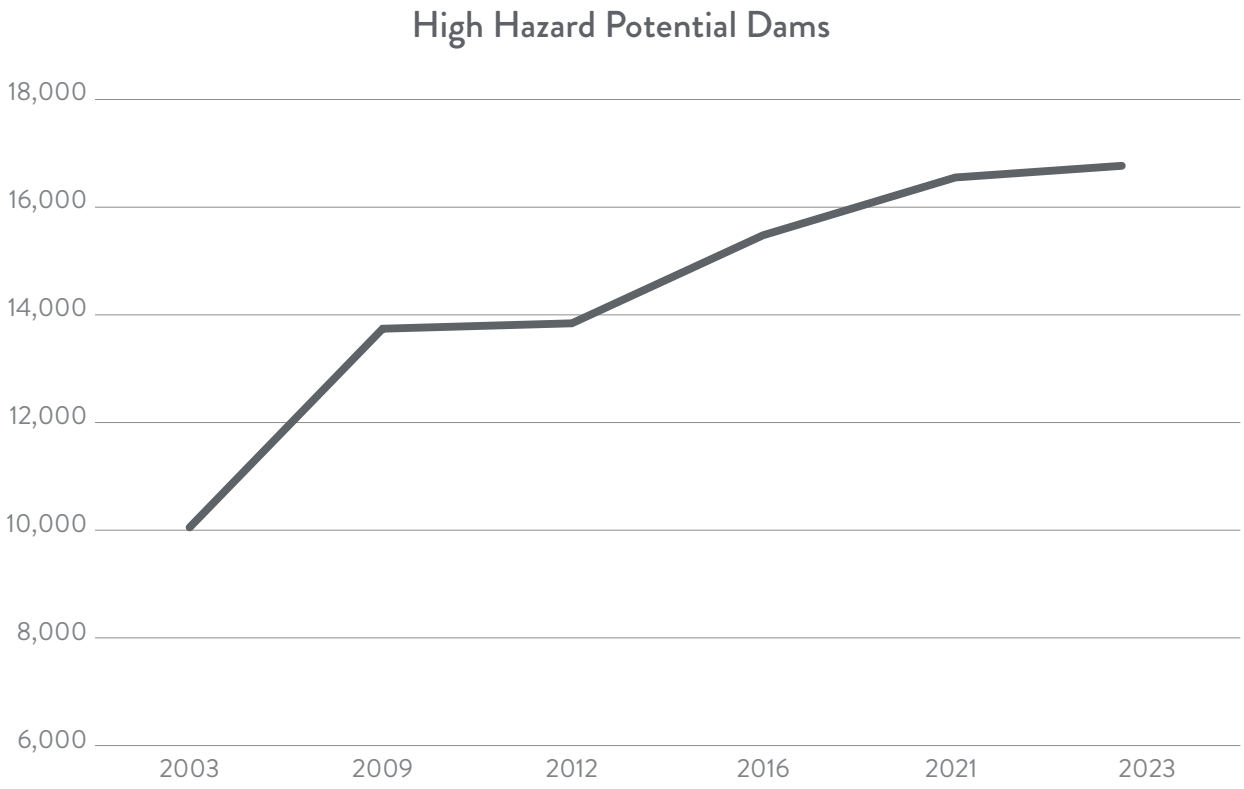
CAPACITY AND CONDITION

Dams are classified by their hazard potential, or the risk posed to downstream communities in the event of a dam failure. In the U.S., more than 16,700 dams are classified as high hazard potential as of August 2024, which means that if one of these dams should fail, the likely result would be loss of life and significant destruction to property. While such a classification highlights risk to communities, hazard potential does not indicate a dam's condition. Approximately 15%, or more than 2,500, of the nation's high hazard–potential dams are assessed to be in poor or unsatisfactory condition.[2] While a dam's hazard potential can often be determined by factors such as downstream development, condition assessments are primarily affected by the relative age of the structure, updated science and techniques for evaluating conditions, weather events, and climate change. High hazard–potential dams nationwide have increased by 20% since 2012, driven mostly by increased development in downstream areas.[3]

On average, the nation's dams are currently 64 years old,[4] and significant repair and upgrades are needed. According to the Association of State Dam Safety Officials (ASDSO), by 2025, 7 of 10 dams in the U.S. will be more than 50 years old.[5] Aging infrastructure and more frequent and intense rain events cause additional strain to the nation's dams. For example, in Vermont, the average age of the state's dams is 89 years. Because of this, many of Vermont's dams were not built using modern codes and standards; thus, they are not designed to withstand increasingly heavy and frequent rain events. Unfortunately, in July 2023, prolonged heavy rainfall over 48 hours produced between three and nine inches of rain in some parts of the state, which resulted in historic flooding and placed significant strain on Vermont's aging dams. Following the flooding, state dam inspectors assessed 400 dams across the state and found that 57 dams were overtopped by flooding, 50 dams sustained "notable damage," and five dams failed.[6]

Photo: Fairfax Falls Hydroelectric Dam, Fairfax, VT, on July 11, 2023, following historic flooding; University of Vermont, Spatial Analysis Laboratory

Increasingly severe rain events are affecting aging dams in other regions of the country as well. Since 2018, heavy rains have resulted in approximately 30 dam failures or near failures across the Midwest.[7] In June 2024, the western abutment of Minnesota's Rapidan Dam failed after several days of heavy rain. The flooding that caused the abutment's failure was the equivalent of a once-in-a-century flooding event and resulted in the destruction of a power station and destroyed part of a riverbank.[8] The Rapidan Dam, which had completed construction in 1910, had gone through several rounds of repairs since 2002 and was assessed to be in poor condition in 2023.[9] In 2021, an engineering report estimated that the cost of repairing the dam would be more than $15 million in addition to more than $6 million that had already been spent on the dam since 2002.[10]



Source: National Inventory of Dams

FUNDING AND FUTURE NEED

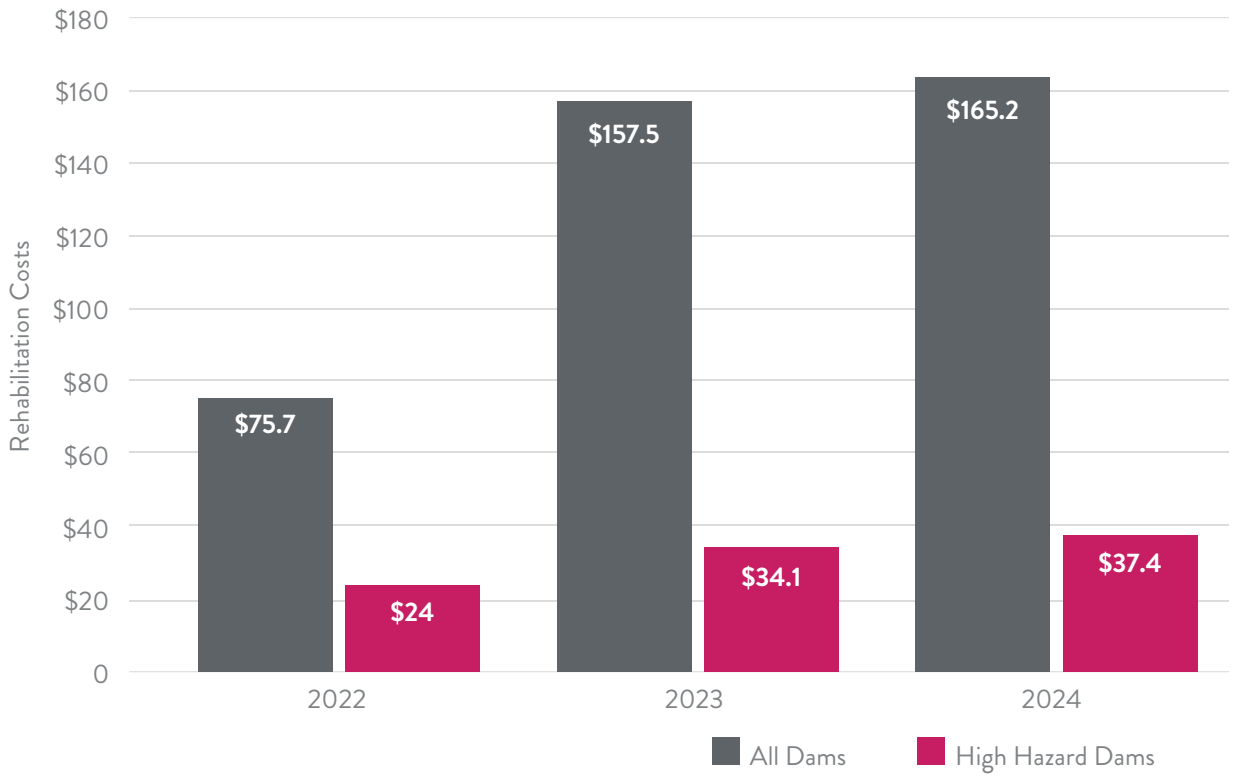
The National Dam Safety Program (NDSP) is the primary source of federal funding for states to improve their dam safety programs that support activities such as inspection and monitoring, emergency preparedness, and staffing needs. This program is only authorized to receive $13.9 million annually. The High Hazard Potential Dam Rehabilitation Grant Program (HHPD) Grant Program, which provides competitive grants to states to support repairs for dams posing the greatest risk to downstream communities, is authorized at $60 million annually. In 2021, the IIJA provided a total of $800 million for these programs as a one-time injection of much-needed support for dam safety. Furthermore, the U.S. Army Corps of Engineers' Water Infrastructure Financing Program (CWIFP), which supports non-federal dam safety projects through low-interest loans, received $75 million under IIJA. Meanwhile, the Department of Agriculture's Natural Resources Conservation Service administers a dam rehabilitation grant program through its Small Watershed Program, which receives about $10 million annually and $118 million in additional funds through IIJA.

Although there are multiple federal funding streams for dam safety, and the IIJA made historic one-time investments in dam safety, the totality of approved resources has not been made available to sustain the focus on safety needs at chronically underfunded structures. Only a portion of IIJA funding for the NDSP and the HHPD Grant Program will ever go to its intended purpose because nearly 50% of this total was redirected in 2024 by Congress and the U.S. Department of Homeland Security for other purposes.

The NDSP has consistently received less than $10 million in annual funding of its $13.9 million yearly authorization. The HHPD Grant Program has not received anywhere near the $60 million it could receive by law. In fact, the program received no federal funding in both Fiscal Years 2023 and 2024. Failure to fund the HHPD Grant Program diminishes the purchasing power of these investments, resulting in insufficient resources to support state program needs such as hiring qualified engineers to conduct dam inspection and monitoring. The lack of funding will also result in fewer resources to repair and rehabilitate high hazard–potential dams, which means that the condition of many of these dams will continue to deteriorate and raise rehabilitation costs that much higher.

In 2024, ASDSO determined that the current cost of repairing the nation's non-federal dams is $165.2 billion, with $37.4 billion needed for just non-federal, high hazard–potential dams.[11] The cost estimate increased by more than $120 billion between 2003 and 2022 primarily due to the growing number of dams being tracked in the National Inventory of Dams, providing a more accurate picture of total need.[12] Individual dam rehabilitation projects can reach over $1 billion, as was the case to repair California's Oroville Dam after its spillway failed in 2017.[13]

Estimated Non-Federal Dam Rehabilitation Cost Needs Over Time in Billions



Source: Association of State Dam Safety Officials

OPERATION AND MAINTENANCE

Nearly every state has a fully operational dam safety program. These programs allow states to receive federal funds to perform necessary dam safety operation and maintenance activities such as developing emergency action plans (EAPs), conducting public outreach, and undertaking regular dam inspection and monitoring. Until recently, Alabama was the only state that did not have a state dam safety program. However, in 2023 and 2024, Alabama took legislative action to create an opt-in dam safety program, allowing for inspection and monitoring of state-owned and privately owned dams. These initiatives move the state closer to eligibility for NDSP State Assistance Grants. State dam safety programs are eligible to receive state assistance grants if they meet certain criteria, including authority to require inspection of all dams to for risk every five years.

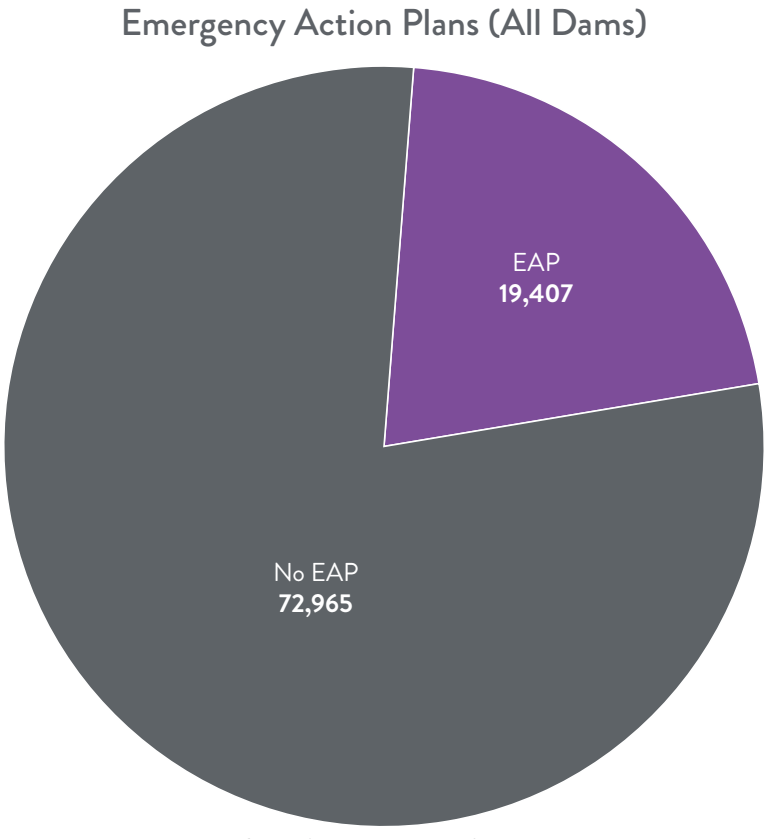
Reduced federal funding for the National Dam Safety Program has limited resources available to states. In turn, reduced funding has compelled states to extend their already constricted resources, putting additional strain on state budgets and stretching state dam safety programs. The consequences of lower funds affect critical components of state dam safety programs such as staffing. State assistance grants may help increase the number of trained engineers on staff to conduct inspections. On average, there are approximately 1,700 regulated dams per state. However, with an average of nine dam inspectors per state, a single dam inspector can be responsible for overseeing the safety of 190 existing dams and the construction of new dams.[14]

Photo: A home before partially collapsing into the Blue Earth River in Mankato, MN, following the 2024 partial failure of the Rapidan Dam; Andrew Weinzierl/AW Aerial

PUBLIC SAFETY

Dam failures can pose significant challenges to impacted communities. In addition to causing billions of dollars in economic losses and the potential loss of life, dam failures can result in damage to interconnected infrastructure systems. Flooding from dam failures can impact bridges and roadways, threaten drinking water supplies, place excessive strain on stormwater infrastructure, and damage levee systems that protect floodplains. Emergency action plans are critical to minimizing damage caused by a dam failure. EAPs identify potential emergency conditions at a dam, specify preplanned actions to reduce property damage and loss of life should those conditions occur, and are initiated in the event of an impending dam failure or other uncontrolled release of water. In May 2020, the Edenville Dam in Michigan failed after significant rainfall. It was later determined that an exercise as part of the dam's EAP was critical to informing evacuation plans, which led to "well-organized and orderly" evacuations of downstream communities.[15] As a result, there were no reported casualties. As of 2024, more than 11,000 state-regulated high hazard–potential dams (nearly 82% of state-regulated high hazard dams, about equal to 2021) have an EAP.[16]

"Low-head dams" pose ongoing safety concerns. A low-head dam is a relatively small, man-made structure spanning a river or stream where water flows over the entire length of the dam. Moderate-to-high flows over these dams create turbulent and recirculating currents that can pull and trap individuals underwater. Because low-head dams can be inconspicuous, people are often unaware of the dangers of these structures. Fortunately, Congress recognized this danger, and in 2022 the Water Resources Development Act authorized the creation of a National Low-Head Dam Inventory, and in 2024 passed legislation to incorporate low-head dams into the National Inventory of Dams. This new inventory will allow not only for low-head dams to be better identified but also will allow for clear warnings about the presence of low-head dams and the danger they pose to human life. Congress authorized $30 million to establish the inventory, and U.S. Army Corps of Engineers received $400,000 in FY24 appropriations to begin work on the inventory.



Source: National Inventory of Dams

Photo: Great Falls Park,McLean, VA; Mark Stenglein

RESILIENCE AND INNOVATION

Worsening rainfall patterns and flooding increasingly strain the structural integrity of the nation's dams. Heavy rainfall contributed to the failure of the Rapidan Dam in Minnesota in 2024, the Edenville Dam in Michigan in 2020, and the Oroville Dam's flood control outlet spillways in 2017. The intensity and frequency of extreme precipitation and flooding are projected to continue increasing in several regions. Further, in many areas (e.g., West, Northwest, the New Madrid zone), non-climatic hazards like earthquakes compound the risk posed by climatic extremes to the nation's dams.

In 2022, Congress took action to address this challenge by passing the Providing Research and Estimates of Changes in Precipitation (PRECIP) Act to help improve how the National Oceanic and Atmospheric Administration (NOAA) estimates probable maximum precipitation (PMP) to better account for changes in rain frequency and intensity. In 2024, the National Academies of Science, Engineering, and Medicine published a report on the current state of PMP estimation and its shortcomings. The report recommended a phased approach to modernizing PMP to a long-term model-based approach that accounts for the effects of extreme weather on precipitation and PMP estimates.[17] Through this renewed effort, enhanced collection of more accurate data on rainfall events will be critical to the engineering community in designing dams and developing better standards, ultimately leading to the construction of dams better able to withstand increased water levels, resulting in fewer flood-related incidents.

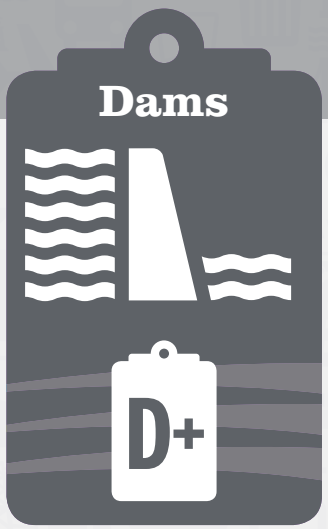
In recent years, dam safety officials and engineers have increasingly used risk-informed decision-making (RIDM) as an approach to dam safety. RIDM approaches decision-making by identifying and assessing existing risks, determining if those risks are tolerable (e.g., impracticable, cost-effective based on improvements gained), and whether existing risk mitigation measures are adequate. Since the 2017 failure of the Oroville Dam spillway, there have been more federal and state efforts to incorporate RIDM into dam management

practices, such as comprehensive inspections over visual inspections.[18] However, implementing RIDM comes with challenges requiring both significant financial resources, which many smaller state and federal agencies do not have, and very particular dam inspection expertise.[19]

Greater use of unmanned aerial vehicles (UAVs) or drones also provides innovative new approaches to dam safety. The ability to equip drones with equipment such as sensors, cameras, and infrared lenses can provide better access to higher and harder to access dam structures and can provide a lower-cost way to improve safety for dam inspectors.[20] Drones also have the potential to be used to prevent invasive plant and vegetation growth around dams. In recent years, the Tennessee Valley Authority has worked with dam safety professionals to test the use of drones to deploy herbicides to control vegetation growth around dam embankments, because the root structures of trees and heavy brush can pose dangers to structures and dam safety.[21]

Removal is also an increasingly appealing option for dams that no longer provide significant benefits. The IIJA made nearly $900 million available to support dam removal projects. Dam removal can produce tangible benefits such as restoring riverine ecosystems and removing hazards incited by dam failure. Removal is also an intervention that can restore or rectify environmental conditions caused by dam construction and ongoing operations placed on nearby communities. In 2014, the City of Manchester, Iowa, removed a 110-year-old low-head dam along the Maquoketa River, resulting in restored riverbanks, improved habitats for fish and other wildlife, and increased access to the river for recreational purposes through the development of a whitewater park.[22] On the other hand, dam removal may also produce unintended consequences such as excessive reservoir erosion, release of toxic and contaminated sediment, increased prevalence of invasive species, and ensuing legal conflicts.[23] Significant uncertainty remains about both the unintended consequences and long-term effects of dam removal, primarily due to limited experience with and lack of data from extensive monitoring of such projects, especially for large dams. It is essential to carefully examine key benefits and trade-offs, set practical goals for environmental recovery after removal, recognize limitations, and ensure effective data sharing from past and future dam removal projects. Cooperation and public engagement should be emphasized throughout planning for dam removal projects to ensure that dams do not become irreversible structures for decades to come. As a result, decision-making regarding dam removal can prioritize better projects balancing public safety with environmental concerns.[24]

Photo: Clementine Dam in Auburn, CA; Karen Donohue



RECOMMENDATIONS TO RAISE THE GRADE

- Fully fund the National Dam Safety Program and High Hazard Potential Dam Rehabilitation Grant Program, ensuring that adequate federal funds can support state dam safety programs and repairs to dams most in need and that pose the most significant risk to communities.
- Continue to build on progress by ensuring that all high hazard–potential dams have an emergency action plan by 2030.
- Complete implementation of a National Low-Head Dam Inventory by 2030, as authorized and prescribed in the Water Resources Development Acts of 2022 and 2024.
- Modernize methods of estimating probable maximum precipitation, as laid out in the 2024 report from the National Academies, to better determine the effects of extreme shifts in rainfall patterns, leading to better data for the engineering community to use in dam design and development of resiliency measures.
- Encourage improved land use planning at the local level so that communication about how dams affect local areas is more accurately known and considered in future planning.
- Carefully examine key benefits and trade-offs of dam removal and set practical goals for environmental recovery after removal, ensure effective data sharing from removal projects, and emphasize public engagement and cooperation throughout the removal process to balance public safety with environmental concerns.

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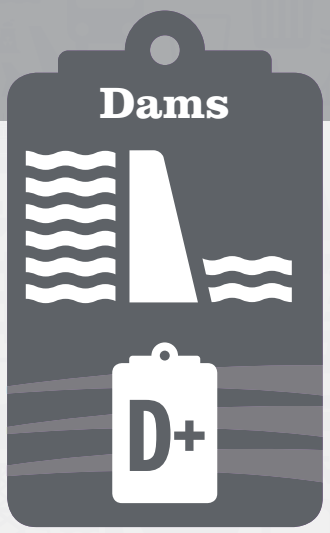

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