



PERSPECTIVES

The Vulnerability of Dams: A Rising Threat to Life & Property

Our perspectives feature the viewpoints of our subject matter experts on current topics and emerging trends.

INTRODUCTION

Dams, dikes, and levees are an integral part of infrastructure in the United States and abroad. They are often used for electrical generation (hydropower), agricultural purposes, water storage, and flood control. In addition, dams are also used to store hazardous material which includes oil products, mining byproducts, and other waste material. Many people first visualize the Hoover Dam or other large concrete and steel structures which control the flow of rivers. However, most of the dams in the United States are earthen embankment dams, which simply consist of piled and compacted soil that is used to retain water. While many dams are federally owned or built, over half of the dams within the United States are privately owned and most consist of smaller earthen embankments.

HISTORY

The importance of inspecting and maintaining one of our nation's most critical infrastructures began in 1972 when congress authorized the U.S. Army Corp of Engineers (USACE) to inventory dams through the National Dam Inspection Act. In 1975, the first National Inventory of Dams (NID) was published. The Water Resources Development Act of 1996 allocated funds for the USACE to continue updating the NID. During this time, the USACE began to work closely with the Federal Emergency Management Agency (FEMA) to further define and classify each dam throughout the United States. In addition to the importance of maintaining dams, large dams are also considered critical infrastructure and are a priority for the Department of Homeland Security to protect, not only against maintenance-related issues but also potential terrorist attacks. Following September 11, 2001, the National Dam Safety and Security Act was passed to provide funding for inspection, maintenance, and security of the dams throughout the United States. This act was re-authorized in the National Dam Safety Program in 2006 and, more recently, was re-authorized through 2023 in the Water Infrastructure Act of 2018.

HAZARD POTENTIAL CLASSIFICATION SYSTEM

Dams which meet the minimum criteria within the United States are classified by the NID based on data provided by federal and state government regulators. The data used to classify dams includes construction permits, building inspections and/or enforcement records, or other applicable specifications or dam records. The purpose of the program was to prioritize each dam throughout the United States for maintenance and inspection. This classification system categorizes dams based on the potential loss of human life, economic loss, lifeline disruption, and environmental impact in the event of a dam failure. The classification system includes low, significant, and high-hazard potential. Below are the minimum criteria for dams to be a part of the NID. Low-hazard potential means that in the event of a failure there would be no probable loss of human life, and low economic and/or environmental losses. Conversely, high-hazard potential would entail probable loss of human life, and high economic and/or environmental losses.

Minimum criteria for dams to be a part of the NID include:

1. High-hazard potential classification (loss of human life is likely if the dam fails).
2. Significant-hazard potential classification (no probable loss of human life but potential for environmental damage, disruption of lifeline facilities, economic damage, or other impacts and concerns).
3. Meeting or exceeding 25 feet in height and exceeding 15 acre-feet in storage.
4. Meeting or exceeding 50 acre-feet storage and exceeding 6 feet in height.

CURRENT CONDITIONS

According to the USACE, the dams within the United States have an average age of 61 years. By 2030, 7 out of 10 of dams in the NID will be over 50 years old. According to the American Society of Civil Engineers' (ASCE) 2017

Infrastructure Report Card, the United States Dams were given a grade of “D.” Due to population growth, almost 18% (~16,482) of the 92,063 dams within the United States are considered to be high-hazard potential dams and are cataloged in the NID. Over the last 20 years, the number of high-hazard potential dams has more than doubled due to development encroaching on pre-existing dams, thereby upgrading their classifications.

Coupled with lack of federal or private funding, more than 2,000 of the high-hazard dams are considered to be deficient. In addition to high-hazard potential dams,

there are 10,882 dams which are classified as a significant hazard. The most recent Association of State Dam Safety Officials’ (ASDSO) cost estimate indicates the combined total to rehabilitate the nation’s non-federal dams exceeds \$66 billion. It could cost nearly \$20 billion to address only the high-hazard dams. It has been estimated that the cost to rehabilitate federal dams is approximately \$27.6 billion. Below is an image taken from the NID website (nid.usace.army.mil/), which shows the concentration of dams throughout the United States.

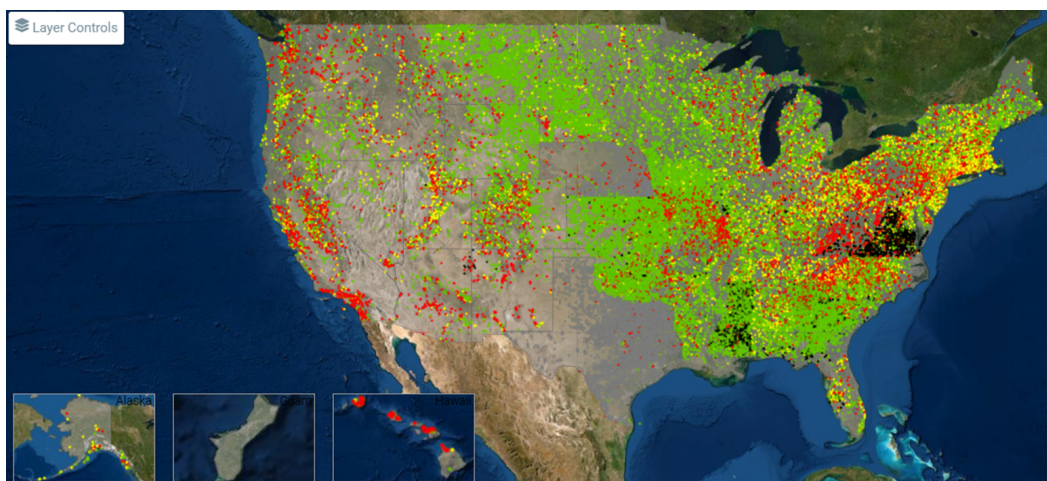


Figure 1 - Concentration of dams throughout the United States (I NID.USACE.ARMY.MIL/).

The red icons indicate dams which have been classified as high-hazard potential, yellow icons indicate significant hazard potential, and green icons represent those with low-hazard potential. Black icons are dams with an undetermined classification.

According to the USACE Dam report card, only 81% of high-hazard potential dams have Emergency Action Plans (EAPs). The purpose of EAPs is to identify potential hazards at a dam and pre-planned measures to respond to catastrophic events which could cause loss of life and property. An EAP also serves as a document which coordinates the efforts of owners and emergency managers to identify areas where there is concern for public safety. Guidelines for EAPs can be found within FEMA’s Federal Guidelines for Emergency Action Planning for Dams (FEMA Publication No. P-64).

WHAT IS BEING DONE ABOUT IT?

The federal government is aware of the dam crisis and has provided some funds to address the issue. Unfortunately, the funds do fall short of the estimated costs to appropriately address the issue. President Biden’s Build Back Better infrastructure bill set aside \$3B for dam-related projects. While this is a significant increase in funding compared to prior commitments from the federal government, it is still not close to meeting the ASACE \$20 billion estimate to repair the high hazard dams or the greater \$66 billion for all dams in need of repair. In addition, it has been a common occurrence in the past that not all federal funding apportioned to dam safety is spent

on intended goals. For example, FEMA’s Rehabilitation of High Hazard Potential Dams Grant Program, authorized by federal law in 2016, spent \$31.6 million, which was only one-fifth of the amount Congress appropriated from 2019-2021.

The recently proposed “Twenty-First Century Dams Act” bill is seeking a \$21.1 billion investment to enhance the safety, grid resilience benefits, and power generating capacity of America’s dams, as well as to provide funding to remove dams that are no longer necessary. While federal funding to that degree would be a historic achievement, many states, local jurisdictions, and private dam owners will need to find ways to fund dam rehabilitation projects in order to prevent potentially catastrophic dam failures from occurring.

All states except for Alabama regulate their dams, including the certification of EAPs. In 2018, state programs spent nearly \$60 million on dam safety regulation, a 22% increase over the previous four years. This increased funding has resulted in significantly higher staffing of dam safety programs across the country. Fortunately, steady progress is also being made toward development of emergency action plans for all high-hazard potential dams. The number of high-hazard-potential dams with EAPs is moving toward the recommended goal of 100%. As of 2018, 81% of dams have EAPs—up from 77% in 2017. Additionally, 34 states reported that over 90% of their high-hazard-potential dams had EAPs on file, with 100% of the high-hazard-potential dams inspected in 2018. Having an EAP in place will provide some level of preparation for the dam owners in the event of a failure.

DAM CONSTRUCTION AND VULNERABILITY

The majority of dams throughout the U.S. are earthen dams. Earthen dams have become an economical construction design used to control the flow of water or impound hazardous material. There are various types of earthen dams, which include simple embankments and zoned embankments. Simple embankments are typically composed of a homogenous soil embankment. A zoned embankment is similar but with a core and trench. Clay is often used as the core due to its impermeability; however,

concrete, sheet piles, or timber are also used to provide a water barrier. Impermeable cores are used to impede the flow of groundwater through dams which could cause seepage and piping failures. Conversely, some dam designs provide a high-permeability core which consists of a section of poorly-graded sand or gravel wrapped in a filter fabric, which allows water to flow through the dam in a controlled manner. The filter fabric allows water to flow into the permeable core but precludes soil particles from moving through the embankment, which can cause the dam to fail in a mechanism known as “soil piping.”

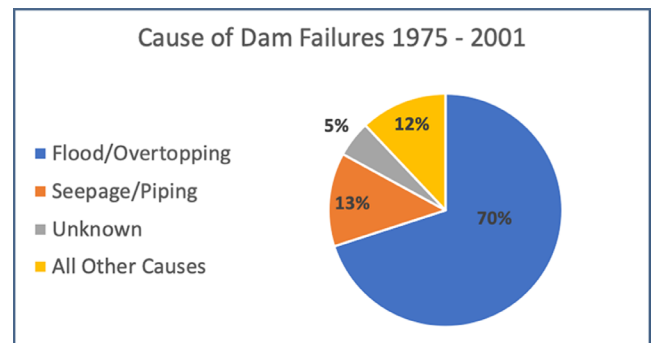


Figure 2 – Cause of dam failures from 1975 to 2001 (I NPDP, 2008B).

As previously seen during storms such as Hurricane Katrina and Hurricane Harvey, dams and levees can fail from heavy rainfall events which exceed the designed storage and discharge capacities of the associated water bodies. According to the National Performance of Dams Program (NPDP), the primary cause of dam failures is flooding (and overtopping) which is followed by water and soil movement through the earthen embankment, via soil piping, as previously discussed. Both failures can be caused by a flood event. The diagram above displays the Cause of Dam Failures from 1975 to 2001 (adapted from NPDP, 2008b).

VISUAL ASSESSMENT

A rapid visual assessment of a dam embankment—to identify potential hazards and effectively assess the condition of a dam or levee—is imperative following a catastrophic rainfall event. Potential hazards would include scour and erosion, slope failures, and subsidence features. Scour, erosion, and slope failures are most common with a

rapid increase of flow through a water body. While scour is a visible surface condition, subsidence features may be associated with a subsurface issue such as piping. Piping occurs through cracks, voids, or weak zones in a dam embankment. Soil particles are eroded or washed through these weak zones creating a path for water to flow through the dam. These rapid visual assessments can be performed by manual inspections of the site supplemented by small unmanned aerial vehicles (UAVs) or drone surveys. Early identification of dam hazards would assist in developing plans to mitigate the potential risk of failure or, in the event of a failure, determining cause and origin.

GEOPHYSICAL AND GEOTECHNICAL ASSESSMENTS

As part of a thorough geotechnical assessment, a geophysical survey should be completed. Geophysical tools such as Ground Penetrating Radar (GPR) and Electrical Resistivity Imaging (ERI) are widely used to detect subsurface anomalies which could be associated with seepage or piping.

Below is a GPR transect with a highlighted anomaly which would be indicative of subsidence or another geologic hazard.

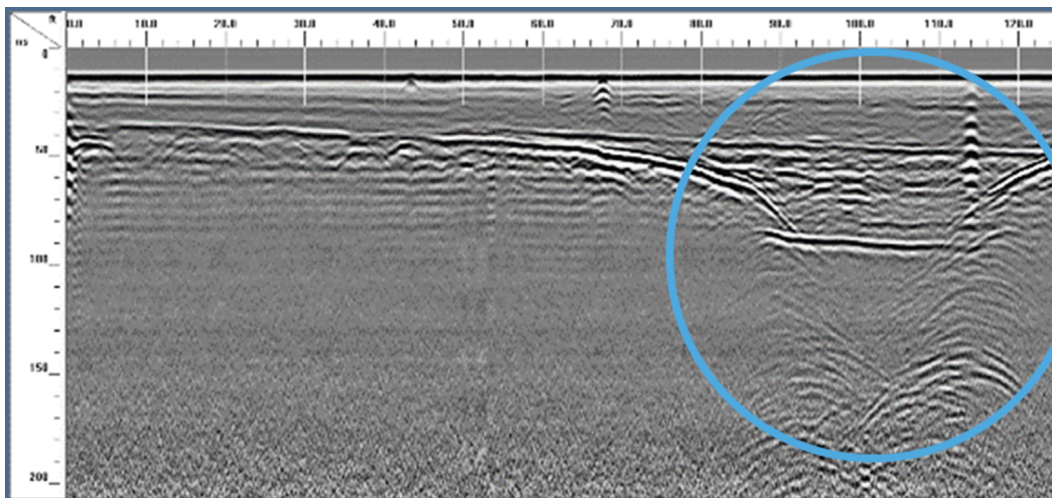


Figure 3 - GPR transect with a highlighted anomaly.

Geophysical surveys should be supplemented with soil borings and/or soil probes in order to develop an accurate soil profile in the areas of interest and to determine the cause of the anomaly identified in the geophysical survey. Soil borings such as the Standard Penetration Test (SPT) boring or soil probes such as the Cone Penetrometer Test (CPT) can identify loose soil zones within dams, which would be indicative of subsidence, slope failure, or piping through the dam.

EVALUATION

Upon completion of the site visit, geotechnical engineers and geophysicists perform a comprehensive forensic assessment by compiling and reviewing the data gathered during the site inspection. Data reviewed includes soil surveys and testing, visual images captured during the site assessment (on the ground or by a rapid UAV or drone survey), and historic documents related to the dam. The forensic evaluation is performed to assess the existing condition of the dam and classify the hazard potential,

identify hazards that may exist, determine the cause and origin of distress, and to develop plans to mitigate the potential for future dam failures.

CONCLUSION

In summary, there is an increasing risk of dam failures which result in loss of life and property throughout the United States. As metropolitan areas continue to grow there is greater need for stormwater control and a reliable source of clean drinking water, which dams can provide. However, much like roads and bridges, if dams are not properly maintained they can be susceptible to failure which can have catastrophic/costly consequences. The dams within the United States have an average age of 57 years, meaning many of the dams are approaching or have exceeded their useful service life. It is imperative that an Emergency Action Plan is developed for each dam classified as a significant and high-hazard dam, and, most importantly, it is crucial that the public be educated on any nearby hazard. An onsite visual inspection by trained professionals, occasionally supplemented with on-site geophysical and geotechnical testing, remains the most effective method to reduce the risk of dam failures.

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W. Sharkey Bowers is a Senior Engineer in J.S. Held's Forensics Practice. He provides professional engineering opinions regarding the cause, origin, and duration of damage to properties caused by soil movement. He is based out of Tampa, Florida, but is licensed in 19 states throughout the country. He has provided sworn testimony in numerous litigated cases in multiple states. The projects he has worked on include first-party insurance claims, as well as third-party builder's risk claims and construction disputes. He has also directed geotechnical investigations to evaluate the subsurface conditions of future development sites to provide site preparation, soil remediation, and foundation recommendations, and designed hundreds of retaining walls throughout the state of Florida.

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