U.S. ARMY CORPS OF ENGINEERS
LEVEE PORTFOLIO REPORT

A Summary of Risks and Benefits Associated With the USACE Levee Portfolio

PREPARED BY
U.S. ARMY CORPS OF ENGINEERS
LEVEE SAFETY PROGRAM

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US Army Corps of Engineers ®

Dear Reader:

I am pleased to present to you the first summary report of the flood risks and benefits associated with levees that are within the U.S. Army Corps of Engineers (USACE) Levee Safety Program.

In 2006, USACE began the task of developing a comprehensive inventory of the nation's levees and, within our traditional program, inspecting and conducting risk assessments. We are in the process of sharing risk assessment information with our non-federal sponsors and communities as well as using that information to guide activities within the USACE Levee Safety Program.

Based on an assessment of nearly 2,000 levee systems, this report looks at flood risk and benefits at a portfolio level. We conducted this review to better understand the relative importance of factors driving the risks in order that we can inform decisions when managing a diverse portfolio of levees. Information in this report is already helping us guide decision making in areas such as research, policy, training, analytical methodology, and governance approaches. This report is intended to bring facts to the table and provide a starting point for conversations at all levels. We hope that you will use it to initiate conversations at all levels of governance.

Along the way, we have uncovered facts about Corps levee systems that remind us of the importance of understanding benefits associated with levees: they reduce flooding risks to over 11 million Americans and $1.3 trillion dollars of the economy, including over 300 colleges and universities, over 30 sports venues, strategic national industries, and key governmental offices at all levels. The data also shows that these systems are integral with society, with about a mile of Corps levees for every McDonald's restaurant in the United States.

We will repeat update this report periodically. This first report will serve as a baseline for future analysis and allow us to measure the effectiveness of our risk management efforts. It is important to note, however, that Corps levees represent only a fraction of the levees in the nation – the remainder are managed by other federal, state, tribal, regional and local entities. As we continue to conduct a National Levee Inventory and Review on levees outside the Corps traditional authorities, we will develop a more comprehensive understanding of all of the nation's levees.

Managing risks associated with levees in the United States will require diligence and cooperation among all levels of government, the private sector and individuals. To be successful in the face of increasing flood hazard and projections of increasing population in flood prone areas, we must all begin to think and act like risk managers.

Sincerely,

Eric C. Halpin, P.E.
Deputy Dam and Levee Safety Officer
Headquarters
U.S. Army Corps of Engineers

VIEWS, OPINIONS, AND/ OR FINDINGS CONTAINED IN THIS REPORT SHOULD NOT BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION, POLICY, OR DECISION UNLESS SO DESIGNATED BY OTHER OFFICIAL DOCUMENTATION.

Cover Photo

View of the Sacramento River near Sacramento, California, March 2010 (Source: USACE).

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PREFACE

USACE STAFF AND THE NON-FEDERAL SPONSOR CONDUCTING A LEVEE INSPECTION IN ST. PETERS, MISSOURI (SOURCE: USACE).

The U.S. Army Corps of Engineers (USACE) levee portfolio includes about 2,220 levee systems totaling approximately 14,150 miles in length. Levee sponsors operate and maintain over 2,000 of these levee systems, spanning roughly 70% of the length contained in the entire levee portfolio. USACE has inventoried approximately 15,000 miles of levees outside of the USACE levee portfolio in the National Levee Database. The condition of these levees is unknown. In addition, there are an unknown number of levees in the U.S. that have yet to be identified or inventoried.

This Levee Portfolio Report shares our current understanding of the portfolio of levee systems within the USACE Levee Safety Program. Managing this portfolio of levees requires an understanding of the flood risks associated with levees in the portfolio, the risk management approaches USACE uses to understand and manage these risks, and the roles of USACE, other federal agencies, states, tribes, regional districts, and local communities in assessing, managing, and communicating levee-related flood risk.

Since 2006, USACE has been working to establish a comprehensive inventory, inspection, and risk assessment of all levees within the levee portfolio. With the inventory and initial inspections complete, the initial risk assessments on the entire portfolio are expected to be completed over the next several years. These efforts provide a more complete picture of the USACE levee portfolio than we have ever had: where levees are located (inventory); their physical condition (inspection); and the flood risk associated with each levee (assessment).

This report aims to summarize the best available information on the USACE levee portfolio, specifically to:

- Promote a broader understanding of benefits and flood risks associated with the USACE levee portfolio for all stakeholders;
- Provide a summary of risk factors associated with the USACE levee portfolio so that those with levee responsibilities, including USACE, can make informed risk management decisions on programmatic investments such as policy and technical guidance, training, and research and development; and
- Establish a baseline set of information on the USACE levee portfolio, including the collective risk across the portfolio, to enable future trends analysis.

EXECUTIVE SUMMARY

As a Nation, we know little about the condition or risk associated with levees outside those inspected and assessed as part of the USACE levee portfolio.

The U.S. Army Corps of Engineers (USACE) Levee Portfolio Report shares our current understanding of the flood risks and benefits associated with the portfolio of levee systems within the USACE Levee Safety Program. The USACE Levee Portfolio Report is organized around risk (e.g., the flood risk associated with levees) to describe the magnitude of risk, key drivers of risk, sources of uncertainty in the understanding of risk, and distinct factors of risk within the USACE levee portfolio. Assessing, managing, and communicating levee-related flood risk to people, property, and the environment is the mission of the USACE Levee Safety Program. Managing this portfolio of levees requires an understanding of the levee-related flood risk within the portfolio, the risk management approaches USACE uses to manage these risks, and the roles of USACE, other federal agencies, states, tribes, regional districts, and local communities in assessing, managing, and communicating risk.

Utilizing the best available information on the USACE levee portfolio, including information gathered from inspections and risk assessments performed within the USACE Levee Safety Program, this report provides valuable information including key findings that allow for improved decision making and management of the portfolio. USACE intends for this report to promote a broader understanding of benefits and risks associated with levees. The summary of risk factors associated with the USACE levee portfolio will help USACE and others with levee risk management responsibilities inform decisions on levee safety related investments, including policy and technical guidance, training, and research and methods development. Finally, this report establishes a baseline set of information that allows for future analysis of USACE levee portfolio trends in inventory and risks.

The USACE Levee Safety Program has conducted a comprehensive inventory, inspection, and risk assessment effort for the entire USACE levee portfolio. This provides a more comprehensive understanding of the portfolio than previously known: where the levees are (inventory); their condition (inspection); and the flood risk associated with each levee (risk assessment). The USACE levee portfolio includes about 2,220 levee systems totaling approximately 14,150 miles in length. Over 1,200 levee sponsors

operate and maintain roughly 2,000 of these levee systems, spanning roughly 70% of the length of the entire portfolio. The remaining almost 200 levee systems are operated and maintained by USACE.

USACE manages its portfolio of levees by systems, but sometimes one levee system can have multiple levee sponsors, each managing one or more levee segment. Levee systems may have multiple levee sponsors responsible for operation and maintenance of segments and other features that are integral to excluding flood water from the leveed area. Nearly 15% of the portfolio has multiple segments that make up a levee system. Performance of the levee is only as good as its "weakest link," therefore engagement with all parties responsible for segments of the levee system is critical. This represents a relatively new way of interacting with those responsible for all the elements of the levee—elements that may not have been designed or authorized as part of a system—and is a priority for the USACE Levee Safety Program.

No levee is flood-proof. Levees reduce the risk of flooding, but no levee system can eliminate all flood risk. A levee is generally designed to exclude floodwater from the leveed area over a limited range of flood events. If a larger flood occurs, floodwaters will flow over the levee.

Risk assessments within the Levee Safety Program provide a systematic, evidence-based approach for estimating and describing the likelihood and consequences of existing and future risk associated with levee systems. Risk assessments consider what can go wrong, how it can happen, the consequences if it happens, and how likely it is to happen. To support decisions in the management of the portfolio, a Levee Safety Action Classification (LSAC) is assigned as a final step in developing a risk characterization for each levee system. LSACs range from Very High risk (immediate action recommended) to Very Low risk (maintain routine activities). LSAC assignments are used by USACE to prioritize resources across the portfolio and to organize widespread levee-related risk information into reasonably commensurate groupings for action.

USACE currently has completed levee risk characterizations and assigned an LSAC to nearly 73% of the portfolio. For remaining 27% of the portfolio, USACE expects to complete levee risk characterizations and LSAC assignments in the next few years. Thus far, 13% of the portfolio consist of levee systems that are Very High, High, or Moderate risk that require interim actions to reduce risk while more long-term and comprehensive risk reduction and risk management solutions are being pursued. These Very High, High, and Moderate risk levees have over 8 million people that live and/or work behind them. USACE has begun sharing information from risk assessments with sponsors and other community risk managers. USACE will continue to develop approaches and tools to share results of risk assessments with all kinds of risk managers, with a particular focus on training its staff to translate complicated risk information into understandable and actionable information.

USACE considers the full range of flood hazards for a levee, from when water first starts loading the levee to when water starts to flow over the top of a levee. An important flood loading that often impacts risk and indicates when flooding behind the levee starts to occur is the flood loading where water starts to overtop a levee. The likelihood of when water starts flowing over the top of a levee varies considerably across the USACE levee portfolio. Within the USACE portfolio, the annual chance of exceedance (ACE) of the flood loading that reaches the top of the levee ranges from 50% to less than 0.02%—in colloquial terms, from the 1-in-2 chance to less than the 1-in-5,000 chance of occurring in

any given year. The majority of the levee systems within the portfolio begin to overtop at flood levels with an ACE of 0.5% (1-in-200 chance) or less. USACE is continuing to invest in collection and assessment of flood hazards through efforts such as the Corps Water Management System and is sharing information with other federal agencies to improve the understanding of hydrologic events.

How the levee performs when faced with flood hazards is a factor in levee-related risk. Levees in the USACE levee portfolio vary widely in age, design and construction practices, and flood regimes (e.g., coastal, river, flashy or long duration). The average age of levees in the USACE portfolio is roughly 50 years. Levees constructed by communities and accepted into the portfolio and levees designed and constructed by USACE in the 1920s–1960s may be designed and constructed to standards less stringent than current best practices.

Risk drivers in levee performance can occur from many different mechanisms that can cause the levee to breach. The most common risk driver in levee performance is when the levee is overtopped and breaches. This risk driver impacts over 40% of the USACE levee portfolio. Seepage through or beneath the levee is the second most common risk driver, impacting 17% of the portfolio.

The most common risk driver in levee performance is when the levee is overtopped and breaches.

Understanding the uncertainty in how a levee will perform (e.g., well or poor) during flood events is important in managing risk. Monitoring performance, regular inspections, risk assessments, and continuous operation and maintenance are essential for the effective management of risk associated with levees.

Approximately 11 million people live or work behind levees and $1.3 trillion of property value exists in the leveed area (e.g., the area that represents the portion of the floodplain where floodwaters are excluded by a levee) of the USACE levee portfolio. Population and property value behind levees is not equally distributed behind all the levees. Over nine million people (86% population behind the USACE levee portfolio) are concentrated behind roughly 150 levees (7% of the USACE portfolio). These 150 levees are in urban areas with populations in excess of 10,000 behind them. While there are very large urban areas behind some levees, most of the levees (1,465 levee systems) in the USACE portfolio have relatively low populations (fewer than 1,000 people) working and living behind them.

In addition to property, population, and economic activity, USACE portfolio levees reduce the risk of flooding to some of our most vital infrastructure. From roads, schools, police and fire stations to historical sites and national treasures, there are countless structures that provide invaluable services to our communities and nation that are located behind levees. These structures help sustain our economy and provide venues for recreation, among other functions. For example, there are almost 4,500 schools located behind levees that collectively enroll over two million students. In addition, over 25% of the nation's oil refining capacity is located behind levees. Damage to, or failure of, these levees could significantly impact local, regional, and national resources.

Flood awareness and emergency preparedness play a key role in risk management for individuals and communities behind levees. Involved, informed individuals and communities behind levees will be better prepared to take meaningful actions to reduce risks to loss of life (e.g., practicing emergency action plans, warnings, and evacuations) or property (e.g., purchasing flood insurance, flood proofing or elevating structures).

USACE will continue to support and apply the results of research and knowledge in social science to better understand how warnings are issued and how they spread through communities that experience severe flooding. This research will advance knowledge about the public warning process, help improve how future public warnings and evacuations for any hazard are implemented, enable levee owners to better assess the existing risk posed by their assets, and investigate nonstructural risk reduction measures alongside levee upgrades.

Risk information for the USACE portfolio allows decision makers at the federal, state, and local levels to understand the impacts of risk and magnitude of investment needs to address risk. An understanding of investment needs to address levee-related risks for the USACE portfolio has not been previously attempted as risk information has not been readily available. However, now that risk assessments are nearing completion, a combined cost estimate to address risks within the portfolio was determined. A portfolio cost estimate does not try to indicate who pays (levee sponsor or federal government) nor does it address other factors that must be considered when making investments, such as environmental and community values, but rather informs investment priorities and decisions through the understanding of primary factors that influence costs to address risk and risk management measures that efficiently and effectively reduce risk. USACE will use this portfolio cost information to inform research needs and guidance updates with an eye toward not only reducing risk, but lowering assessment, repair, and mitigation costs.

Flood awareness and emergency preparedness play a key role in risk management for individuals and communities behind levees.

The cost to address risk in the USACE levee portfolio ranges from $6.5 billion to $38 billion, with an expected cost of about $21 billion. The expected cost of $21 billion is broken down into approximately $13 billion for levee infrastructure improvements to mitigate risk drivers in levee performance before the levee overtops, approximately $8 billion in armoring of levees to mitigate risk drivers in levee performance when the levee overtops, and about $300 million to improve evacuation effectiveness within the leveed area. The estimated cost to improve evacuation effectiveness includes measures such as improved evacuation plans, community outreach, and warning systems. USACE will work with levee sponsors to provide information that can improve evacuation effectiveness, particularly since the cost to improve evacuation effectiveness is significantly less than implementation of levee infrastructure improvements and evacuation effectiveness directly reduces risk to loss of life.

As a nation, we know little about the condition or risks associated with levees outside those inspected and assessed as part of the USACE levee portfolio. As such we do not have a true national look at the risks and benefits levees provide to the nation or whether people know that they live or work behind a levee. USACE continues to promote the awareness of location of levees in the nation and the risks associated with levees. USACE is coordinating with states, tribes, local communities and private levee owner-operators to conduct a one-time inspection and risk assessment for all levees in the nation. USACE will include information on the location, condition, risks and benefits of these levees in the National Levee Database to increase accessibility of levee information to those living and working behind levees, and to improve understanding of the nation's benefits and risks related to levees.

USACE LEVEE SAFETY PROGRAM OBJECTIVES

Maintain an effective program governance framework through a combination of maintaining competent staff, updated and relevant guidance, and credible processes and tools.

Increase the understanding of benefits and risks of levee systems by assessing and communicating them throughout Levee Safety Program activities.

Contribute to effectively and efficiently managing flood risk in communities with levees by identifying opportunities to manage flood risk and taking actions in a risk-informed manner. Risk management will be applied on a continuing basis in support of making wise federal investments and encouraging actions to manage flood risk outside of federal investments.

DID YOU KNOW?

The USACE Civil Works program is divided into eight (8) Major Subordinate Commands, also known as Divisions.

The Divisions are further divided into 38 Districts.

Each Division and District operates under the command of a U.S. Army officer.

SECTION 1: INTRODUCTION

THE USACE LEVEE SAFETY PROGRAM

The United States Army Corps of Engineers (USACE) established the Levee Safety Program in 2006 to work alongside levee sponsors and communities with levees within the USACE levee portfolio to better understand, prioritize, and manage the flood risks associated with levees.

The Levee Safety Program builds on USACE's long history of working with communities to evaluate and manage levees and other flood risk management infrastructure.

The Levee Safety Program provides expertise on, and support for, assessing, managing, and communicating levee-related flood risk to people, property, and the environment behind levees.

The USACE levee portfolio includes about 2,220 levee systems totaling approximately 14,150 miles in length. Levee sponsors operate and maintain over 2,000 levee systems that make up roughly 70% of the length contained in the entire portfolio. The remaining approximately 200 systems are operated and maintained by USACE. Appendix C contains a detailed discussion on the development of the USACE levee portfolio data used in this report.

Managing this portfolio of levees requires an understanding of the flood risks associated with levees, the risk management approaches USACE uses to understand and manage these risks, and the shared responsibility of USACE, levee sponsors, communities, and other stakeholders to manage these risks.

Prior to the devastating floods of the early 20th century, local communities and citizens were almost wholly responsible for levees and other "flood control" projects. Beginning with the Flood Control Act of 1917 and followed by several additional Flood Control Acts, Rivers and Harbors Acts, and Water Resources Development Acts, USACE has been directed by Congress to design, construct, and sometimes maintain levees to reduce the impact of flooding in communities.

In the 100 years since the Flood Control Act of 1917, the role of USACE, and the federal government more broadly, has changed. The responsibility for flood risk management, which swung from communities to the federal government in the early 20th century, now has stabilized as a partnership and shared responsibility. Local communities, states, and tribes share a responsibility with the

federal government to recognize and mitigate flood risk through a combination of traditional infrastructure (e.g., levee embankments and floodwalls) and nonstructural approaches, including local land use planning and ordinances, flood warning systems, and evacuation planning and preparedness. In addition, communities, states, and tribes share the costs of planning, designing, and building congressionally-authorized flood risk management projects and usually bear the full responsibility for the operation and maintenance of these projects, including levees.

The National Levee Safety Act of 2007 (Water Resources Development Act [WRDA] 2007, Title IX) was a turning point for the USACE Levee Safety Program. The National Levee Safety Act directed USACE to inventory, inspect, and assess risks associated with the USACE levee portfolio. In addition, Congress recognized that many levees exist outside of the USACE levee portfolio and directed USACE to establish a database with an inventory of all the nation's levees. This database, the National Levee Database (NLD) (http://nld.usace.army.mil), is a publicly-available inventory of the nation's levees. USACE is working with interested federal, state, tribal, and local partners to collect available levee information for inclusion in the NLD. The NLD is an important resource for sharing levee information with states, tribes, regional levee districts, and other federal agencies. As a publicly-available source of levee information, the NLD promotes community and public awareness of the benefits and flood risks associated with levees.

As part of its Levee Safety Program, USACE has developed a scalable risk assessment methodology for levees to facilitate risk-informed decision making, which is central to the assessment, management, and communication of levee-related flood risks. For the USACE levee portfolio, USACE has conducted a risk assessment for a majority of levees and anticipates completing risk assessments for all levees over the next several years.

The USACE Levee Safety Program is primarily executed through USACE's 38 Civil Works Districts and 8 Divisions (Major Subordinate Commands, or MSCs). Levee Safety Officers (LSOs) are the leads for levee safety issues, recommendations, and decisions at each level of the USACE Levee Safety Program organization: Districts, Divisions, and Headquarters. LSOs are ultimately responsible for the decisions and actions of the Levee Safety Program within their area. LSOs are registered professional engineers, demonstrate leadership abilities, and are competent in

DID YOU KNOW?

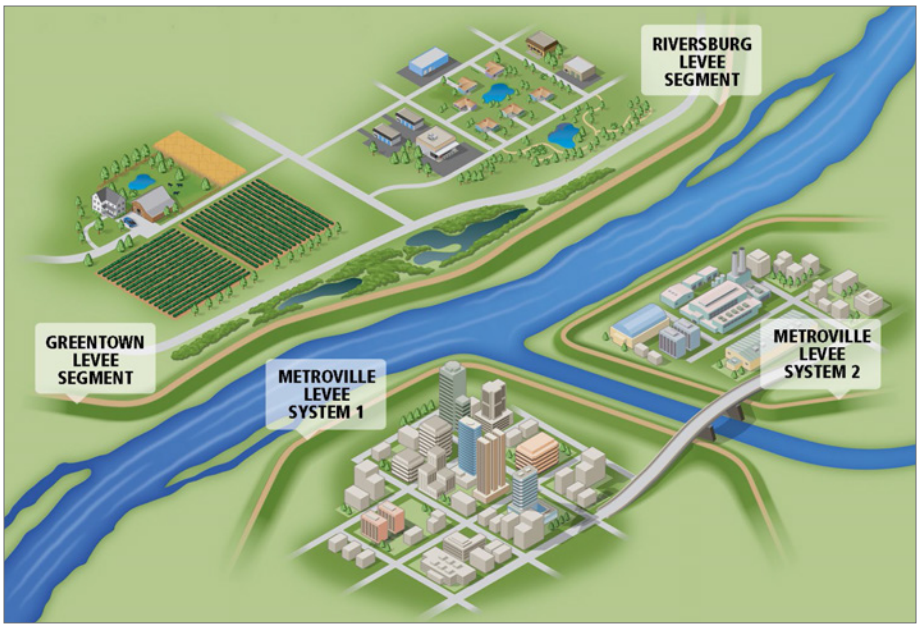
The National Levee Safety Act of 2007 (amended by the Water Resources Reform & Development Act (WRRDA) 2014 and WRDA 2016) authorizes USACE to conduct a one-time inspection and risk assessment of all the nation's levees. USACE is working with federal agencies, states, tribes, regional districts, and levee owner and operator entities who are interested in applying USACE inspection and screening-level risk assessment methodologies to their levees to create a comprehensive understanding of flood risks posed by the nation's levees. This effort is being piloted in 2017, with collected information being added to the NLD. Currently, more than 6,000 levee systems outside the USACE levee portfolio totaling 15,000 miles have been inventoried in the NLD, but have not yet been inspected or assessed.

levee safety. Districts, Divisions, and Headquarters each have a Levee Safety Program Manager to coordinate and implement the Levee Safety Program activities within their area. Levee Safety Program Managers are registered professional engineers or registered professional geologists with management and communication abilities and competency in levee safety.

WHAT IS A LEVEE: KEY TERMS AND PHRASES FOR UNDERSTANDING THE USACE LEVEE PORTFOLIO

A levee is a man-made barrier along a waterway or canal (that does not cross it) with the principle function of excluding flood waters from a limited range of flood events from a portion of the floodplain referred to as the **leveed area**.

A levee is also referred to as a **levee system**, which includes one or more levee segments and other features that collectively are integral to excluding flood waters from the leveed area. Levee features may include embankment sections, floodwall sections, closure structures, pumping stations, and interior drainage works. Highway and railroad embankments or other features that are integral to the performance of excluding flood water from the leveed area also are considered to be part of the levee system. Levees may be built along canals, waterways, coastlines, and rivers.



ONE LEVEE PROJECT MAY INCLUDE MULTIPLE LEVEE SEGMENTS AND SYSTEMS. THIS ILLUSTRATION SHOWS 4 SEGMENTS AND 3 SYSTEMS.

A levee breach occurs when part of a levee gives way, creating an opening through which floodwaters pass into the leveed area.

Levee safety is the art, science, and practice of managing flood risks posed by levee systems. Levee safety is a component of overall flood risk management that includes activities such as increasing individual and community resiliency, emergency preparedness/action planning, land use management, risk-informed decision making about risk reduction measures, and post-disaster recovery and assistance.

Most levees within the USACE levee portfolio have a **levee sponsor** who is responsible for all or part of the levee's operation, maintenance, repair, replacement, and rehabilitation. Some of these sponsors also participated in the design of the original project and sometimes helped pay for it through a cost-sharing agreement. Across the nation, levee sponsors are integral partners to the USACE Levee Safety Program in assessing and making levee safety decisions. Levee sponsor operation and maintenance responsibilities are included in the Code of Federal Regulations (33 CFR 208.10) and project-specific agreements with USACE.

LEVEES DO NOT ELIMINATE FLOODING IN LEVEED AREAS

No levee is flood-proof. Levees reduce the risk of flooding, but no levee system can eliminate all flood risk. A levee is generally designed to exclude floodwater from the leveed area over a limited range

17TH STREET CANAL LEVEE BREACH IN NEW ORLEANS, LA, SEPTEMBER 3, 2005 (SOURCE: BRETT DUKE, *THE TIMES-PICAYUNE* ARCHIVE).

of flood events. If a larger flood occurs, floodwaters will flow over the levee. Overtopping occurs when floodwaters exceed the height of a levee and flow over its crown.

Floodwaters can also breach or damage levees. A breach may occur gradually or suddenly. The most dangerous breaches happen quickly during periods of high water. The resulting torrent of floodwaters can quickly inundate a large area behind the breached levee with little or no warning.

In some cases, when a levee is overtopped, it may erode the levee, worsening the flooding and potentially causing a breach in the levee. To prevent overtopping, communities sometimes place sandbags on top of levees to increase their height. These and other "flood fighting" efforts can help prevent a disaster; however, they do not always succeed. Therefore, they should be viewed as last-ditch steps rather than a first line of defense. In addition, flood fighting in one area may result in induced flooding in another area.

Levees can be damaged in several other ways. For instance, strong river currents and waves can erode the surface on the waterside of the levee. Debris and ice carried by floodwaters—and even large objects such as boats or barges—can collide with and gouge the levee. Trees growing on a levee can blow over, leaving a hole where the root wad and soil used to be. Burrowing animals can create holes that enable water to pass through a levee. If severe enough, any of these situations can lead to a weakness that could cause a levee breach.

DID YOU KNOW?

One levee system may include multiple levee segments operated and maintained by different entities.

However, because levees operate as a system, the USACE Levee Safety Program assesses, manages, and communicates with levee sponsors and the public based on levee systems rather than segments.

Managing risk associated with one levee system with multiple entities or communities that may have differing responsibilities, resources, and perspectives is a challenge USACE and communities face together.

DID YOU KNOW?

In 2016, four rainfall/flood events caused estimated damages of $16 billion, including $10 billion from a single event.

In August 2016, a large area of southern Louisiana received 20 to 30 inches of rainfall over several days. More than 30,000 people were rescued from the floodwaters that damaged or destroyed over 50,000 homes, 100,000 vehicles, and 20,000 businesses. This was the most damaging U.S. flood event since Superstorm Sandy impacted the Northeast in 2012. (Source: NOAA National Centers for Environmental Information)

OVERTOPPING OF THE L-550 LEVEE IN ATCHISON COUNTY, MISSOURI, DURING A MISSOURI RIVER FLOOD, JUNE 2011 (SOURCE: USACE).

In seismically active areas, earthquakes and ground shaking can cause a loss of soil strength, weakening a levee and possibly resulting in failure. Seismic activity also can cause levees to slide, slump, settle, or spread, all of which can lead to failure. Failure of the levee could lead to a breach if the failure occurs during a flood event or if the failure is not repaired prior to the next flood event.

Flooding in the leveed area can also be caused by the incorrect operation or the lack of operation of a levee feature such as a gate for a pipe passing through the levee, a closure structure for a railroad or road crossing, or a pump station necessary to remove water behind the levee (e.g., interior drainage). Proper operation of all levee features is critical to ensure the levee's expected performance is met.

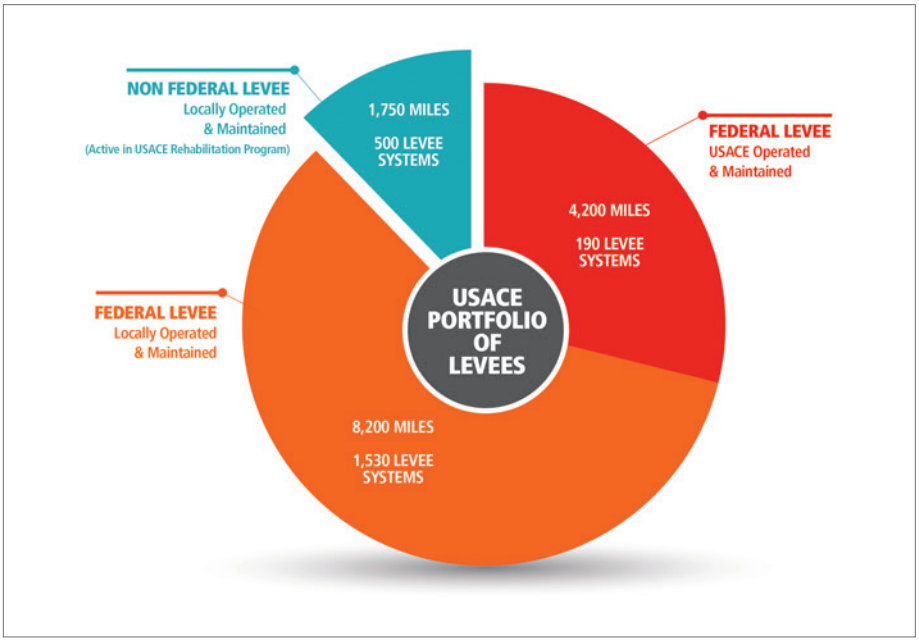
LEVEES INCLUDED IN THE USACE LEVEE PORTFOLIO

The levees within the portfolio can be divided, broadly, into three categories based on whether the levee system is a federal project (congressionally authorized), and who retains primary responsibility for operation and maintenance of the levee.

Federal Levee, Levee Sponsor Operated and Maintained: Almost 70% of the levees in the portfolio are federal projects that are operated and maintained by a levee sponsor. Approximately 1,530 levee systems totaling 8,200 miles in length are locally-operated and maintained federal flood risk management projects.

These congressionally-authorized federal flood risk management projects generally are planned, designed, and constructed by USACE and a cost-sharing levee sponsor, and operated and maintained by that levee sponsor after construction has been completed. Examples of levee sponsors for congressionally-authorized levees include levee districts, water management districts, city or county governments, state governments, tribal governments, and other special entities that have the authority to enter into agreements with USACE. This category of levees also includes levees that were not designed or constructed by USACE, but were incorporated into a federal project by specific congressional action and continue to be operated and maintained by a non-federal entity.

Because these are federal projects, with federal investment in planning and construction, USACE has a responsibility to ensure that the federal project provides the intended benefits to communities and the nation. This federal responsibility is implemented through the USACE Levee Safety Program activities and by the evaluation of any proposed alterations to the project that could impact the function and safety of the federal project (e.g., "Section 408" permissions, shorthand for 33



BREAKDOWN OF USACE PORTFOLIO OF LEVEES (SOURCE: NATIONAL LEVEE DATABASE).

USC 408, the section of U.S. Code that establishes the authority).

Federal Levee, USACE Operated and Maintained: Levees that USACE has direct responsibility to operate and maintain, as well as to rehabilitate and modify using existing authorities, account for approximately 190 levee systems totaling 4,200 miles in length. This category includes USACE-constructed and operated systems, and systems that Congress has directed USACE to operate and maintain. The Mississippi River and Tributaries (MR&T) project (authorized by the 1928 Flood Control Act) levee systems (67 levee systems with a combined length of 3,700 miles) are included in this category because USACE has responsibility for major maintenance and repair, and construction of the federal project is still ongoing. All levees in this category are considered federal projects, although local communities or levee sponsors may retain some operation and maintenance responsibilities. Regardless of USACE operation and maintenance responsibilities associated with the levee system, all local communities retain their authorities and responsibilities for local land use regulation, floodplain management, and emergency planning and response.

Non-Federal Levee, Locally Operated and Maintained: Levee systems constructed and operated and maintained by a levee district, water management district, city or county government, state government, tribal government, or other special entities are considered part of the USACE levee portfolio when these levee systems are eligible for the USACE Rehabilitation Program (authorized under Public Law 84-99, as amended (33 USC 701n)). USACE continues to inspect eligible non-federal levees on a regular basis (approximately every two years) to ensure eligibility requirements are maintained. Approximately 500 non-federal levee systems totaling 1,750 miles in length nationwide are currently eligible in the Rehabilitation Program.

DID YOU KNOW?

The levees within the portfolio can be divided, broadly, into three categories based on whether the levee system is a federal project (congressionally authorized), and who retains primary responsibility for operation and maintenance of the levee.

NATIONAL LEVEE INVENTORY AND REVIEW EFFORTS

The National Levee Database has information on almost 30,000 miles of levees across the U.S., including approximately 15,000 miles of levees that are not part of the USACE portfolio. Communities in all 50 states, the District of Columbia, and the territories of Guam and Puerto Rico have levee systems they depend on to manage the risk of flooding. Appendix E of this report has more information

ABOUT THE REHABILITATION PROGRAM

The USACE Rehabilitation Program is a voluntary program that provides for the rehabilitation (e.g., repair) of damage to eligible federal and non-federal flood risk management projects damaged by floods and coastal storms. Over 6,600 miles of the USACE levee portfolio is eligible to receive federally-funded post-flood repairs by USACE (if funded by an emergency authorization of Congress), underlining the importance of aligning the guidance for the USACE Levee Safety Program and Rehabilitation Program on assessing, managing, and communicating levee-related risks.

Participation in the Rehabilitation Program can happen in two ways. Congressionally-authorized federal levees are eligible after their construction, once the levee sponsor takes responsibility for operation and maintenance. Non-federal levees that are owned, operated, and maintained by public entities (not private levees) may participate in the Rehabilitation Program if they meet the program eligibility requirements.

Once in the Rehabilitation Program, each levee is periodically evaluated against eligibility requirements. Levees may become ineligible for the Rehabilitation Program due to a variety of reasons, including dissolution of the levee sponsor, withdrawal of sponsorship by the levee sponsor, or inadequate operation and maintenance records.

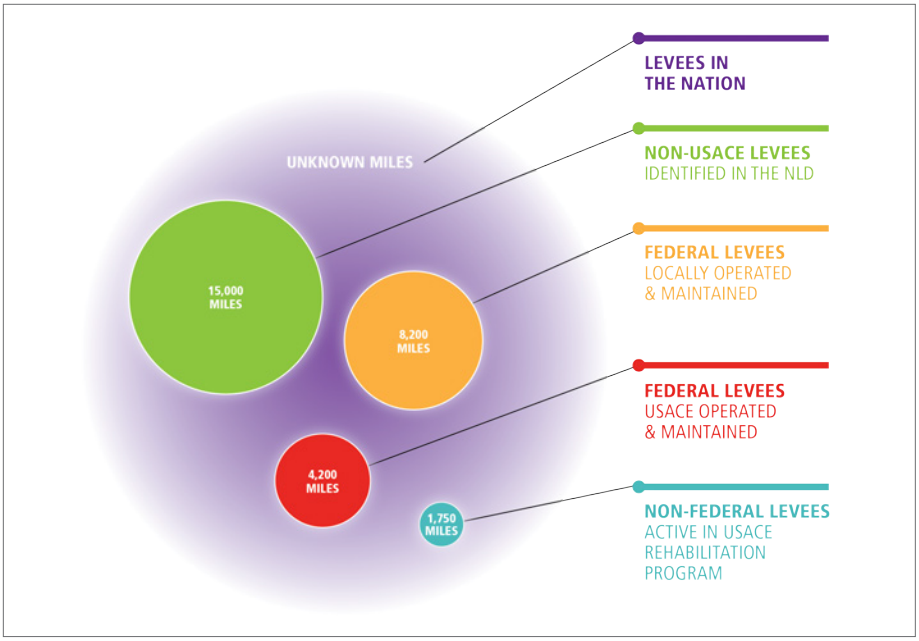
Of the 6,600 miles, 4,850 miles are federal levees that are operated and maintained by a levee sponsor and 1,750 miles are non-federal levees. Federal levees operated and maintained by USACE do not qualify for the Rehabilitation Program.

DID YOU KNOW?

The National Levee Database (NLD), maintained by USACE, includes information about levees within the USACE levee portfolio as well as levee information beyond the USACE portfolio provided by other federal, state, tribal, and local partners.

USACE is coordinating with federal, state, tribal, and local partners to collect available levee information and complete the inventory of the nation's levees. Levee information is included in the NLD to assist in sharing information with partners and to promote community and public awareness of benefits and flood risk associated with levees.

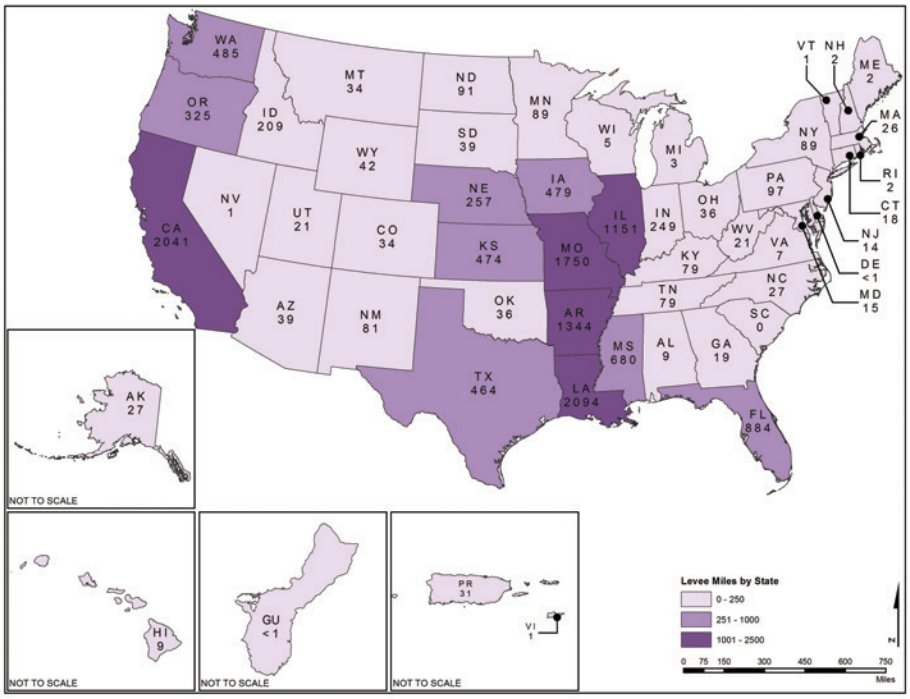
For more information: http://nld.usace.army.mil/



USACE PORTFOLIO LEVEES REPRESENT AN UNKNOWN PORTION OF THE TOTAL LEVEES IN THE UNITED STATES. THERE ARE APPROXIMATELY AN EQUAL NUMBER OF MILES OF LEVEES IN THE NATIONAL LEVEE DATABASE THAT ARE INSIDE THE USACE LEVEE PORTFOLIO AS OUTSIDE.

about levees in each state and territory.

An unknown number of levees are not part of the USACE levee portfolio, including levees built, operated, and maintained by states, communities, or private land owners that are not participating in the USACE Rehabilitation Program and levees built, operated, and maintained by other federal agencies (e.g., Bureau of Reclamation, National Park



MILES OF LEVEES IN THE USACE PORTFOLIO BY STATE (SOURCE: NATIONAL LEVEE DATABASE).

Service). Some states and federal agencies, such as the National Park Service, maintain their own levee safety programs for levees under their responsibility.

The National Levee Safety Act of 2007 as amended[1], authorizes USACE to conduct a one-time inspection and risk assessment of those levees outside of the USACE levee portfolio. USACE is working with interested levee owners/operators to collect levee information and assess the condition and flood risks associated with each levee. This information can be used by states and levee owners/operators to make informed decisions on managing flood risks associated with levees and will improve the understanding of flood risks posed by the Nation's levees. This effort is ongoing with collected information being added to the NLD. Currently, the 15,000 miles of levees outside of the USACE levee portfolio have not yet been inspected or assessed.

A BRIEF HISTORY OF LEVEE DESIGN AND CONSTRUCTION STANDARDS

Early Native Americans constructed raised earthen structures along the Ohio and Mississippi Rivers as safe havens from flooding. From that point until the 1930s, techniques became more sophisticated, but generally focused on elevating above flood waters. From the early days of the country until the 1930s, levees were constructed by farmers and local and regional entities in a sporadic and unsophisticated manner and without the benefit of modern engineering and science practices.

The Flood Control Act of 1917 established federal responsibility for flood risk management, including, specifically, flood risk management ("flood control" in the parlance of the day) plans for the lower Mississippi and Sacramento Rivers.

The devastation and significant loss of life caused by the great floods on the Mississippi and Ohio Rivers during the 1920s and 1930s spurred Congressional response and resulted in the Flood Control Acts of 1928 and 1936. These Acts established federal interest in the design and construction of flood structures such as levees and dams that were typically constructed by USACE at full federal expense. These acts prompted the construction of thousands of miles of levees, many built to withstand the "standard project flood," the largest reasonable flood that could be expected (usually at 500-1,000-year frequency flood).

As the science and engineering understanding of soil mechanics, hydraulics, and hydrology began to rapidly evolve in the late 1930s and early 1940s, USACE developed levee design and construction standards, almost always based on local or regional experiences. In 1978, USACE published its first levee design and construction

[1]*As amended by WRRDA 2014 and WRDA 2016.*

A LEVEE ON THE MISSISSIPPI RIVER IN LOUISIANA DURING THE GREAT FLOOD OF 1927 (SOURCE: HULTON ARCHIVES/GETTY IMAGES).

standards encompassed in Design and Construction of Levees (Engineer Manual (EM) 1110-2-1913), primarily based on the established levee standards for the Mississippi River and Tributaries project. This EM was updated in 2000 to include updates to the typical levee cross section, relief well design, emergency flood protection, the use of soil cement for levee erosion protection, and to reflect engineering and design standards for levees beyond the Mississippi River Valley. This EM is currently under revision and expected to be released in 2018. Although many other entities use USACE's standard, there is no national standard or guidance for levee design, construction, or operation and maintenance.

Beginning in the 1960s, other federal program changes impacted federal and local decision making related to levees.

- Congress enacted the National Flood Insurance Program (NFIP) in 1968. One of the purposes of the NFIP was to address the inability to secure private insurance to address economic damages associated with flooding. The NFIP is a federal program administered by the Federal Emergency Management Agency (FEMA) and enables property owners in participating communities to purchase flood insurance as protection against flood losses, while requiring state and local governments to enforce floodplain management ordinances that reduce future flood damages. Communities voluntarily join the NFIP to receive benefits, including subsidized insurance for people and businesses in that community. Currently, over 20,300 communities voluntarily participate in the NFIP. Congress has mandated federally regulated or insured lenders to require flood insurance on mortgaged properties that are located in high hazard flood zones (also referred to as a Special Flood Hazard Area (SFHA). A SFHA is the land area that is expected by be impacted by the 1-percent-annual-chance flood. The U.S. Government found that the 1-percent-annual-chance flood struck a fair balance between reducing the flood risk to the public and overly stringent regulation. Residents who live in SFHAs are required to purchase flood insurance if they have a mortgage from a federally regulated lender and must carry the insurance for the life of the mortgage. Residents with a mortgage on a building outside of a SFHA can also purchase flood insurance. Generally, areas behind an accredited levee system are not defined as a SFHA. Although, it was not the intent, the 1-percent-annual-chance flood became a target for many communities' levees as it eliminated the mandatory requirement for insurance for homeowners behind levees. USACE is working closely with FEMA to ensure that all communities that participate in the NFIP have risk information for levees collected by USACE, so that they may use that

information to not only inform future NFIP decisions, but effectively make investments to manage risk.

- The 1986 Water Resources and Development Act required additional financial contribution from locals to cost share projects constructed by USACE including cost share, provision of easements, rights of way, and real estate. Sponsors were also responsible for providing all operations, maintenance, repair, rehabilitation, and replacement of flood control works. These additional financial burdens on local communities made affordability of new levees and repairs of existing levees a larger concern, resulting in communities advocating for levees constructed to reduce the risk of flooding posed by the 1-percent-annual-chance flood and satisfy the requirements for an accredited levee system defined in 44 Code of Federal Regulations (CFR) 65.10. The requirements for an accredited levee system in 44 CFR 65.10 became a de facto, unintentional adoption of an actuarial standard as a safety standard.

From the 1960s to 2005, there was substantial flooding associated with riverine flooding and coastal storms. Although this damage spurred interest in floodplain management, catastrophe was narrowly avoided as most major levee systems protecting heavily urbanized areas held and there was little loss of life.

Hurricanes Katrina and Rita (2005) changed everything. Economic damages exceeded $200 billion and resulted in the loss of 1,800 lives, thrusting the role of levees prominently back in the national spotlight. Congress responded with $15 billion investment in repairing the levee system around New Orleans and passed the National Levee Safety Act (Water Resources and Development Act of 2007, Title IX), which calls for the development of recommendations for a National Levee Safety Program. In 2014 (WRRDA 2014), Congress authorized a National Levee Safety Program, but it has not been implemented due to budgetary constraints.

USACE conducted a complete technical, policy, and governance review of the levees in and around New Orleans. The performance of the incomplete Hurricane and Storm Damage Risk Reduction System was studied by the Interagency Performance Evaluation Taskforce (IPET)—more than 150 government, academic, and private-sector scientists and engineers. The IPET released a report that detailed findings and lessons learned, which included significant findings regarding the design of I-wall type floodwalls and incorporating a systems approach to planning, design, construction, and assessment and evaluation of levee systems. These lessons learned were fundamental in shaping the development of the USACE Levee Safety Program and have since been incorporated into USACE procedures and practices in the assessment, management, and communication of risk associated with levees.

Although levees are abundant and integral to economic development in many communities in the nation, many government officials and the general public have only a limited understanding of levees and the risks associated with them.

DID YOU KNOW?

There are no national engineering standards for designing levee systems.

When engaged in levee planning and design, USACE designs levees according to specific agency standards (e.g., Engineer Manual 1110-2-1913: Design and Construction of Levees).

Outside of USACE, an international consortium developed the "International Levee Handbook" to capture best practices across the entire lifecycle of levee systems. Best practices include risk-based design of levees and associated flood risk management infrastructure, integrated with nonstructural risk management approaches.

SECTION 2: USACE LEVEE PORTFOLIO CHARACTERISTICS

THERE IS NO TYPICAL LEVEE

On the surface, nearly all the levees within the portfolio are what you would expect: trapezoidal earthen embankments represent 97% of the total length of the portfolio. The remaining 3% are floodwalls.

Most levees in the portfolio are located along the nation's rivers and other inland waterways. Levees in coastal areas make up roughly 5% of the levees within the portfolio and are primarily found along the Gulf Coast. Design and maintenance of levees in coastal areas must consider shifting sea levels, wave action, and the potential for high-velocity/high-impact storm surges. Levees in coastal areas are often part of a coastal storm damage/flood risk reduction system, complementing barrier islands, dunes, jetties, and other non-levee structures and nonstructural features.

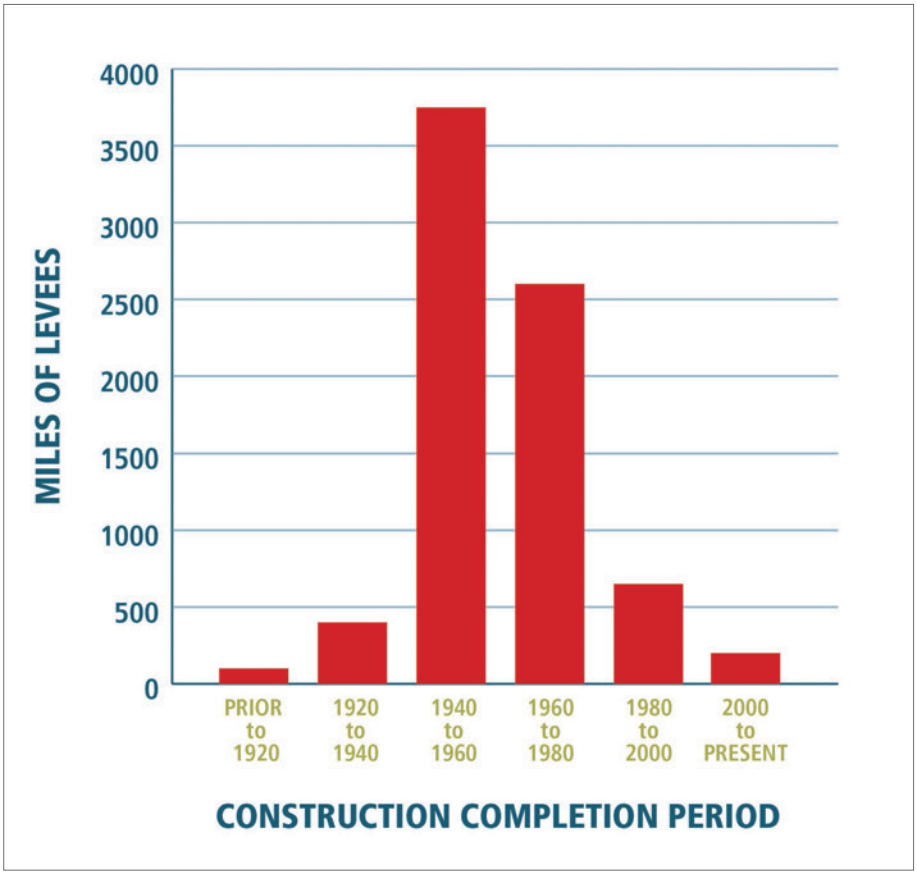
The average age of levees in the USACE portfolio is roughly 50 years. Historically, engineering practices for levee design and construction have widely varied across the nation, and original construction often predated modern engineering practices.

FLOODWALL DURING THE MISSISSIPPI RIVER FLOOD OF 2011 IN THE MEMPHIS DISTRICT (SOURCE: USACE).

Further, many levees have a long and complex construction history that spans decades.

There is no "one size fits all" approach for communities to use levees as part of their flood risk management strategy. Approximately 1,750 miles of the portfolio were not designed or constructed by USACE and approximately 10,000 miles of levees are operated and maintained by levee sponsors who are primarily responsible for the structure. Levees in the portfolio vary widely in age, design specifications, and materials. Further, the levees in the portfolio are located in different flood regimes (e.g., coastal, river, lake, flashy or long duration), and therefore operation and maintenance strategies must be tailored.

Each levee reflects the standards of the day—engineering standards and local conditions during its design and construction. Levees across the country often were constructed with readily available materials. Materials used for levee construction range from fine, clean sands (prone to seepage and erosion) to high-plasticity clays (impervious to seepage but prone to slope instability). The standards



DISTRIBUTION OF THE CONSTRUCTION OF LEVEES IN THE USACE PORTFOLIO. NOTE: CONSTRUCTION PERIODS SHOWN REPRESENT THE ORIGINAL LEVEE CONSTRUCTION DATE OR CONSTRUCTION DATE OF THE LAST SIGNIFICANT LEVEE MODIFICATION OR ALTERATION. MANY LEVEES HAVE A LONG AND COMPLEX CONSTRUCTION HISTORY THAT OFTEN SPANS SEVERAL DECADES.

of the day are embedded in the infrastructure and stay with it until the structure itself is physically modified. Levees constructed by communities and levees designed and constructed by USACE in the 1920s–1960s may be designed and constructed to standards less stringent than current best practices. Monitoring performance, regular inspections, risk assessments, and continuous operation and maintenance of the levee are essential to understanding the likelihood that the levee system will perform as expected.

DIVERSITY OF LEVEE OPERATION AND MAINTENANCE RESPONSIBILITIES ACROSS THE PORTFOLIO

More than 70% of the total portfolio length are federal or non-federal levees (eligible in the Rehabilitation Program) operated and maintained by levee sponsors. This equates to over 1,200 levee sponsors that operate and maintain approximately 10,000 levee miles in the USACE portfolio.

DID YOU KNOW?

Floodwalls are generally incorporated in levee systems when there is not sufficient space for a levee (e.g., in developed urban areas).

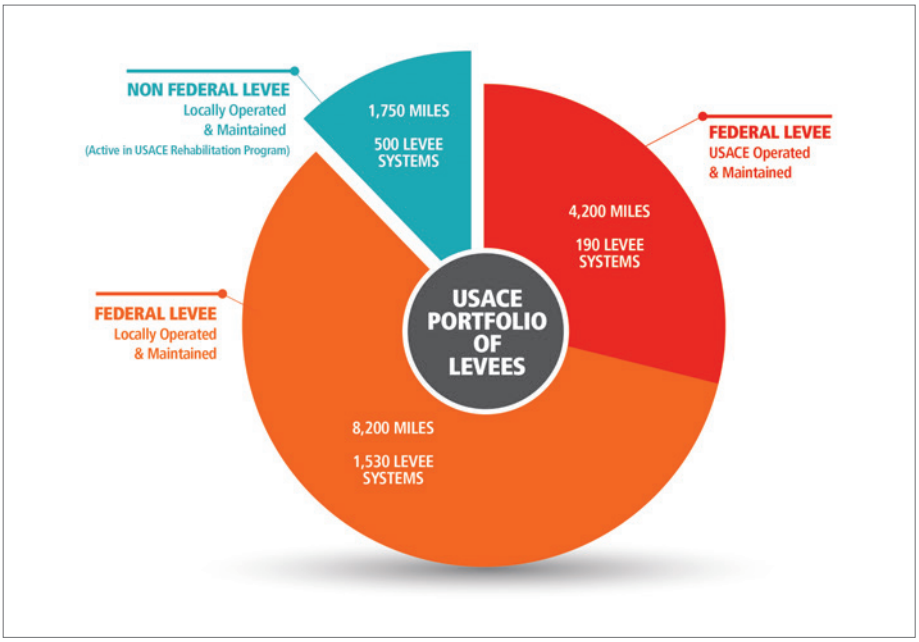
Following Hurricane Katrina and the failure of cantilever type floodwalls (also referred to as I-walls), USACE updated its guidance for design and construction of floodwalls.

The Mississippi Valley Division, which includes several major cities along the Mississippi River, has approximately 200 miles of floodwalls.

DID YOU KNOW?

In 2015, the average age for retirement in the U.S. was 63 years old—older than many of the levees in the USACE levee portfolio.

Across the nation, there is a lot of variation in the entities responsible for the operation and maintenance of levees in the USACE levee portfolio, ranging from state agencies to local volunteer levee districts to everything in between. Because levee sponsors are embedded in the community and are the local risk information provider for levees, USACE views its relationship as primarily with the levee sponsor. USACE organized its Levee Safety Program risk communication efforts to work with sponsors to involve other community and public entities and partners.

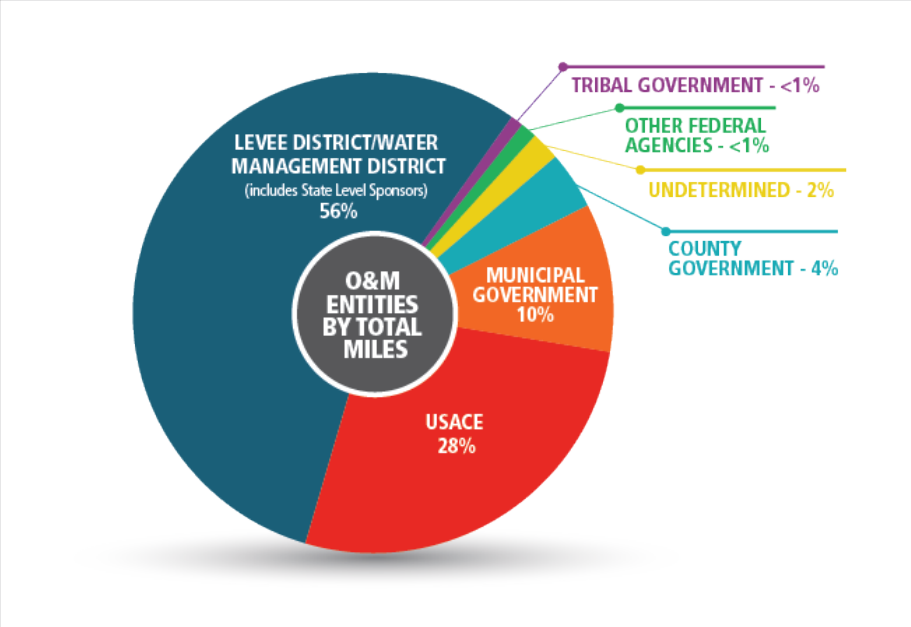


BREAKDOWN OF USACE PORTFOLIO OF LEVEES (SOURCE: NATIONAL LEVEE DATABASE).

Levee districts or water management districts are responsible for operation and maintenance of 55% of the portfolio length. Most of these districts are formed primarily for flood risk management in urban areas. Some are formed for draining, ditching, and improving non-federal land for agricultural and sanitary purposes. These groups are generally authorized to build and maintain drains and levees within their jurisdiction, to use all necessary private land within their corporate bodies for that purpose, and sometimes have taxing authority as necessary.

Municipal or county governments are responsible for operation and maintenance of 15% of the portfolio length. These entities are usually an administrative division having corporate status and powers of self-government or jurisdiction. Municipal or county governments would be responsible for the levees they operate and maintain, as well as other public works responsibilities. They often—but do not always—have taxing authorities. This level of government also usually has direct emergency management responsibilities as well.

USACE operates and maintains roughly 28% of the portfolio length through various authorities. At nearly 27% of the portfolio length, levees as part of the MR&T project make up almost all of the USACE-operated and maintained levees. These levees are managed by a combination of states and levee districts in conjunction with USACE. Unlike most other levee systems, the levees have an annual operation and maintenance appropriation from Congress and are part of a more comprehensive, landscape-scale flood risk management system that includes not only levees, but bypass channels and deed-restricted inundation areas that can be opened to store excess floodwaters (floodways). Since the MR&T project is currently under construction through federal efforts, USACE is more involved in day-to-day operation and maintenance of the MR&T levee systems.



BREAKDOWN OF USACE PORTFOLIO OF LEVEES BY ENTITY RESPONSIBLE FOR OPERATION AND MAINTENANCE AND THE PERCENTAGE OF MILES OF THE TOTAL PORTFOLIO (SOURCE: NATIONAL LEVEE DATABASE).

COMPLEX SYSTEMS CAN INCLUDE MULTIPLE SEGMENTS AND LEVEE SPONSORS

Levee systems with multiple segments and other features that are integral to excluding flood water from the leveed area—including embankment sections, floodwall sections, closure structures, pumping stations, and interior drainage works—reinforce the importance of the USACE Levee Safety Program's emphasis on assessing, managing, and communicating risk across an entire levee system.

USACE manages its portfolio of levees by systems, but sometimes one levee system can have multiple levee sponsors, each managing one or more levee segment. Nearly 15% of the levees with levee sponsors have multiple segments.

As performance of the levee is only as good as its lowest point or weakest link, engagement with all parties responsible for segments of the levee is critical. This represents a relatively new way of interacting with those responsible for all the elements of the levee—elements that may not have been designed or authorized as part of a system—and has been a priority for the USACE Levee Safety Program.

For example, the portfolio of the Mississippi Valley Division is dominated by the 3,700 miles of levees that are part of the MR&T project. The levees within the MR&T are concentrated in the Memphis, New Orleans, and Vicksburg Districts. The MR&T project, including its levees, reservoirs (dams), and floodways, currently mitigates the flood risk for more than 4 million people, 1.5 million homes, 33,000 farms, and many transportation routes (e.g., highways, railroads, and riverine transport).

Outside of the Mississippi Valley Division, locally operated and maintained federal levees dominate the portfolio. This requires USACE Districts to maintain communication and engagement with levee sponsors, who are responsible for the levees' operations, maintenance, repair, replacement and rehabilitation, which are important both to ensure the levee performs as expected and that local communities understand and manage the risks associated with these levees. USACE still has a role to play, though. As authorized federal projects, USACE retains responsibilities for regular inspections, risk assessments, and engagement with the levee sponsor.

Two USACE Divisions, the Northwestern Division (NWD) and Southwestern Division (SWD), have a significant portion of the non-federal levees participating in the Rehabilitation Program within their area of responsibility. These levees are locally constructed, operated, and maintained. USACE has an obligation and authority to verify these non-federal levees maintain program eligibility requirements

DID YOU KNOW?

The Floodplain Management Services (FPMS) Program *is a technical assistance program available to communities to enhance the awareness of people who live and work in leveed areas regarding the actions they can take to keep themselves and their property out of harm's way. Through FPMS, USACE can provide technical services, planning assistance, and guides and pamphlets for floodplain management. All FPMS Program activities are delivered through USACE Districts and provided to state, regional, and local governments or other non-federal public agencies, 100% federally funded, within program funding limits.*

and to work with the sponsor to communicate risks associated with their levee to local communities that rely on them.

FINDINGS AND DISCUSSION

As a nation, we know little about the condition or risks associated with levees outside of those inspected and assessed as part of the USACE portfolio and included in this report. As such we do not have a full national look at the risks and benefits levees provide or whether people know that they live or work in a leveed area.

To better understand the condition and risks associated with levees outside the USACE Portfolio:

- USACE will continue to work to improve awareness of location of levees in the U.S and the risks associated with levees.
- USACE will cooperate with states, tribes, local communities and private levee owner/operators to conduct a one-time baseline inspection and risk assessment for all levees in the nation. USACE will include information on the location, condition, risks, and benefits of these levees in the National Levee Database to increase accessibility of risk information to those living and working behind levees and to improve understanding of the nation's benefits and risks related to levees. In carrying out this activity, USACE staff will provide on-the-job training for interested levee owner/operators in inspection and risk assessment, risk management, and risk communication, and share assessment methodologies and tools.
- USACE will work with federal agencies to incorporate their levee information in the National Levee Database.

The value of a risk-informed approach is supported by analysis in this report. In addition to changes in design and construction standards, major cities have grown up behind levees and the behavior of water in our rivers, lakes, and coasts has changed due to a variety of factors (e.g., more stormwater runoff due to development, building of upstream dams, changing weather patterns). As such, a standards-based-only approach (i.e., focus on the levee only) may be overinvesting in risk management measures for some areas and underinvesting in others.

- USACE has made significant investments in inspections and risk assessments of levees in the USACE portfolio and has begun to use that information to prioritize more detailed risk assessments, repair priority and sequencing and is a contributing factor in funding feasibility and other planning studies. USACE will continue to look for opportunities to use this information to reduce risk to human life, economic damages, and harm to the environment.
- USACE will work with elected officials, emergency managers, and other community leaders to improve the ability of risk managers to use risk information in an actionable manner.

The wide variety of levee sponsor authorities and responsibilities complicates USACE's ability to provide meaningful and practical risk-management strategies and products. To manage risk effectively, one must often look at managing what is behind the levee, such as changes in land use or improving warning and evacuation. Some levee sponsors have neither land-use decision-making authority nor a role in emergency preparedness and must rely on others to use their levee-specific information. USACE does not collect information about the specific authorities and responsibilities of levee operators.

- USACE will work with levee sponsors to improve understanding of the different levee sponsor authorities, including limitations and the range of responsibilities. This information will be used to improve and tailor technical assistance, tools, and training to ensure risk information gets in the hands of all risk managers in a community.
- USACE will work with communities to exchange levee information to promote public awareness of the benefits and risks associated with levees.

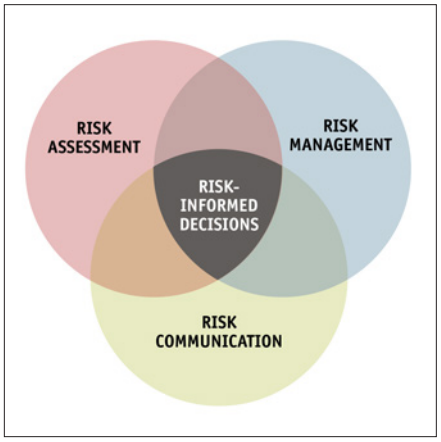
SECTION 3: THE USACE LEVEE SAFETY PROGRAM RISK FRAMEWORK

THE RISK FRAMEWORK

The USACE Levee Safety Program Risk Framework consists of three basic activities: risk assessment, risk management, and risk communication. This framework provides an analytical method for gathering, recording, and evaluating information that leads to recommendations for decisions or actions related to levee systems.

Risk assessments provide a systematic, evidence-based approach for estimating and describing the likelihood and consequences of existing and future risk associated with levee systems. Risk assessments consider what can go wrong, how it can happen, the consequences if it happens, and how likely it is to happen.

Risk management is the activity in which measures are identified, evaluated, implemented, and monitored to effectively and efficiently manage risks. For the USACE Levee Safety Program, risk management encompasses activities related to making risk-informed decisions, prioritizing evaluations of risk, prioritizing risk reduction activities, and making program decisions associated with



USACE LEVEE SAFETY PROGRAM RISK FRAMEWORK.

managing a portfolio of levee systems. Risk management includes evaluating the environmental, social, cultural, ethical, political, and legal considerations as part of decision making. The risk management process emphasizes an ongoing and iterative process, and the necessity of adapting to new information.

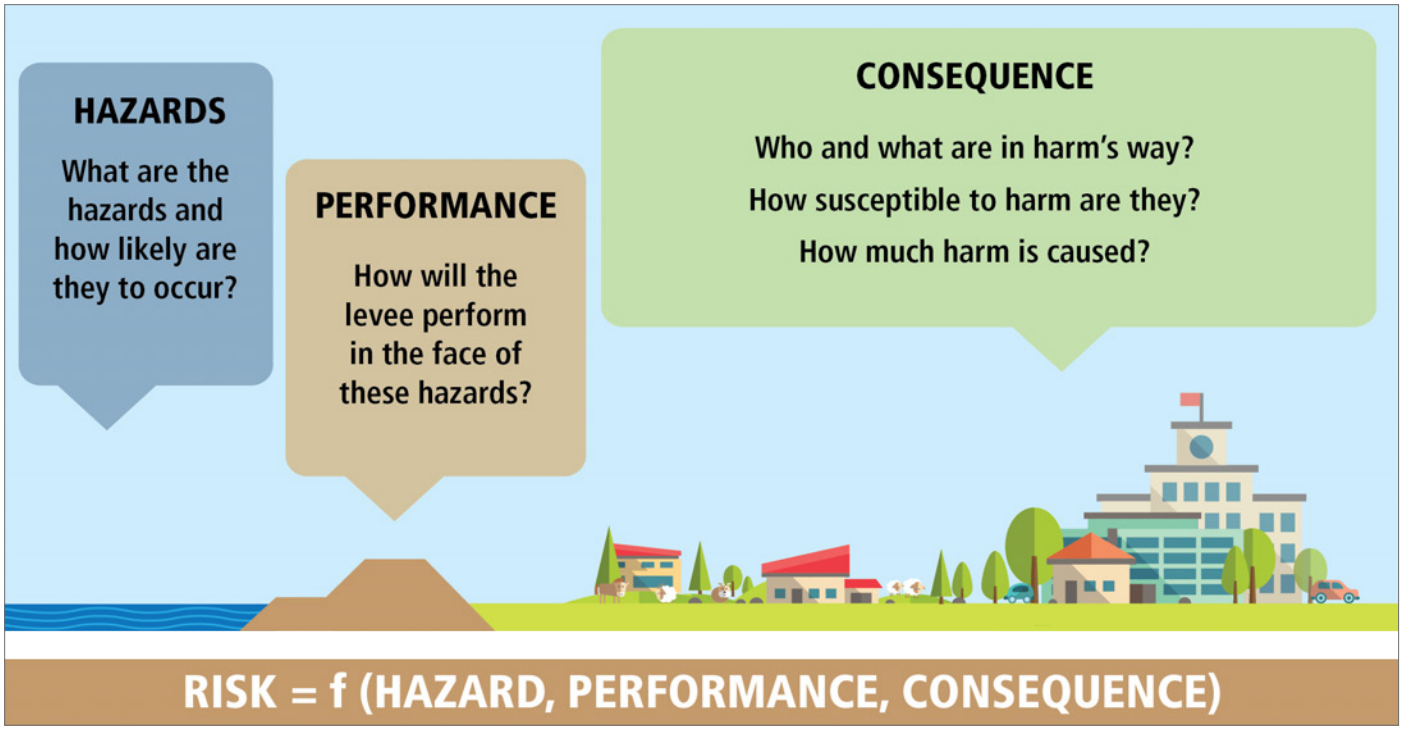
Risk communication is the open exchange of information between risk assessors, decision makers, and those who are affected by the risks and risk management measures. Risk communication is a critical component of an effective risk-informed decision process and should begin early and continue throughout the entire process.

The analytical approach of the risk framework assists USACE and levee sponsors to:

- Carefully assess risks to people as well as economic, environmental, and other social effects in the areas behind levees;
- Implement risk management activities that prioritize fixing the highest risk deficiencies first, which maximizes flood risk reduction benefits; and
- Make an articulate case with elected officials and other risk managers regarding the priority of investments and solutions, and educate people living and working behind levees to help inform their decisions regarding personal risk management activities such as flood insurance, evacuation measures, flood proofing, relocation, and others.

Risk terminology can vary among different internal and external organizations.

Risk is a measure of the probability (or likelihood) and consequences of uncertain future events. If there is no chance of an event occurring, then there is no



LEVEE RISK IS A FUNCTION OF HAZARDS, PERFORMANCE, AND CONSEQUENCES.

risk. If there are no consequences resulting from an event occurring, then there is no risk. The characteristics of seemingly identical risks can be extremely different. Risk also can be considered from other attributes, such as existing risk, future risk, historical risk, transferred risk, and transformed risk. Risk, in general, is viewed differently based on perspective.

The term **risk** is used throughout this report to refer to the flood risk posed by the levee system itself.

LEVEE RISK ASSESSMENTS

A risk assessment captures, both quantitatively and qualitatively, the various components of risk to the people, property, and environment located behind a levee system.

During the risk assessment process, risk assessment teams use existing data, historical performance, engineering judgment, and consequence estimation to characterize the relative risks posed by levees in terms of a relative probability of breach and potential risk to life, property, and the environment. Risk assessments also seek to identify uncertainty about the understanding of the risk posed. Risk assessments are scalable based on the information at hand, funding available, and intended uses for the information.

Risk assessments combine and synthesize three distinct factors of levee risk:

- **Hazard:** includes factors such as discharge, stage, duration, velocity, coincident earthquake, and magnitude and duration of water on the levee;
- **Performance:** identifies and prioritizes the most likely failure modes that could lead to a levee breach, such as overtopping, seepage, erosion, slope failure, culvert gate malfunction, floodwall instability, or culvert failure; and
- **Consequences:** estimates potential consequences including life loss and economic damages considering factors such as the magnitude (e.g., depth, velocity) and timing (e.g., day v. night, rate of rise), distribution of people and property, environmental impacts, and expected effectiveness of evacuation plans.

FLOODING SCENARIOS BEHIND LEVEES NOT DUE TO LEVEE BREACH OR MALFUNCTION

Leveed areas may flood if the floodwaters go around the levees. This "wrap around" flooding can occur if the levee is not tied into high ground. Some levees are purposely designed in this manner to prevent overtopping. This type of flooding is relatively common in very flat areas where it is difficult to tie into high ground or where the levee is intentionally higher to prevent a catastrophic breach of the levee caused by overtopping.

A period of heavy rain in a basin also may lead to flooding in the leveed area if the rainwater is not able to drain or be pumped out from inside the leveed area quickly enough. This flooding typically occurs despite the levee, not because of it. Some levee systems include pump stations to clear stormwater that collects behind the levee, pumping the water over the levee into the river, but many do not. If the flooding occurs because of lack of adequate "interior drainage" components within the levee, such as pump stations, the scenario would fit under the "component malfunction" inundation scenario.

A levee risk assessment will result in a risk characterization, which takes the information from the risk assessment to characterize the risk to support decision making. Recommended actions from a risk assessment could include interim risk reduction measures; additional monitoring, investigations, or analyses; or specific risk-management measures.

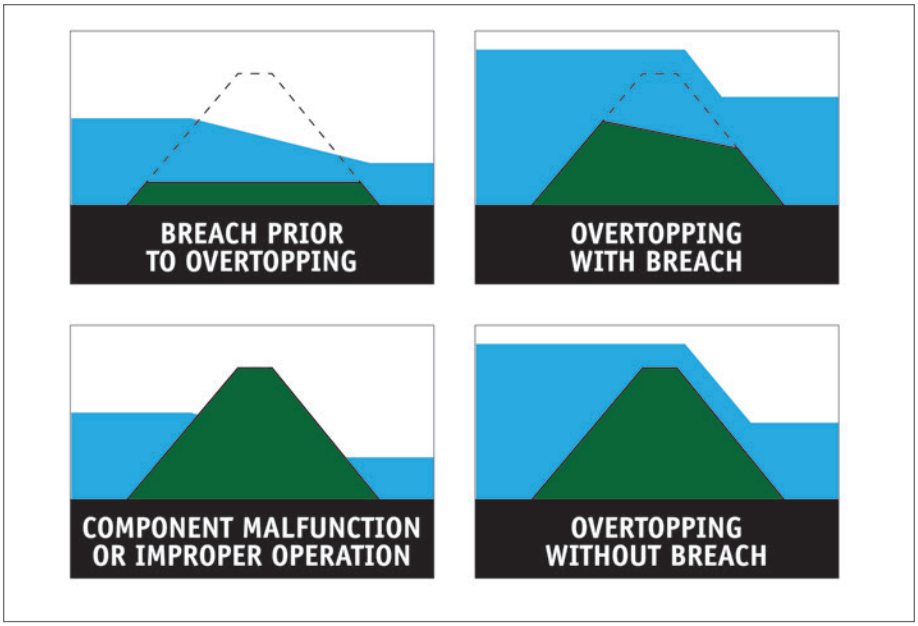
A levee risk assessment is not a one-time action. Our understanding potential flooding and its interaction with any given levee changes over time. These changes result from changes in technology, physical changes within the watershed (e.g., human and natural land cover changes), and changes in weather patterns. The physical condition of the levee may improve or become worse over time as the result of damage from new floods, changes in operation and maintenance practices, and man-made structural changes. Potential consequences behind a levee may increase or decrease with land use changes, changes to transportation systems, and emergency planning activities.

Because of these changes over time, levees require continuous monitoring and regular assessments to manage risk. Sometimes new information is collected through USACE activities such as levee inspections or risk assessments, but USACE and levee sponsors also consider new information made available through updates to FEMA Flood Insurance Studies, local stream gauges managed by the U.S. Geological Survey, or levee performance monitoring during a flood.

A USACE levee risk assessment goes beyond assessing the levee against a specific design standard. Assessing a levee against its design standards only tells part of the story. It does not account for levee performance beyond the design flood events or consequence of overtopping or breach prior to overtopping, and therefore does not adequately describe the full risk associated with the levee. Thus, the factors affecting levee-related risks for any specific levee may be factors beyond the levee itself.

USACE conducts risk assessments across all segments within a levee to evaluate risks regardless of who is the responsible party. This process is important to comprehensively determine the flood risks associated with the entire levee system.

USACE risk assessments are scalable. Most levees in the USACE portfolio have undergone, at a minimum, a screening-level risk assessment utilizing available information (e.g., inspections, historical performance data, observations). If the screening-level risk assessment indicates a high



FOUR PRIMARY INUNDATION SCENARIOS FOR THE LEVEED AREA.

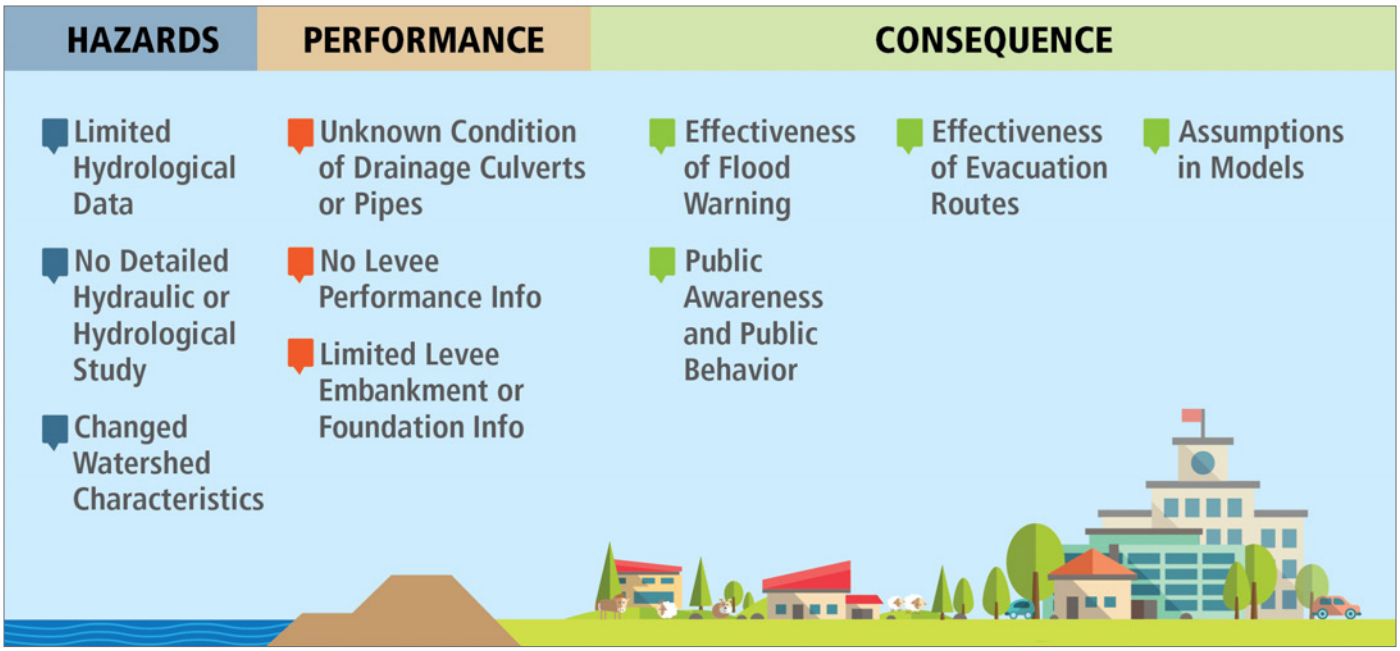
risk—or high uncertainties about levee performance, consequence, or hazard—a more quantitative risk assessment may be warranted.

The term "levee risk," is used to refer to the risk posed by the levee system should the levee breach. Because levees exist in floodplains, there is always a risk that water could rise higher than the levee, allowing water to flow over the levee into the area behind. When USACE conducts a risk assessment, it considers the likelihood associated with four primary inundation scenarios that impact flood risk for the leveed area, and the consequences of each of those scenarios. These scenarios are:

- **Levee breach prior to overtopping:** Before the water reaches the top of the levee, the levee breaches and floodwaters flow into the leveed area.
- **Levee overtopping with breach:** Water reaches the top of the levee and flows over, causing erosion and subsequent levee breach that allows floodwaters to rapidly inundate the leveed area.
- **Malfunction of levee system components:** Levee system components, such as closures, fail to operate and floodwaters flow into the leveed area before the water reaches the top of the levee. For malfunctioning or improperly-operated closure systems, a rapid release of flood waters can occur, but is often constrained by an opening that reduces the magnitude and speed of inundation. Pump station malfunction typically does not pose a threat to public safety due to slow rise of floodwaters, although economic damages from floodwaters can occur.
- **Levee overtopping without breach:** The levee performs as expected, but the water levels are higher than the levee and the leveed area floods. This inundation scenario is not related to the risk posed by the levee.

The risk of flooding posed by the levee (e.g., levee breach prior to overtopping, levee overtopping with breach, and malfunction of levee system components) will be explored throughout this report.

Levee risk assessments often indicate two inundation scenarios with the most significant influence on flood risk associated with levees: levee overtopping with breach and breach prior to overtopping. These two inundation scenarios produce similar extent and depths of flood inundation and have similar economic damages; however, the breach prior to overtopping inundation scenario generally has higher potential loss of life due to less advance warning (floodwater may be on the levee, but overtopping or breach may not be considered imminent) and decreased evacuation effectiveness compared to the overtopping with breach scenario.



UNCERTAINTIES IN THE UNDERSTANDING OF HAZARDS, PERFORMANCE, AND CONSEQUENCES IMPACT OUR PERCEPTION OF RISK.

RISK CHARACTERIZATION: THE USACE LEVEE SAFETY ACTION CLASSIFICATION APPROACH

To support levee portfolio risk management decisions, a Levee Safety Action Classification (LSAC) is assigned as a final step in developing a risk characterization of a levee system. LSACs range from "Very High" (immediate action recommended) to "Very Low" (maintain routine activities).

The LSAC assignment is based on levee risk from a life safety perspective, but also recognizes economic and environmental considerations. In a USACE levee system risk characterization, a LSAC is established based on the levee breach prior to overtopping, malfunction or improper operation of levee system components, and levee overtopping with breach inundation scenarios; the risks associated with each scenario are combined to inform the LSAC assignment. The flood risk associated with the overtopping without breach scenario is not used to inform the LSAC assignment, but it is assessed and communicated to the levee sponsor as part of the risk assessment.

The USACE Levee Safety Program always shares the results of its risk assessments and risk characterization with sponsors and communities as part of an ongoing dialogue about the factors that contribute most to risk of levee breach and what is at stake should a levee breach or overtop (e.g., population behind a levee, economic damage, public infrastructure, and environmental consequences).

The levee system risk characterization also will identify the sources of uncertainty that impact the understanding and characterization of the levee risk. Uncertainties in the understanding and estimation of hazard, performance, and consequences associated with levee systems are unavoidable, and to some degree exist for all levee systems. In some situations, the uncertainties may be significant enough that a risk characterization cannot be made and the levee system is given a "No Verdict" LSAC. When the uncertainties may be significant but a risk characterization can be made, the LSAC assignment reflects the worst likely scenario from a life safety perspective.

Because the LSAC is a result of the risk characterization, levees that are "poor performance" systems and levee systems with

USACE LEVEE SAFETY ACTION CLASSIFICATION TABLE*

RISK	ACTIONS FOR LEVEE SYSTEMS AND LEVEED AREAS IN THIS CLASS (ADAPT ACTIONS TO SPECIFIC LEVEE SYSTEM CONDITIONS.)	RISK CHARACTERISTICS OF THIS CLASS
VERY HIGH (1)	Based on risk drivers, take immediate action to implement interim risk reduction measures. Increase frequency of levee monitoring, communicate risk characteristics to the community within an expedited timeframe; verify emergency plans and flood inundation maps are current; ensure community is aware of flood warning systems and evacuation procedures; and, recommend purchase of flood insurance. Support risk reduction actions as very high priority.	Likelihood of inundation due to breach and/or system component malfunction in combination with loss of life, economic, or environmental consequences results in very high risk.
HIGH (2)	Based on risk drivers, implement interim risk reduction measures. Increase frequency of levee monitoring; communicate risk characteristics to the community within an expedited timeframe; verify emergency plans and flood inundation maps are current; ensure community is aware of flood warning and evacuation procedures; and, recommend purchase of flood insurance. Support risk reduction actions as high priority.	Likelihood of inundation due to breach and/or system component malfunction in combination with loss of life, economic, or environmental consequences results in high risk.
MODERATE (3)	Based on risk drivers, implement interim risk reduction measures as appropriate. Verify risk information is current and implement routine monitoring program; assure O&M is up to date; communicate risk characteristics to the community in a timely manner; verify emergency plans and flood inundation maps are current; ensure community is aware of flood warning and evacuation procedures; and, recommend purchase of flood insurance. Support risk reduction actions as a priority.	Likelihood of inundation due to breach and/or system component malfunction in combination with loss of life, economic, or environmental consequences results in moderate risk.
LOW (4)	Verify risk information is current and implement routine monitoring program; assure O&M is up to date; communicate risk characteristics to the community as appropriate; verify emergency plans and flood inundation maps are current; ensure community is aware of flood warning and evacuation procedures; and, recommend purchase of flood insurance. Support risk reduction actions to further reduce risk to as low as practicable.	Likelihood of inundation due to breach and/or system component malfunction in combination with loss of life, economic, or environmental consequences results in low risk.
VERY LOW (5)	Continue to implement routine levee monitoring program, including operation and maintenance, inspections, and monitoring of risk. Communicate risk characteristics to the community as appropriate; verify emergency plans and flood inundation maps are current; ensure community is aware of flood warning and evacuation procedures; and recommend purchase of flood insurance.	Likelihood of inundation due to breach and/or system component malfunction in combination with loss of life, economic, or environmental consequences results in very low risk.
NO VERDICT	Not enough information is available to assign an LSAC.	

*LEVEE RISK IS THE RISK THAT EXISTS DUE TO THE PRESENCE OF THE LEVEE SYSTEM, AND THIS IS THE RISK USED TO INFORM THE DECISION ON THE LSAC ASSIGNMENT. THE INFORMATION PRESENTED IN THIS TABLE DOES NOT REFLECT THE OVERTOPPING WITHOUT BREACH RISK ASSOCIATED WITH THE PRESENCE OR OPERATION OF THE LEVEE SYSTEM.

high consequences may have the same LSAC assignment. However, the actions to manage the total risk will be different—either to reduce the potential consequences (e.g., improve evacuation planning, remove structures from the area likely to be flooded) or to improve the levee performance (e.g., structural modifications to the levee, repairs or rehabilitation of levee components).

LSAC assignments are used by USACE to prioritize resources across the portfolio and to organize widespread levee-related risk information into reasonably commensurate groupings for action. For example, the group of levees with Very High risk are generally the highest priority group for ongoing and effective risk communication with the levee sponsor, developing a range of interim risk reduction measures (IRRMs), and considering additional risk assessment activities to reduce the uncertainty related to the risk characterization and to better understand the risk associated with the levee.

When considered by the levee sponsor, community, and USACE, the risk characterization can assist in more effective management and communication of risks posed by levees. Effective management of levee risk involves a shared responsibility between USACE, levee sponsors that operate and maintain the levee, and local communities that live behind the levee. Shared responsibility includes prioritizing actions to manage and reduce levee risk, continually monitoring levee risk, and continually promoting awareness of levee risk to those who live and work behind them.

FINDINGS AND DISCUSSION

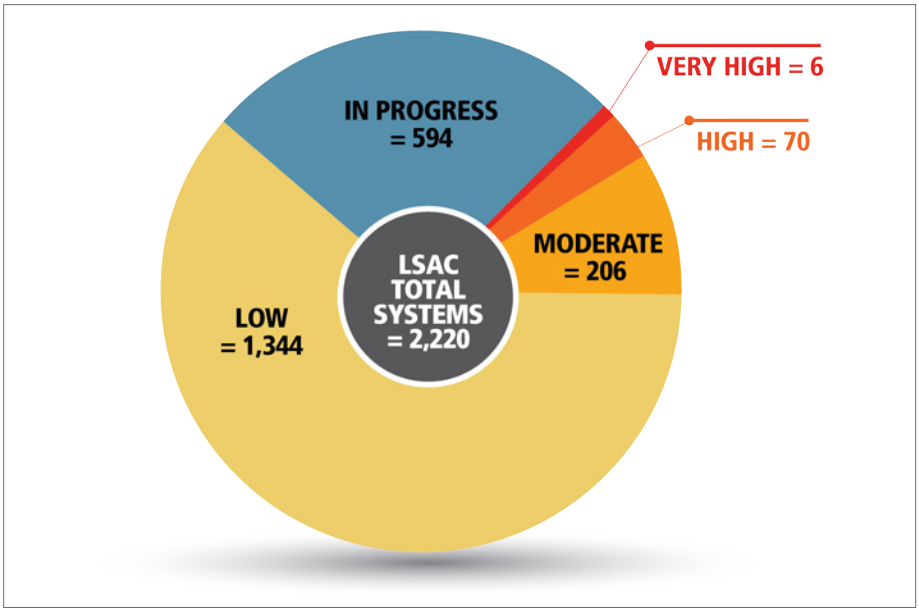
USACE has recently begun sharing information from risk assessments with sponsors and other Community risk managers. This has required a deliberate change in thinking from a condition-based framework, based on inspections, to a more comprehensive analysis of information that synthesizes hazard, levee performance, and potential consequences. In addition, there may be a reluctance to share risk information with the public, when an immediate and viable risk management solution has not been identified.

- USACE will continue to work to develop approaches and tools to share results of risk assessments with all kinds of risk managers, with a particular focus on training its staff to translate risk information into understandable and actionable information. Further, USACE will continue to provide opportunities for sponsors to take part in inspections and risk assessments, both as information providers and as a way to spread knowledge and increased understanding of risk assessments.
- USACE will share this report widely with sponsors and other risk managers.

SECTION 4: RISK CHARACTERIZATION OF THE USACE LEVEE PORTFOLIO

RISK CHARACTERIZATION OF THE USACE LEVEE PORTFOLIO

USACE currently has completed levee risk characterizations and assigned an LSAC to nearly 73% of the levees in the portfolio. For remaining 27% of the levees in the portfolio, USACE expects to complete levee risk characterizations and LSAC assignments in the next few years. While conducting risk assessments of the full portfolio, USACE prioritized levee systems with higher populations at risk and potential economic consequences so that USACE, levee sponsors, and other stakeholders can inform management decisions. As additional levees are screened, the total percentage of Very High, High, and Moderate risk levees is likely to drop, because these levees are expected to trend toward Moderate or Low risk.



LEVEE SAFETY ACTION CLASSIFICATIONS OF THE USACE PORTFOLIO, BASED ON COMPLETED RISK ASSESSMENTS AS OF MARCH 2017.

OVERALL PORTFOLIO RISK

Approximately 13% of the levees have been characterized as Very High, High, or Moderate risk (LSAC I, II or III). These levees are considered to pose risk requiring further, and often immediate, actions by the levee sponsor, USACE, or the community to reduce risk.

Approximately 60% of the levees have been assigned a classification of Low risk (LSAC IV). For these levees, the likelihood of inundation due to breach and/or system component malfunction in combination with loss of life, economic, and environmental consequences results in low risk.

There are no levees that have been assigned a Very Low risk (LSAC V) thus far. USACE has conducted screening-level risk assessments in a prioritized manner to identify higher risk levees within the portfolio rather than focus on discerning the difference between Low risk and Very Low risk levees. As more risk reduction actions are taken and as uncertainty is reduced through additional data gathering and more quantitative risk assessments, Very Low risk levees will likely be identified within the portfolio.

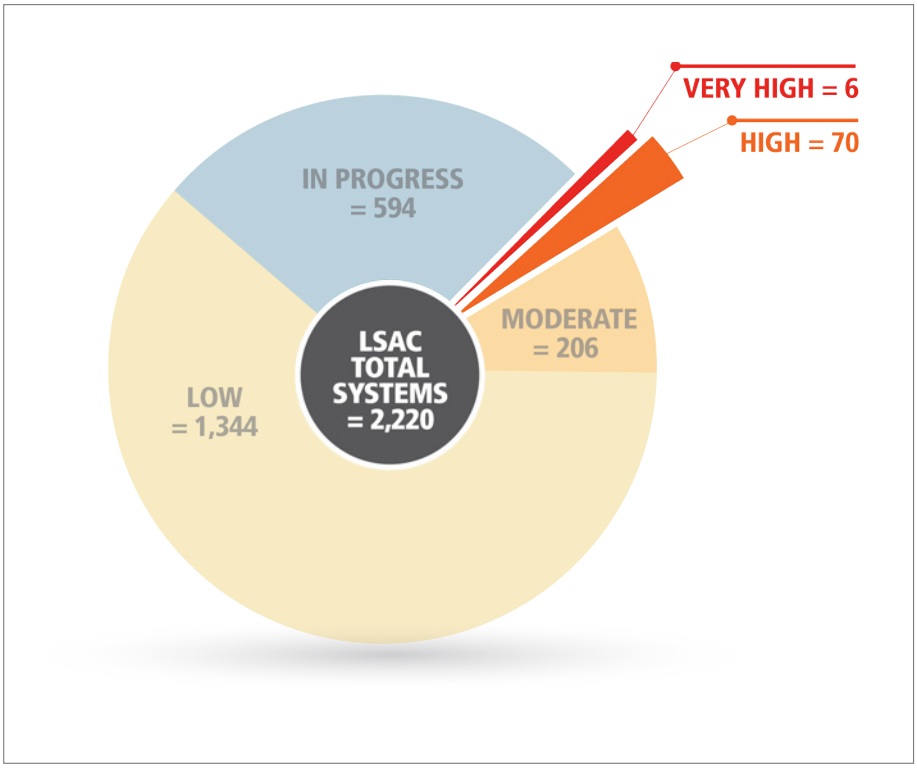
Risk characterization of each levee is driven by a unique combination of the three components of the risk equation: hazard, performance, and consequences. The section that follows aims to describe levee risk in a combination of

DIVERSITY IN RISK ACROSS THE LEVEE PORTFOLIO

The levee portfolio spans 7 orders of magnitude in risk, meaning that the highest risk levee has 10 million times more risk than the lowest risk levee. The portfolio also spans the risk spectrum. This diversity in risk offers many challenges in developing levee guidance and training requiring adaptation and flexibility. The levee portfolio is truly not a one size fits all kind of infrastructure portfolio.

CORRELATION BETWEEN LEVEE RISK AND LEVEE HEIGHT

Levees with Very High and High risk are generally taller than Moderate or Low risk levees. The height of the levees interplays with all three components of the risk equation and in part explains the large population at risk and the levee performance risk drivers identified. A breach of a taller levee generally results in greater inundation depths and/or a wider area of impact, thus increasing the breach consequences.



VERY HIGH AND HIGH RISK LEVEES ARE A SMALL FRACTION OF THE TOTAL PORTFOLIO.

factors and considerations typical for that grouping. That said, it is important to note that there is no typical levee and one of the main benefits of risk assessment is an in-depth look at each and every levee to better understand what factors contribute to the risk for a particular community.

VERY HIGH AND HIGH RISK LEVEES (LSAC 1 & 2 LEVEES)

There are 76 levee systems (2,500 miles of levees) characterized as having High or Very High risk. Generally speaking, levees in these risk classifications have relatively large populations behind them, combined with significant levee performance issues.

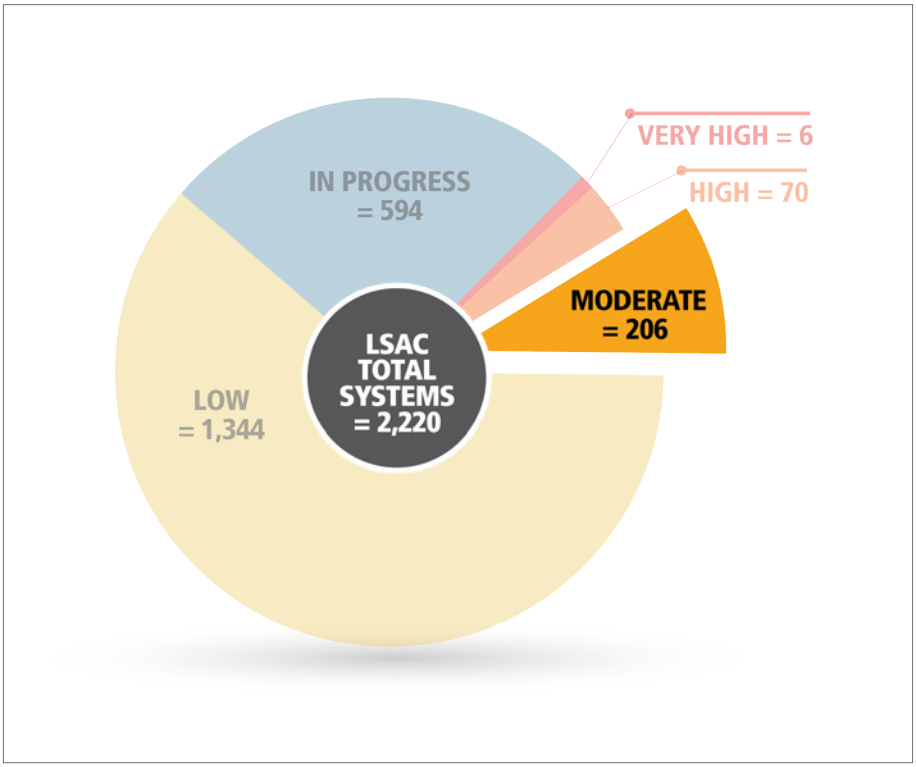
Approximately 5 million people live and work behind Very High or High risk levees. While the Very High and High risk levees represent less than 4% of the levees, about 45% of the population behind the entire portfolio lives and works behind these more urban levees. Over half of these levee systems have more than 10,000 people behind them.

Eighty percent of these levees were found to have one or more levee performance concerns that would likely result in a breach prior to overtopping. Most of the performance concerns were identified by direct observations during past flood events resulting in less uncertainty in the levee performance

Likelihood of breach prior to overtopping. Levees in High and Very High risk categories often are classified as such due to a high potential for breach prior to overtopping. When a levee breaches prior to water getting to the top, the breach is often sudden and unexpected, releasing water with significant velocities into an area where people have not evacuated. When the high likelihood of breach prior to overtopping is combined with larger, more urban populations, there is a greater potential for life loss.

Seepage through or under a levee (e.g., embankment and foundation seepage and piping) is the most common risk factor observed on nearly 60% of these High/Very High risk levees. Deteriorated or distressed culverts are the most significant factor contributing to seepage. Another significant factor contributing to seepage issues are deteriorated or poorly maintained relief wells or toe drains (these represent 40% of the High/Very High risk levees).

Embankment erosion and closure system malfunction/improper operation are major risk drivers for breach prior to overtopping failure on 30% and 33% of these levees, respectively.



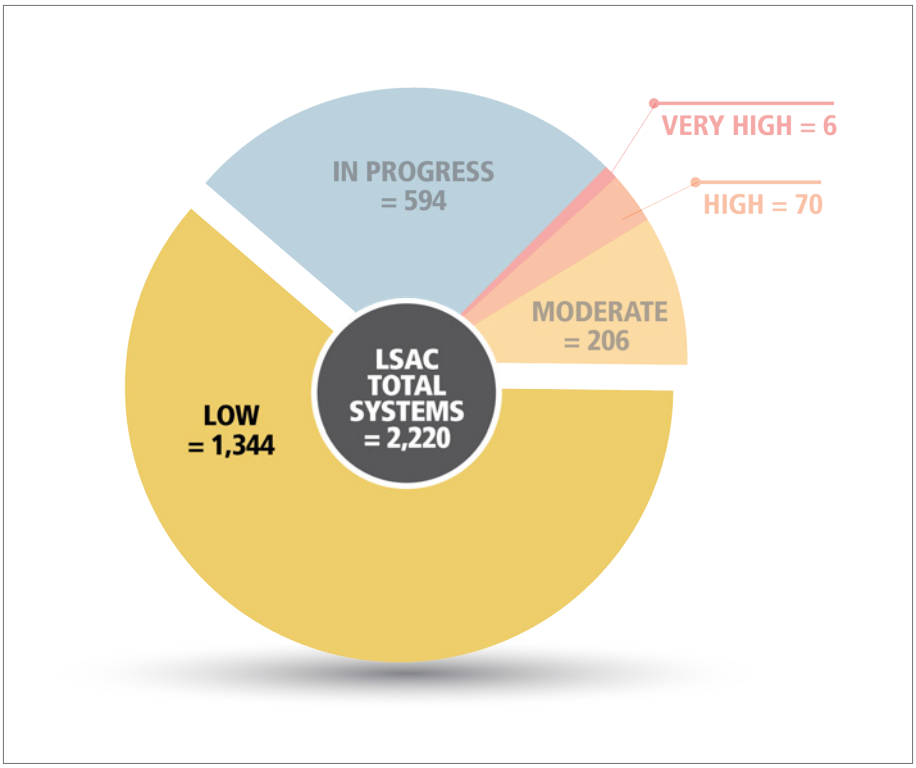
MODERATE RISK LEVEES ARE A SIGNIFICANT FRACTION OF THE PORTFOLIO.

Likelihood of overtopping with breach. Overtopping followed by breach is another major risk driver for many of the Very High and High risk levees. Even if structural measures are implemented to minimize the potential for breach prior to overtopping, the risk for many of these levees may remain high for overtopping with breach. Sixteen percent (16%) of the High and Very High risk levees have overtopping followed by breach as the highest risk driver for their system. This risk is high due expected frequency of overtopping with breach and large populations behind the levee. There is greater uncertainty, in general, with the risk associated with overtopping frequency. The age of the hydrological data—37% of High risk levees have hydrological data more than 20 years old—increases the uncertainty associated with expected performance.

MODERATE RISK LEVEES (LSAC 3)

There are 206 levee systems (2,600 miles of levees) that have been characterized as Moderate risk. The Moderate risk levees have similar levee heights and flood loading hazards to that of Very High and High risk levees.

Approximately 3.1 million people live and work behind Moderate risk levees. While the Moderate risk levees represent about 9% of the levees, about 27% of the population behind the entire



LOW RISK LEVEES DOMINATE THE USACE PORTFOLIO.

portfolio lives and works behind these levees. Almost 80% of the Moderate risk levees have over 1,000 people in the leveed area and about 25% of these levees have over 10,000 people behind them.

Likelihood of breach prior to overtopping. Just under 50% of the levees in this group were found to have one or more performance failure modes that would likely result in a breach prior to overtopping.

Embankment and foundation seepage and piping comprise the most common failure mode (30% of these levees). Note, this is about half of the percentage of levees with this factor as a major risk driver for the Very High and High risk levees. Embankment erosion and closure system malfunction or improper operation are both found to be major risk drivers on fewer than 20% of the Moderate risk levees.

Likelihood of overtopping with breach. Overtopping with breach is also a major risk driver for many of the Moderate risk levees. The loading frequencies used in the risk assessments for 36% of the moderate risk levees are based on hydrology data and analyses that are more than 20 years old, which mirrors the average data and analysis age of the entire portfolio and remains a source of uncertainty for the portfolio.

LOW RISK AND VERY LOW RISK LEVEES (LSAC 4 & 5 LEVEES)

There are 1,344 levee systems (5,800 miles of levees) within the portfolio that have been characterized as Low Risk (LSAC 4). There are currently no levee systems in the portfolio categorized as Very Low Risk (LSAC 5). Relative to the higher risk levees, there is a much smaller population living and working behind these levees and there are generally not the same performance concerns.

Approximately 1.4 million people live and work behind Low risk levees. While the Low risk levees represent about 83% of the portfolio, only about 15% of the population behind the entire portfolio lives and works behind these levees. These levees often reduce the risk of flooding to rural areas and fewer than 2% of these levees have communities with more than 10,000 people behind them and about 83% of the Low risk levees have communities with fewer than 1,000 people in the leveed area.

The Low risk levees are generally shorter in height and overtop more frequently than higher risk levees in the portfolio. The risk is not greater for Low risk levees that frequently overtop due to the limited flood depths and fewer people behind the levees.

I-WALLS ALONG THE 17TH ST. CANAL IN NEW ORLEANS (SOURCE: USACE).

Most of these levees have experienced significant past flood loadings with approximately 70% of these levees having a maximum historical flood loading to at least the mid-height of the levee.

Likelihood of breach prior to overtopping. Sixteen percent (16%) of the Low risk levees were found to have one or more performance failure modes that would likely result in a breach prior to overtopping. Unlike the higher risk levees, this risk characterization of the Low risk levees has lower confidence due to the fact that only 29% of the assessments are based on direct observation of performance during a flood event.

Embankment erosion is the most common performance risk driver for the Low risk levees. Embankment erosion is a significant risk driver for 14% of these levees. Embankment and foundation seepage and piping are a major risk driver for about 12% of the Low risk levees.

Likelihood of overtopping with breach. Most of these Low risk levees (84%) do not have a performance failure mode associated with breach prior to overtopping that contributes significantly to risk. The risk of these levees is lower due to a combination of the frequency of the flood hazard, low inundation depths, and the relatively small population behind these levees. Overtopping with breach may be the controlling inundation scenario and may occur during a relatively frequent event; however, the low consequences keep down the risk.

FINDINGS AND DISCUSSION

Levee risk is concentrated in the portfolio. High/Very High risk levees represent a small portion of the overall portfolio length

(18%), but contain a high portion of the overall portfolio potential consequences (5 million people, $500 billion in property value). Levees in this category nearly always have one or more structural concerns regarding the levee itself.

- USACE recommends improvements to the warning and evacuation plans for Very High risk through Moderate risk levees due to the concern for the large and sometimes transient or vulnerable populations behind them.
- USACE will recommend increased monitoring programs during floods where warranted by levee performance issues. Monitoring improves effectiveness of warning and evacuation plans and allows for a better characterization of the risk.

Because levee risk is quite often a combination of risk factors (high/uncertain hazard + performance issues + potential life loss and property damage), risk cannot be effectively managed by focusing on the levee alone. A comprehensive array of risk management measures must be employed to effectively reduce or manage risk — activities such as warning and evacuation planning, flood proofing or elevating structures or key infrastructure, and buyouts must be equally considered with improvements to the levee itself.

SANDBAGS PLACED ON TOP OF A LEVEE NEAR FOREST, MISSOURI, DUE TO OVERTOPPING CONCERNS FROM A RISING MISSOURI RIVER IN JUNE 2011 (SOURCE: USACE).

- USACE will update levee risk assessments periodically to evaluate how changes to the hazard, performance, or consequences have changed over time and how those changes impact risk.
- USACE will continue to conduct and sponsor research for improving the understanding of human behavior during flood events, building upon the development of the 2015 *A Guide to Public Alerts for Dam and Levee Emergencies* (Mileti & Sorensen).

High/Very High risk levees nearly always have one or more performance concerns that could lead to breach, combined with significant population at risk. The risk of breach prior to the levee overtopping can take a community by surprise leading to potential loss of life.

- USACE will explicitly discuss controlled overtopping risk management options with sponsors where indicated. Measures such as structural armoring of the overtopping locations to minimize the potential for breach and controlling the location of the overtopping to reduce consequences should be considered. Because there are often concerns regarding economic damages and equity when considering such measures, USACE will work with sponsors to involve a full suite of community stakeholders and risk managers in this risk management discussion.

SECTION 5: HAZARDS: WHAT AND HOW LIKELY ARE THEY TO OCCUR?

HAZARD COMPONENT OF THE RISK EQUATION USED BY THE USACE LEVEE SAFETY PROGRAM.

OVERVIEW

The key questions to be answered related to hazards are: what is the nature of the flood hazard and how likely is a given flood level? The primary hazard that is considered for levees is flooding; however, there are instances when coincident flood and earthquake probabilities are assessed. Flooding can come in many different forms: primary river flooding, tributary flooding, flooding from surface runoff/stormwater, and flooding from coastal storm events due to surge.

To better understand the flood hazards within the USACE levee portfolio, the primary considerations in risk assessments are sources, magnitude, duration, and velocity of floodwaters. Once the hazard is described, the next step is to determine how likely it is to occur. In most instances, this is done using existing flood stage frequency and discharge data obtained from river gauges, detailed flood insurance studies, and other project documents. The probability of water on the levee (loading) is then analyzed for seven different scenarios:

- When will water first start loading the levee?
- How likely is water to reach 25% of the levee height? 50%? 75%? 100% (top of the levee)?
- How likely is water to reach the authorized capacity for the flood risk management project?
- What was the likelihood associated with the largest historical flood?

There can be a lot of uncertainty associated with these data due to the period of record, age of the data, and the level of detail of the hydrology and hydraulic analyses. These uncertainties are also captured and considered during the risk assessment.

LEVEE SYSTEM OVERTOPPING FREQUENCY, OR HOW HIGH ARE OUR LEVEES?

The likelihood (or chance) of the flood level that reaches the top of the levee being exceeded in any given year is referred to as the incipient overtopping annual chance of exceedance (ACE). At this flood level, water will begin to flow over the levee.

Levees in the USACE portfolio range from an incipient overtopping ACE of 50% to less than 0.02% — in colloquial terms, from 1-in-2 chance to less than 1-in-5,000 chance of occurring in any given year. The majority of the levee systems within the portfolio have an incipient overtopping ACE of 0.5% or less (1-in-200 chance).

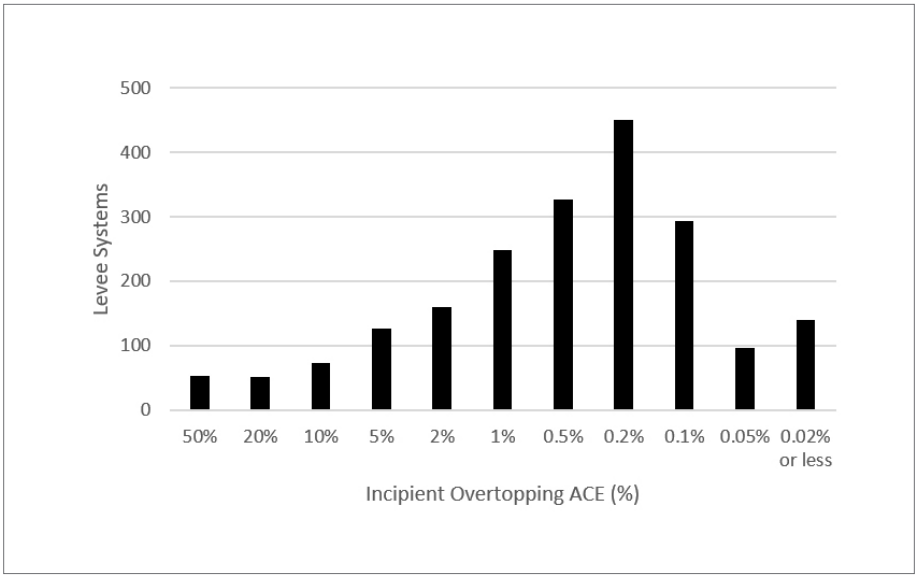
It is important to note that for levees in poor condition, the levee system may breach and flood the leveed area before overtopping

(breach prior to overtopping scenario). It is for this reason that you cannot judge a levee solely on the expected overtopping frequency.

The incipient overtopping ACE can change over time. Levees are designed and built based on estimates for the probability of experiencing a particular flood level. The magnitude, duration, and frequency of that anticipated water level has likely changed over time. Flood frequencies within a watershed are influenced by numerous factors, including development within the watershed; installation or management of flood controls (e.g., dams or reservoirs) within the watershed; longer-term changes in hydrology, such as more frequent and/or heavier storms; and changes in spring rainfall patterns or winter snowmelt.

There are approximately 500 levee systems in the USACE portfolio that have been overtopped and about 100 of these systems are known to have breached due to these overtopping events.

USACE risk assessments assume that most levees will breach if they are overtopped. While this is not always the case, unless the levee is armored or otherwise reinforced, it can be expected to erode from the backside when a significant amount of water flows over the top. Risk mitigation measures



THE DISTRIBUTION OF LEVEE SYSTEMS WITHIN THE USACE LEVEE PORTFOLIO FOR INCIPIENT OVERTOPPING ACE FROM LESS THAN 50% (2-YEAR) TO LESS THAN 0.02% (5,000-YEAR). THE MAJORITY OF LEVEE SYSTEMS HAVE AN INCIPIENT OVERTOPPING ACE BETWEEN 1% AND 0.1%.

such as structural armoring of the overtopping locations to minimize the potential for breach, controlling the location of the overtopping to reduce consequences, and improved warning and evacuation plans are the types of risk management alternatives that can be considered for these levees.

Many factors contribute to the design height of a levee—and thus its incipient overtopping ACE. For example, in urban areas, USACE and levee sponsors historically designed and built levees to withstand to the "standard project flood"—the largest reasonable flood that could be expected in the basin because of the grave consequences flooding could have in an urban area. Further, in urban areas, a more robust system can be justified for congressional authorization and federally cost-shared construction under the "National Economic Development" plan, because the economic benefits of the flood risk management provided by the system outweigh the costs.

The 1986 Water Resources Development Act (WRDA '86) provided new requirements for local cost sharing of flood control projects constructed by USACE (65% federal/35% local), a change from generally 100% federally-funded projects. WRDA '86 also required that lands, easements, rights of way, and real estate were to be provided by levee sponsors along with an agreement for local sponsors to provide for all operation, maintenance, repair, rehabilitation, and replacement of flood control works. These additional financial considerations on local communities made affordability a more pressing concern, and may have begun an

A FLOODED ROADWAY (SOURCE: ISTOCK).

unintended shift toward designing levees to meet the minimum NFIP requirement (1-percent-annual-chance flood) rather than to meet a risk standard, reinforcing the mistaken assumption that the 1-percent-annual-chance flood standard of the National Flood Insurance Program was a "safe" level of flood risk reduction.

Currently, there are almost 500 levees across the nation that are accredited as part of the NFIP (source, FEMA), and roughly 270 of these levees are within the USACE levee portfolio. Accredited levees in the USACE levee portfolio have about 3.6 million people and property value of about $400 billion behind them. Approximately 30% of accredited levees in the USACE levee portfolio are characterized as having a Very High, High, and Moderate risk. This highlights why accreditation for NFIP does not provide a guarantee of low risk to the public and property and should not be inferred to be a public safety standard. These Very High, High, and Moderate risk levees that are accredited have about 2.5 million people and property value of $290 billion behind them. Over half of these Very High, High, and Moderate risk levees that are accredited have one or more performance risk drivers (e.g., seepage, erosion, etc.) for flood loadings prior to overtopping. These facts illustrate that despite accreditation, which focuses on the performance of the levee for the 1-percent-annual-chance flood, the risk associated with levees goes beyond the performance of the levee itself and is characterized by the combination of hazard, performance, and potential consequences.

FACTORS THAT CONTRUBUTE TO FLOOD HAZARD

Risk associated with flooding in a particular leveed area changes over time. The probability of flooding in the leveed area can increase if storm intensity increases, floods are longer in duration, or more runoff reaches the levee due to development. These and other factors and changes in hydrology effectively decrease the expected performance of the levee, resulting in more frequent overtopping or increased potential of the levee breaching. For example, the following factors all play a part in understanding the flood hazard:

- **Frequency of water on the levee.** Frequency and duration of the flood loading play a significant role in the risk characterization of levees. Levees that are subject to frequent flood loadings may have a higher aggregate risk than levees that are subject to very infrequent events.
- **Duration of high water.** Levees that experience long duration flood events are more likely to develop performance issues associated with breach prior to overtopping failure modes such as embankment and foundation seepage and piping. A levee breach during a long duration event may result in a larger inundation area and deeper flood depths that may increase consequences. Conversely, in short duration events, people may have limited warning time to evacuate.
- **Flood hazard is variable.** Rivers and drainage basins are ever-changing due to regional/global climate change and man-made activities that increase or decrease runoff within a watershed. The frequency of loading of coastal levees is impacted by similar factors, such as sea level rise and subsidence (settling) of the levee.
- **Age of flood hazard data.** The loading frequencies used in the risk assessments for nearly 40% of all levees in the USACE portfolio are based on hydrology data and analyses that are more than 20 years old. The lack of current hydrology and accompanying hydraulics modelling across the entire portfolio is a source of uncertainty in the risk characterization for many levees.

FINDINGS AND DISCUSSION

In many cases, our understanding of the flood hazard is based on outdated information. The loading frequencies used in the risk assessments for 37% of the Very High and High risk levees are based on hydrology data and analysis that is over 20 years old. Understanding the flood hazard can be the lynchpin of levee risk assessments. Rivers and the drainage basins are ever-changing due to regional/global climate change and man-made activities that increase or decrease runoff. The frequency of loading of levees in coastal areas is impacted by similar factors, such as sea level rise and by regional subsidence.

- USACE developed and maintains the Corps Water Management System (CWMS, http://www.hec.usace.army.mil/cwms/cwms.aspx)—a system that has greatly enhanced the availability of hydrologic models, hydraulic models, and reservoir operations models within watershed basins across the nation. USACE is continuing to invest in CWMS to improve hazard information. While CWMS does not address all of the uncertainty regarding flood hazard, it is an important tool for improving the understanding of the flood hazard.

- USACE will work with other federal agencies to share information and improve understanding of extreme hydrologic events.
- USACE will continue to support the existing network of stream gauges in the United States, as well as addition of new gauging stations. The collection of water level data and flow data is an absolute critical input to understanding flood hazards.

Levees accredited in the National Flood Insurance Program (NFIP) can have high risk. Two hundred and seventy of the approximately 500 accredited levees in the nation (source, FEMA) are part of the USACE portfolio. Approximately 30% of accredited levees in the USACE levee portfolio are characterized as having a Very High, High and Moderate risk. This highlights why accreditation under the NFIP does not provide a guarantee of low risk and should not be inferred to be a public safety standard. One of the reasons for this disconnect is that NFIP accreditation focuses on assessing levees at the 1-percent-annual-chance flood, the risk associated with levees go beyond the performance of the levee itself and is characterized by the combination of hazard, performance, and potential consequences.

- USACE is working closely with the Federal Emergency Management Agency (FEMA) to ensure that all communities that participate in the NFIP have risk information for levees collected by USACE, so that they may use that information to not only inform future NFIP decisions, but effectively make investments to manage risk. Every time USACE conducts an inspection or risk assessment on an NFIP levee, regardless of its accreditation status, that information is shared with FEMA and the community. FEMA can coordinate with the community about how this information may affect levee accreditation.
- USACE is updating the methodology it uses to make NFIP accreditation recommendations, moving toward using a risk assessment to make these recommendations. This methodology looks at all potential floods that could occur at any elevation on the levee, giving a more accurate representation of risk.

A FLOODED ROADWAY (SOURCE: ISTOCK).

USACE EFFORTS TO UNDERSTAND HYDRAULIC HAZARDS FOR FLOOD RISK MANAGEMENT PROJECTS

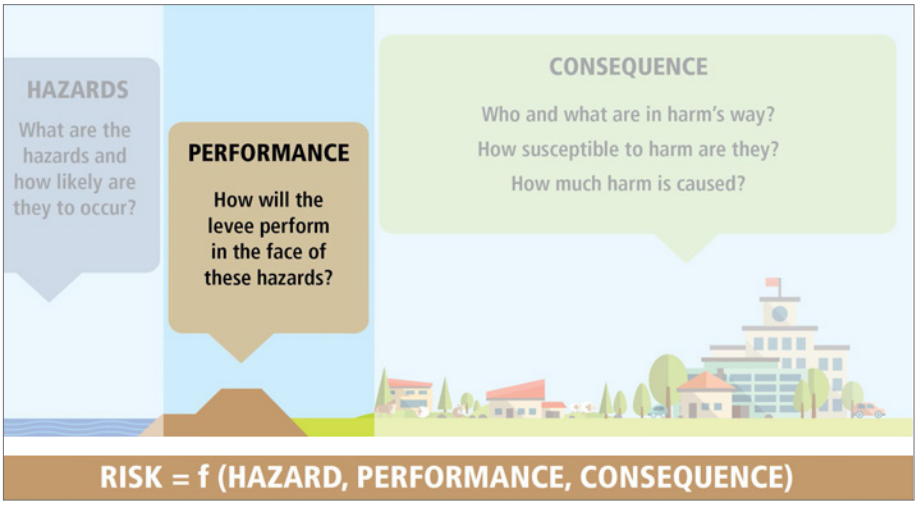
Understanding the flood hazard is critical for assessing and managing risks associated with levees. The frequency of the flood loadings informs the likelihood of hydraulic hazards that affect the levee and when combined with levee performance informs the likelihood of a levee breach. During levee risk assessments, USACE utilizes the best available information for assessing flood hazards. This available information may not be up-to-date or comprehensive due to the lack of available hydrological data or limited past hydraulic/hydrological studies.

USACE seeks to maintain investments in collecting up-to-date data, state-of-the-art technical tools, guidance, competency training, and research related to flood hazards.

The USACE Hydraulic Engineering Center (HEC), a Center of Expertise in hydrology and river hydraulics analysis, provides routine technical assistance and annual training to USACE personnel to better model and improve understanding of the flood hazards in the portfolio.

USACE maintains the Corps Water Management System (CWMS)—a system that has greatly enhanced the availability of hydrologic models, hydraulic models, and reservoir operations models within watershed basins across the nation. The models developed for CWMS provide valuable information and platforms to build further analyses needed to assess the flood loading frequency for levee systems. These CWMS models also allow the hydrologic frequency to be analyzed in a watershed systems context and account for complexities such as reservoir regulation, effects of adjacent levees, or break-out flows. Since 2013, USACE has spent $58 million and completed models for 95 out of 201 watershed basins across the nation.

SECTION 6: LEVEE PERFORMANCE: UNDERSTANDING LEVEE COMPONENTS AND EXPECTED PERFORMANCE



PERFORMANCE COMPONENT OF THE RISK EQUATION USED BY THE USACE LEVEE SAFETY PROGRAM.

OVERVIEW

The levee risk assessment process evaluates the levee performance (or structural reliability of the levee system) by answering the question: How will the levee react or "perform" during a flood? Existing data from inspections, design reports, construction drawings, planning studies, previous flood performance, and local information are used to analyze the potential for breach prior to and during overtopping and the relative likelihood of that occurring.

The USACE levee risk assessment considers the likelihood of seven primary failure modes:

- Embankment and foundation seepage and piping;
- Embankment stability;
- Embankment erosion;
- Closure structures malfunction;
- Floodwall stability;
- Floodwall seepage and piping; and
- Levee overtopping resulting in breach.

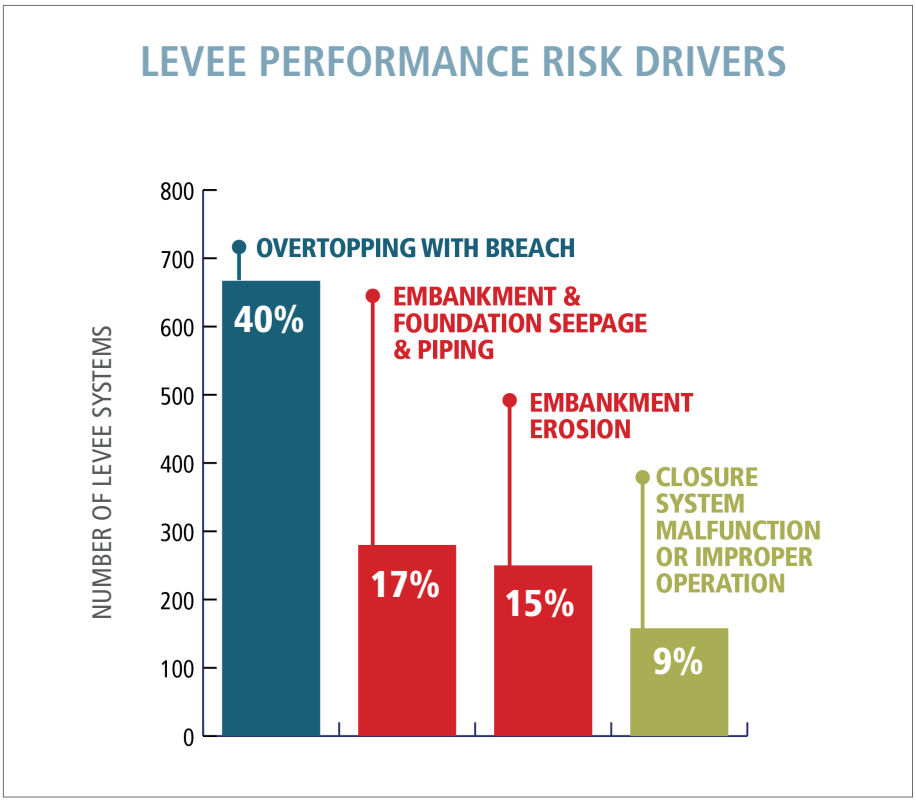
There are also secondary factors that are assessed for their contribution to the likelihood of the primary failure modes: encroachments, woody vegetation, animal burrowing, sod cover quality and culvert and relief well condition.

There can be substantial uncertainty about the likelihood of how the levee will perform depending on the extent the levee has been exposed to flood loading and unknown or unavailable levee design or performance information. These uncertainties are identified and documented in the risk assessment.

Levee overtopping with breach is the most common failure mode impacting levee performance within the portfolio. Embankment and foundation seepage and piping and embankment erosion are the two most common failure modes prior to overtopping with 17% and 15% of the portfolio levees impacted.

EARTHEN LEVEE EMBANKMENTS: VARIABLE SLOPE AND HEIGHT

The USACE levee portfolio mostly consists of levee embankments that are constructed with earthen materials with a specific slope and a crest. The performance of levee embankments is related to the



TOP FOUR LEVEE PERFORMANCE RISK DRIVERS IN THE USACE PORTFOLIO, BASED ON OVER 1,600 LEVEE SYSTEMS WITH COMPLETED RISK ASSESSMENTS.

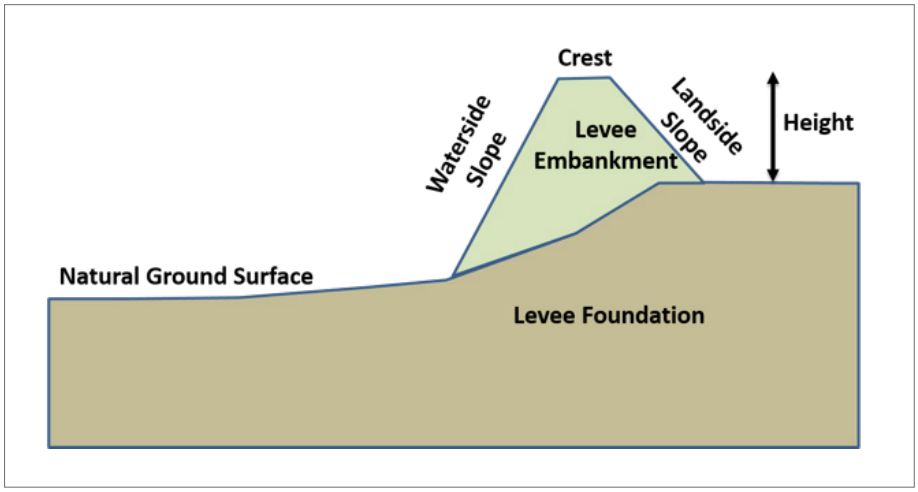
characteristics of materials used to construct it (e.g., fine-grained materials such as clay or silt or coarse-grained materials such as sand or gravel); construction techniques used to place and compact the materials; the embankment configuration (e.g., height, crest width, and slopes); flooding conditions (e.g., duration, turbulence, velocity, etc.); and levee embankment foundation conditions (e.g., compressibility, strength, transmissivity, etc.).

Before more modern levee engineering standards were established, earthen embankment levees were typically constructed of locally available materials from nearby borrow pits or dredging operations in adjacent rivers or streams. As a result, older earthen embankment levees consist of a wide range of soils including fine-grained soils (clays and/or silts), coarse-grained soils (sands and/or gravels), and rock fill; these various soil types impact the levee performance under a full range of flooding conditions.

Generally, steeper-sloped levees have less stability and less resistance to erosion when overtopped and may experience more performance issues such as a greater number of soil slumps or slides or erosion damage.

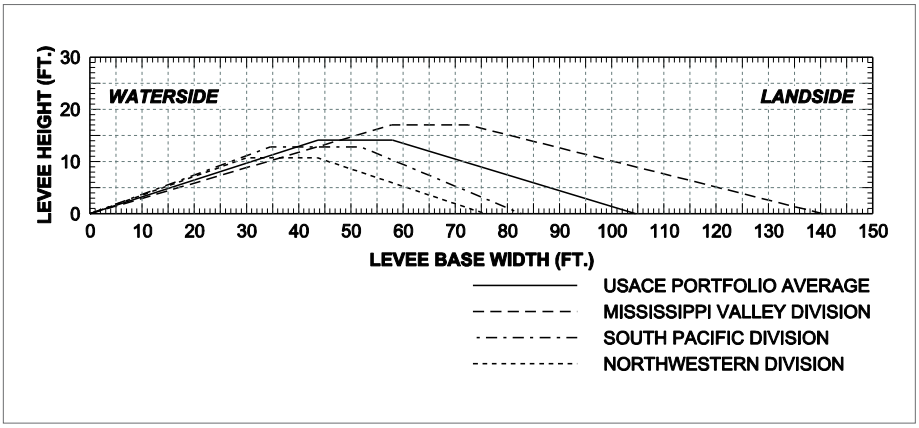
Based on the period of the construction for levees following a significant flood event or congressional appropriations for a levee system, levees in a region will often have some regional consistency in size and shape. Levee sponsors and USACE may see similar issues in levees across a region when conducting regular levee inspections and assessments.

For levees within the USACE portfolio, the average levee height is approximately 14 feet, the



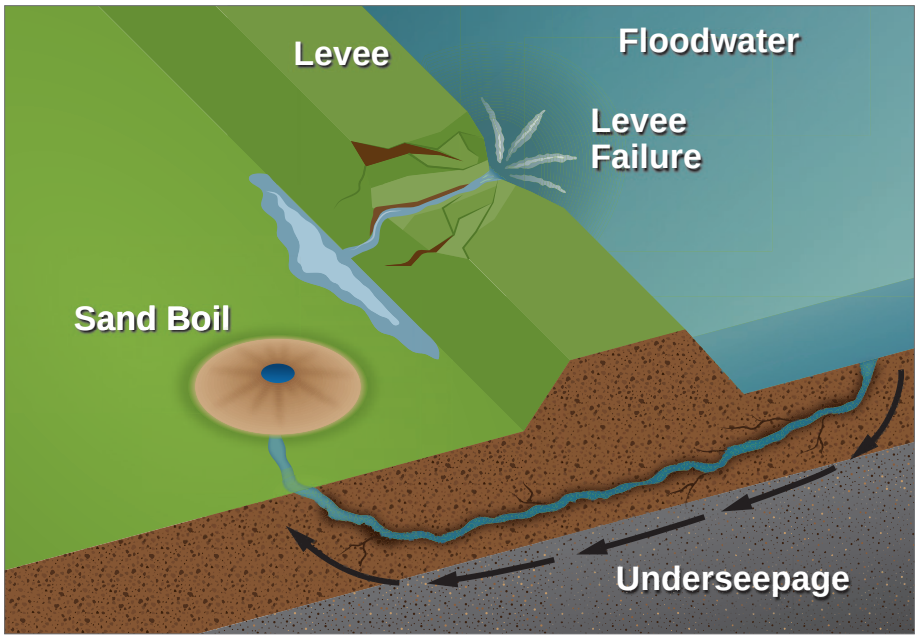
CROSS-SECTION OF A TYPICAL EARTHEN LEVEE.

maximum levee height is 40 feet, and the minimum levee height is under 3 feet. Evaluating the three USACE divisions with the largest amount of levee miles in the portfolio, average levee height and slope is quite variable. The Mississippi Valley Division contains over 6,200 miles of levees and generally has taller and wider levees than the average levee section in the nation. The Northwestern Division (NWD) contains over 2,400 miles of levees and the South Pacific Division (SPD) contains over 2,300 miles of levees. SPD and NWD generally have shorter and narrower levees than the average U.S. levee.



THE AVERAGE LEVEE SECTION IN THE U.S., AVERAGE LEVEE SECTION IN MISSISSIPPI VALLEY DIVISION, AVERAGE LEVEE SECTION IN NORTHWESTERN DIVISION, AND AVERAGE LEVEE SECTION IN SOUTH PACIFIC DIVISION.

Flooding hazards that can affect embankment performance include overtopping, wave, surge, static loading, and river currents along the embankment. Because of these hazards, poor embankment performance can occur due to embankment and foundation seepage, embankment instability, embankment erosion, and/or overtopping of the embankment. Nearly 40% of all levee systems in the portfolio have been identified to perform poorly during overtopping and will likely breach. Many of the levees in the portfolio lack either sufficient armoring or embankment materials to resist overtopping.



A TYPICAL EMBANKMENT AND FOUNDATION SEEPAGE AND PIPING FAILURE MODE WITHIN THE FOUNDATION OF THE LEVEE.

Embankment and Foundation Seepage

Embankment and foundation seepage is the second most common performance-related risk driver in the portfolio. Nearly 17% of the portfolio has been identified to perform poorly due to embankment and/or foundation seepage. Embankment and foundation seepage performance is mostly driven by the characteristics of the embankment and foundation or the characteristics and condition of pipes and culverts that penetrate the embankment or foundation. Past performance of the levee with regards to embankment and foundation seepage is a major indicator of future poor performance and is significantly considered in the risk assessment. The lack of past performance causes uncertainty in characterizing the risk, especially for embankment and foundation seepage. Thus, monitoring levees during flood events for seepage is essential to improve the performance (if

A VIEW OF THE TERRACED FLOODWALL THAT ALSO SERVES AS WALKING PATH ALONG THE NAPA RIVER, CALIFORNIA (SOURCE: USACE/DEDE CORDELL, HTTPS://FLIC.KR/P/AQWPUG).

flood fighting is required) and the understanding of the risk.

Embankment Erosion

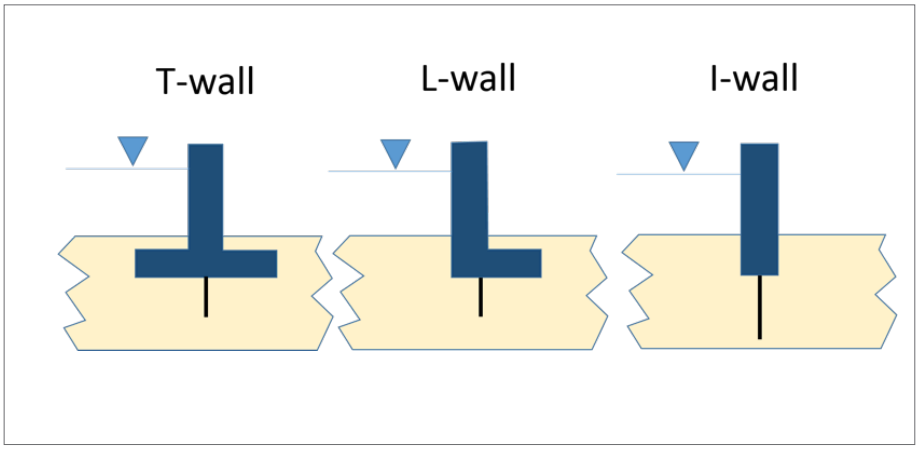
Nearly 15% of the portfolio has been identified to perform poorly due to embankment erosion. Embankment erosion performance for levees is dependent on the erodibility of the embankment given the stream/river velocity conditions along the embankment. For many levees in the western portion of the nation, embankment erosion is fairly common due to a greater prevalence of rivers or streams with high velocity flows combined with silty and/or sandy levee embankments. The location of the embankment erosion usually occurs along sharp stream/river bends. The past performance of the levee system is an important indicator of the potential for future embankment erosion.

Embankment Instability

Embankment instability is the least common risk driver for levee embankments in the portfolio. Only 8% of the portfolio has been identified to perform poorly due to embankment instability. Embankment instability is primarily caused by the embankment configuration, the levee embankment materials and/or foundation conditions and the flood loading (including duration of the flood to cause saturation of the levee embankment). Weak levee embankment and/or foundation soils can lead to embankment instability. The embankment slopes and height relative to the material and foundation strength are important factors where taller embankments with steeper slopes tend to have poorer performance.

FLOODWALLS

Roughly one quarter (more than 500 systems) of the USACE levee portfolio have floodwalls that make up all or part of the levee with the combined length of all the floodwalls totaling almost 500 miles. Ninety-seven percent (460 miles in total length) of the floodwalls are found in federal levees, with nearly 180 miles found in USACE-operated and maintained levee systems and roughly 280 miles found in levee sponsor-



TYPICAL FLOODWALL TYPES IN THE USACE LEVEE PORTFOLIO.

ANNUAL TESTING OF THE WASHINGTON, D.C., 17TH ST CLOSURE ENSURES THE STRUCTURE CAN BE ERECTED PROPERLY IN THE EVENT OF HIGH WATER (SOURCE: USACE/ALFREDO BARRAZA, HTTPS://FLIC.KR/P/NCOMZD).

operated and maintained levee systems.

Every USACE Division has floodwalls associated with levee systems within its boundaries. The Mississippi Valley Division (MVD) has the majority of the floodwalls within the portfolio at 200 miles of floodwalls. Beyond MVD, the South Pacific Division (SPD, 80 miles), Great Lakes and Ohio River Division (LRD, 76 miles), and North Atlantic Division (NAD, 55 miles) have a combined length of 211 miles of floodwalls. Floodwalls are commonly found in urban levee systems with a population of 10,000 people or greater in the leveed area. Floodwalls have been used in urban areas where land area along the levee is not available to construct an earthen levee embankment that requires a larger footprint.

Flooding hazards that can affect floodwall performance include overtopping, wave, surge, and waterside erosion. Floodwalls along navigable channels also may be subject to barge or water vessel impacts that can weaken or cause a breach during high water. Poor floodwall performance can occur due to floodwall instability (i.e., overturning of the floodwall or structural failure of critical wall components), seepage beneath the floodwall, or overtopping of the floodwall. The average floodwall height in the portfolio is six feet but can be greater than 35 feet.

Based on risk assessments completed, only 10% of the levee systems with floodwalls are expected to have poor performance due to instability or seepage beneath the floodwall, and have the floodwall as a risk driver. Floodwall instability is the most common contributor to poor floodwall performance.

INSTALLING A CLOSURE SYSTEM FOR A LEVEE SYSTEM NEAR THE NATIONAL MALL IN WASHINGTON, D.C. (SOURCE: USACE/ALFREDO BARRAZA, HTTPS://FLIC.KR/P/NCOSTC).

Within the USACE levee portfolio, there are three typical floodwall types: T-walls, L-walls, and I-walls, named for the shape of the floodwall and its footing. Impacts of floodwalls on levee-related flood risk were highlighted in the lessons learned and findings from the performance of the New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRRS) during Hurricane Katrina in 2005 (IPET 2007–2010). Four significant levee breaches occurred during Hurricane Katrina as a result of poor performance of I-walls. I-walls make up approximately 30% of the floodwalls in the portfolio with a total length of almost 150 miles. Within the USACE portfolio, I-wall heights range from under 3 feet to up to 20 feet.

I-walls under flood loadings are prone to develop a waterside gap adjacent to the wall which, if unaccounted for, can cause the wall to become unstable. I-walls also are vulnerable to overtopping erosion, which can lead to instability. Since Hurricane Katrina, USACE risk assessment methodologies for levees have incorporated these lessons learned, and new USACE design and construction guidance has been issued to address these I-wall vulnerabilities (Engineering and Construction Bulletin 2017-3, Design and Evaluation of I-walls Including Sheet Pile Walls).

CLOSURE STRUCTURES

Closure structures are commonly used to provide temporary closure of an opening in the levee system. Often these openings in the levee system are due to roadway, railway, or pedestrian walkway crossings through the levee. Closure structures may be temporary, such as sand bags, stop log closures, and removable panels that require

RELIEF WELLS ALONG THE MISSISSIPPI RIVER INSTALLED SINCE THE 2011 FLOOD EVENT (SOURCE: USACE).

placement prior to an impending flood event. Closure structures may be a permanent feature of the levee system, such as gate closure structures (e.g., swing gates, miter gates, rolling gates, etc.) that require operation prior to an impending flood event. Within the USACE levee portfolio, the most common types of closure structures are:

- **Culvert Gate Closure** – found in 521 levee systems.
- **Sandbag Closure** – found in 234 levee systems.
- **Stoplog or Bulkhead Closure** – found in 189 levee systems.
- **Movable Gate Closure** – found in 150 levee systems.
- **Post and Panel Closure** – found in 113 levee systems.
- **Soil and Plastic Closure** – found in 92 levee systems.

Roughly half (almost 970) of levee systems within the USACE levee portfolio have closure structures that require installation or operation during flood events to ensure the levee performs as intended. It is not uncommon for levee systems to have multiple closure structures. Closure structures are found in roughly 50% of the federal levee systems and 35% of the non-federal levee systems in the USACE levee portfolio. Every USACE Division has closure structures associated with levee systems within its boundaries.

Closure structures are found both along levee systems with little to no population and very high (greater than 100,000) population in the leveed area. Closure structures are most commonly found in levees with more than 1,000 people behind them; roughly 70% of these levee systems have closure structures. Closure structures are less commonly found in levee systems with fewer than 1,000 people behind them; only 40% of these levee systems have closure systems.

Closure structures can range from under 3 feet in height (common for sand bag closures) to greater than 16 feet (common for structural closures like moveable gate closures).

Malfunction of closure structures can occur due to closure structure condition (a critical factor for post and panel, stop log or bulkhead, and culvert gate closures); operating plan and experience in closure operation (a critical factor for moveable gate and sand bag closures); and closure construction method for soil and plastic closures.

Risk assessments indicate that 20% of the levees with closure structures are expected not to perform as intended due to the lack of operation plan or experience, secure storage location for closure installation materials, poor condition, and lack of recent maintenance. Levee-related flood risks for closure structures can be reduced through modest investments in operation and maintenance activities, including routine testing, inspection, proper installation, availability of closure materials (e.g., sand bags), and functionality of culvert/flap gates.

SEEPAGE CONTROL SYSTEMS

Seepage control systems such as toe drains and pressure relief wells are commonly used to help safely relieve seepage pressures through and/or beneath levees and prevent a levee breach due to embankment and/or foundation seepage. These seepage pressures can occur during flooding events due to pervious materials such as sand within the levee foundation and/or embankment. If seepage pressures become excessive, levee instability and/or seepage and internal erosion of the levee embankment and/or foundation can occur, leading to a levee breach.

Seepage control systems can consist of pressure relief wells, toe drains, a partial penetrating toe trench, horizontal drainage blankets, or any combination of these features. Toe drains and partially penetrating toe trenches are generally designed to relieve shallow seepage forces near the toe of the levee, while pressure relief wells are generally used to control deeper seepage pressures. Horizontal drainage blankets are sometimes placed in conjunction with toe drains or trenches to assist in relieving seepage within the embankment or at the interface of the levee embankment and foundation. There are over 440 levee systems with seepage control systems. Seepage control systems are found in roughly 20% of the federal levee systems (35 USACE-operated and maintained systems and 380 levee sponsor-operated and maintained systems) and in only 6% (27) of the non-federal levee systems in the USACE levee portfolio. Every USACE Division has seepage control systems associated with levee systems within its boundaries, thus they are utilized widely throughout the United States.

Other seepage control measures may be utilized such as a seepage cutoff wall within the embankment and/or foundation or seepage berms that are used on the landside of the levee near the toe to resist seepage pressures. Detailed documentation of the types and dimensions of seepage cutoff walls and berms is not captured within the USACE levee inventory documented in the National Levee Database, but these features are present across the entire USACE portfolio. The presence and benefits of seepage cutoff walls and seepage berms for the embankment and/or foundation seepage failure mode are identified during the risk assessment process.

It is estimated that there are over 10,000 relief wells associated with the USACE levee portfolio and over 275 miles of toe drains.

Poor seepage control system performance can occur due to defects or deterioration in the seepage control system, which may cause levee embankment or foundation materials to pass freely through the system or a clogged seepage control system that will not relieve seepage pressures as intended. Poor seepage control system performance can lead to embankment/foundation seepage failure modes or levee instability, and subsequently a levee breach.

Based on risk assessments completed on the portfolio, where seepage control systems are present, about 25% are highly likely to contribute to embankment and foundation seepage failure modes and 40% are a source of uncertainty regarding the performance of the levee. Thus, seepage control systems require routine and periodic monitoring and testing as well as maintenance to ensure proper performance.

USACE Engineer Manual (EM) 1110-2-1914, Design, Construction, and Maintenance of Relief Wells, recommends that well systems be tested every five years and maintenance is required if the well system efficiency reduces below 80% of the original. With maintenance costs at $10,000–$25,000 per well depending on the size, depth, and severity of clogging, life cycle cost studies should be considered when using seepage control systems such as relief wells.

USACE LEVEE INSPECTORS INSPECT THE CONDITION OF A PIPE DURING A ROUTINE LEVEE INSPECTION ON THE SACRAMENTO RIVER, CALIFORNIA (SOURCE: USACE/CHRIS GRAY-GARCIA, HTTPS://FLIC.KR/P/E6LDQ6).

PIPES AND CULVERTS

Pipes and culverts are features in levee systems commonly used for management of interior drainage; however, improper construction or deterioration of the culvert or pipe can lead to seepage-related failure of the levee system. Culverts are a very common levee system feature in the portfolio with approximately 1,900 levee systems (85%) having at least one culvert or gravity drain through or beneath the levee. With approximately 16,000 culverts that run through or beneath levees in the USACE portfolio, most levee systems have multiple culverts.

USACE Engineer Manual (EM) 1110-2-2902, Conduits, Culverts, and Pipes, recommends minimum culvert diameters of 36 inches for agricultural levees and 48 inches for urban levees. These minimum diameters for culverts are necessary to allow for adequate inspections and maintenance; however, the majority of the culverts in the portfolio are less than 48 inches in diameter and half of the culverts in the USACE portfolio are 24 inches or less in diameter due to a variety of reasons.

The two most common types of culverts in the portfolio are corrugated metal pipes and concrete pipes. Culverts constructed from corrugated metal pipes, approximately 40% of the culverts in the portfolio, are no longer considered good practice for levee construction due to the concerns of pipe corrosion leading to pipe failure and difficulties in achieving adequate compaction around them leading to seepage-related failure modes.

Culverts often have closure features that prevent flood water from entering the leveed area. The most common closure features on culverts are flap gates and sluice gates. As with levee closure structures, regular operation and maintenance, including testing mechanical closure structures, is important to maintaining the reliability and performance expected.

Deteriorating culverts and improper culvert construction techniques are a significant source of poor levee performance. Roughly 40% of the levee systems that have culverts are highly likely to contribute to seepage and piping failure modes leading to a levee breach. Culverts running through the embankment or foundation are the most common contributor to embankment and foundation seepage for the levee portfolio. This is primarily due to the poor condition of the culvert.

The cost of replacing failing culverts has increased over time due to updated engineering standards, including requirements for positive closure devices on at-grade drainage pipes and seepage filter requirements around the pipe, among other improved practices. More rigorous standards for pipes and culverts reflect the increased knowledge about their potential impacts to levee performance.

Pipes or culverts through levees, whether they are large or small, present operation and maintenance challenges for the levee sponsor as well as USACE. Large pipes correlate with costlier repairs and higher potential for pipe failure/

THE PUMP STATION AT THE WEST CLOSURE COMPLEX IN NEW ORLEANS, LA; THIS IS THE LARGEST DRAINAGE PUMP STATION IN THE WORLD (SOURCE: USACE).

collapse. Small pipes, on the other hand, are less costly to repair but harder to inspect and maintain and more likely to clog. Levee sponsors' Operations, Maintenance, and Inspection Plans are more effective when customized to the number, size, and types of culverts running through their levee systems. For example, incorporating videotaping/remote sensing, culvert replacement plans, and a robust inspection and maintenance schedule are best practices for such plans.

PUMP STATIONS

Pump stations are used to manage interior drainage behind levee systems to prevent flooding, and are most often used during flood events inside the leveed area. The operation of pump stations varies by levee system; some are in use every day, others may only be operational once or twice a year.

There are over 2,500 pump stations within the USACE portfolio. Pump stations represent a significant operation and maintenance responsibility for levee owners/operators, regardless of the frequency of their operation. This responsibility requires staff to operate and maintain the pump station, including maintenance of pumps, pipes, valves, and pump structures, and meet power requirements (main and backup) to ensure proper pump station function during flood events.

The failure of a pump station can result in slowly rising flood levels, which is unlikely to lead to loss of life but has a potential for economic damages. Regular testing and operation and maintenance of pumps is an important component of reducing flooding inside the leveed area. In most cases, pump station functionality is unlikely to result in a prior-to-overtopping levee breach, but may be an operation and maintenance priority for a levee sponsor because it can reduce regular nuisance flooding in the leveed area.

FINDINGS AND DISCUSSION

USACE is already reaping the benefits of information obtained from our levee risk assessments by improving policies and investments in understanding of the mechanics, challenges, and impacts of key risk drivers. USACE has collected risk information across the portfolio to inform the most important policy, guidance, and tool updates.

- USACE has been working for the last few years to improve risk-informed decision making. Levee Safety Program – Policy and Procedures (EC 1165-2-218) provides the policy, procedures, and guiding principles of the levee safety program in a risk framework. Design, Construction and Evaluation of Levees (EM 1110-2-1913) includes guidelines for utilizing risk-informed levee design and construction methodologies. Both are scheduled for release in 2018.

- USACE will be making available two tools aimed at helping any levee owner/operator improve their understanding of the condition and risks associated with their levees. The first tool is the Levee Inspection System, an electronic, tablet-based inspection tool that aids inspectors in collecting condition information including GIS-locations of deficiencies or areas of concern. Additionally, inspection information will be able to be directly uploaded to the National Levee Database and able to be used by emergency managers immediately to inform evacuation and flood fighting efforts. Further, it will allow levee owners/operators to track condition trends over time, store photographs and other pertinent information. The second tool is the Levee Screening Tool, a simplified, risk assessment tool that USACE currently uses to conduct screening-level risk assessments. USACE is making these tools available over the next year with the intent to make it easier for owner/operators to conduct these activities on their levees and to promote a common methodology for understanding levee risk across the nation.

The most significant risk driver for breach prior to overtopping in the USACE portfolio is embankment and foundation seepage and piping. The estimated cost to mitigate this risk driver is the largest cost of any single breach prior to overtopping failure mode in the portfolio. Aging and deteriorating culverts penetrating through the embankment or foundation is the most common contributor to embankment and foundation seepage for the portfolio. Repair and replacement of the culverts within the levee portfolio is a significant future investment need.

- USACE has invested heavily in the revision of two engineering manuals (EM 1110-2-1913 and EM 1110-2-2902) that are slated for publication in next few years and will be critical for addressing the risk of embankment and foundation seepage and piping. On a similar note, USACE is conducting state-of-the-art research in collaboration with international partners to understanding the phenomenon of seepage and piping failure mode.

Risk characterization of a levee system is based on a "weakest link" approach, identifying the risk factors associated with the most critical levee-related flooding outcomes (e.g., breach prior to overtopping). A risk assessment may not necessarily identify all the risk factors associated with a levee system. For example, if a particular culvert is identified as a risk driver, the assessment would not necessarily be able to answer the question of what risk is posed by the "next worst" culvert.

- USACE recognizes the difficulty of physically inspecting culverts and the prevalence of culverts as risk drivers within the USACE portfolio. USACE is working to understand the role pipes and culverts play in seepage and piping failures of levees, and improve culvert and pipe inspection technologies.

SECTION 7: CONSEQUENCE: WHO AND WHAT ARE IN HARM'S WAY?

CONSEQUENCE COMPONENT OF THE RISK EQUATION USED BY THE USACE LEVEE SAFETY PROGRAM.

OVERVIEW

There are three main factors considered in estimating the consequences in the leveed area of a potential levee breach.

- **Exposure:** Who and what can be harmed if the levee were to breach prior to or during overtopping? During flooding, people, private and commercial property, public infrastructure (e.g., roads, hospitals, police stations, water treatment plants, and schools), and the environment are often exposed to and impacted by flood waters. These factors are captured quantitatively in a risk assessment as population at risk, the value and number of structures at risk, and critical infrastructure at risk. Impacts to the natural environment (e.g., released pollutants), impacts to agricultural interests, and other social impacts (e.g., historic structures) are captured qualitatively through discussion with the levee sponsor, USACE District, and risk assessment team members.
- **Vulnerability:** How susceptible to harm are the people and property located behind the levee system? Vulnerability is measured by people's ability/willingness to evacuate the area prior to flooding and the ability for property to withstand flooding. This vulnerability is evaluated through flood depths and velocities, assessment of the communities' level of emergency preparedness, assessment of the ability and willingness of residents to evacuate, and the ability of the local roads to handle an influx of traffic during an evacuation.
- **Consequences:** How much harm will be done if the levee breaches? The consequences of a levee breach are assessed for loss of life and economic damages. The loss of life and economic damage estimates are calculated based on the depth of flooding in relation to the people and property who are still in harm's way when the water arrives. Estimates of consequences can have a large degree of uncertainty, because it is unknown when and where a levee will breach and how people will react when it does. To capture and discuss this uncertainty, a consequences narrative is developed for each levee system during the risk assessment process.

EXPOSURE: WHO IS IN HARM'S WAY?

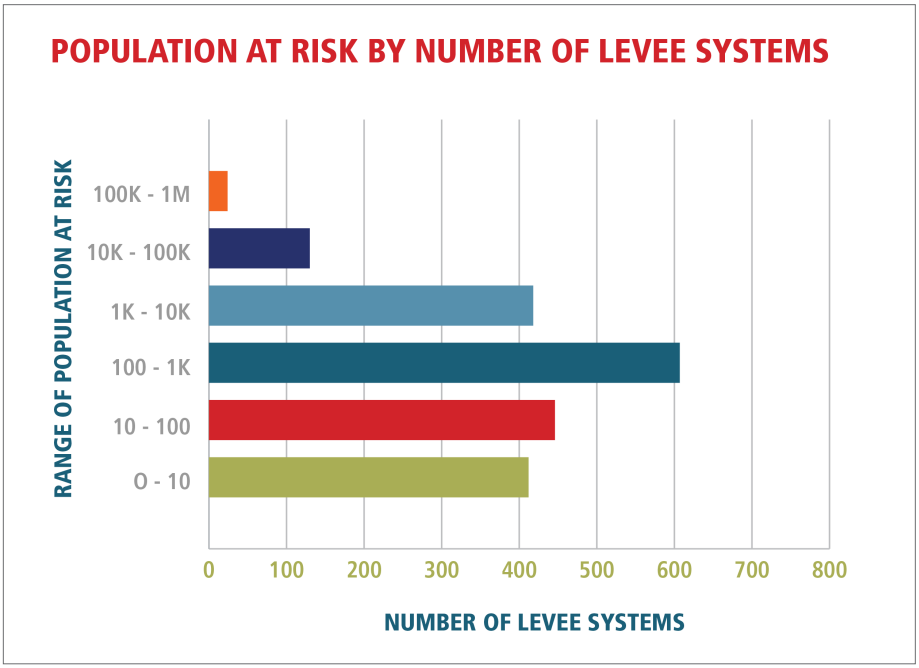
Approximately 11 million people live and work in the area behind USACE portfolio levees, approximately the same as the

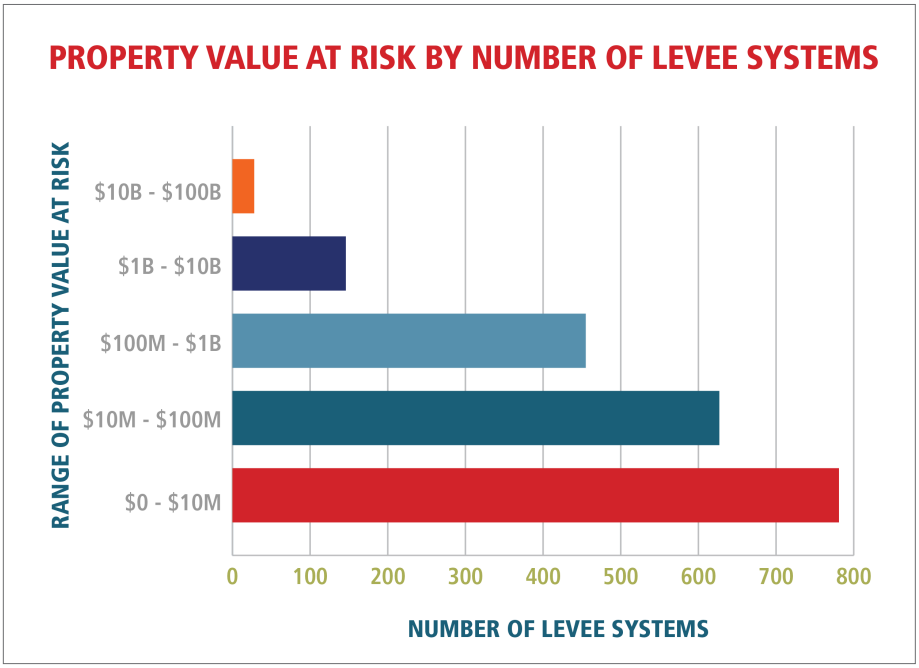
combined population of Los Angeles, Chicago, and Houston. This population is not equally distributed behind all the levees. Some leveed areas are significantly more urban than others—86% of the 11 million people are concentrated behind roughly 150 levee systems. These levee systems are along urban areas with populations in excess of 10,000 in the leveed area. While there are highly urban areas along levees, most of the levees in the USACE portfolio (more than 1,400 levee systems—more than 70% of the portfolio) have relatively low populations living behind them (fewer than 1,000 people).

In addition to the populations within leveed areas, a levee also may manage flood risk for critical infrastructure such as hospitals, electrical power generating facilities, and schools, and prevent impacts to the economic value of structures (houses, businesses, factories, etc.) in the leveed area. The breadth of consequences of levee-related flooding in the portfolio reinforces the important role of communities as partners in assessing, managing, and communicating levee risk.

EXPOSURE: WHAT IS IN HARM'S WAY?

The leveed areas of USACE portfolio levee systems vary from 0.10 acres to 7,500 square miles, for a total of 122,000 square miles. Not surprisingly, the size of the leveed area correlates directly to the length and height of the levee system, the taller and longer the levee, the more area lies behind it.





THE USACE PORTFOLIO IS DIVERSE, WITH LEVEES RANGING FROM HIGHLY URBANIZED - WITH LARGE POPULATIONS AND LARGE PROPERTY VALUES IN THE LEVEED AREAS - TO VERY RURAL.

Approximately $1.3 trillion of property value exists behind the USACE levee portfolio. Mirroring population, there are a relatively small number of highly urban levees (174 levee systems) that have leveed areas with property

DID YOU KNOW?

The USACE portfolio includes approximately 14,150 miles of levees, enough to extend from Los Angeles to New York City more than 5 times.

The leveed area in the portfolio is approximately 122,000 square miles, approximately the area of the state of New Mexico, the fifth largest state in the U.S.

Levees in the portfolio reduce the risk of flooding to more than 300 colleges and universities.

More than 30 major venues for professional sports teams are located behind levees in the portfolio.

Levees in the portfolio reduce the risk of flooding to refineries across the United States that collectively contribute more than 25% of the national daily refinery capacity.

value in excess of $1 billion, with the majority of levees (1,863 systems) having less than $100 million in property value. Regardless of the density of property, population, and economic activity, USACE portfolio levees reduce the risk of flooding to some of our most vital infrastructure. From roads, schools, police and fire stations to historical sites and national treasures, there are countless structures behind levees that provide invaluable services to our communities and nation. These structures also help to sustain our economy and provide venues for recreation, among other activities.

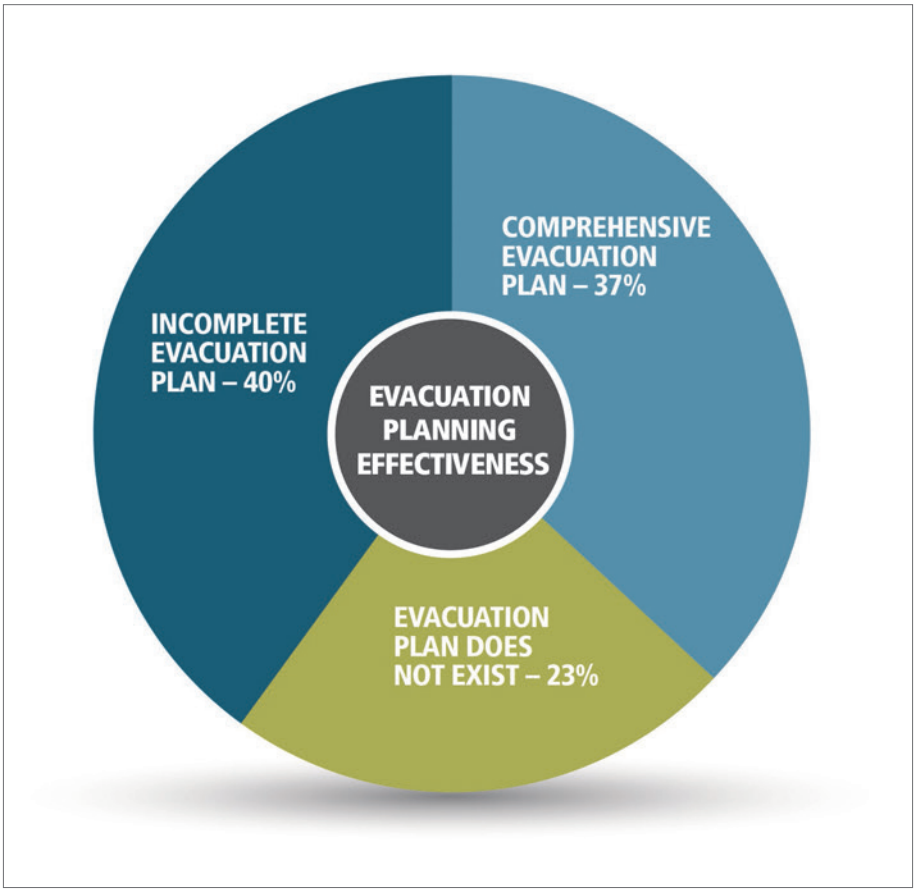
For example, there are almost 4,500 schools located behind levees that collectively enroll over two million students. In addition, more than 25% of the nation's daily oil refining capacity sits behind levees. Damage to or breach of these levees could significantly impact local, regional, and national resources.

HOW MUCH HARM COULD BE CAUSED?

Assessing, managing, and communicating flood risk to people, property, and the environment are primary missions of the USACE Levee Safety Program and life safety is the primary consideration in the levee risk characterization and LSAC assignment. Risk assessments quantify potential for loss of life and direct economic damages by determining the people, structures (residential, commercial, or industrial), infrastructure, and environment that will be in harm's way when water arrives, and comparing those estimates to potential loss of life and damages to occur from inundation. Characteristics of the flood inundation—such as flood depths, velocity, and duration—affect the loss of life and damages caused.

The deeper the water is expected to be, the higher the risk for loss of life and the greater the damage done to structures. This risk is assessed for three inundation scenarios: a breach of the levee prior to the levee overtopping, malfunction of levee system components, and overtopping of the levee with subsequent breach. The potential for loss of life is considered to be greater when the levee breaches prior to overtopping because it happens suddenly and people are typically more surprised by sudden flooding. When people see water coming over a levee it becomes more apparent that evacuation is needed. Furthermore, a sudden hole in a levee can create a situation where there are significant water depths and velocities in the immediate vicinity to the breach.

Within the USACE levee portfolio, the potential for life loss associated with a levee breach ranges from more than 2,000 lives to none.



COMMUNITIES BEHIND ONE QUARTER OF THE LEVEES IN THE PORTFOLIO DO NOT HAVE AN EVACUATION PLAN.

Roughly 2% of the portfolio levees have potential life loss estimates in the 100s to 1,000s. Levees that have populations at risk of 1,000 to 100,000 or more are often near urban areas. Twenty-eight percent of the portfolio levees have potential life loss estimates in the 1s to 100s. These levees have 1 to 10,000 or more population at risk with a mixture of urban or rural areas behind them. Thus, there is significant variability in factors (e.g., depth of flooding, urban or rural area, excavation effectiveness, etc.) across the portfolio that affect potential life loss. Since potential for life loss is a primary factor in the LSAC assignment, Moderate to Very High risk levees typically have a potential for life loss combined with a likely flood hazard and concerns with poor levee performance.

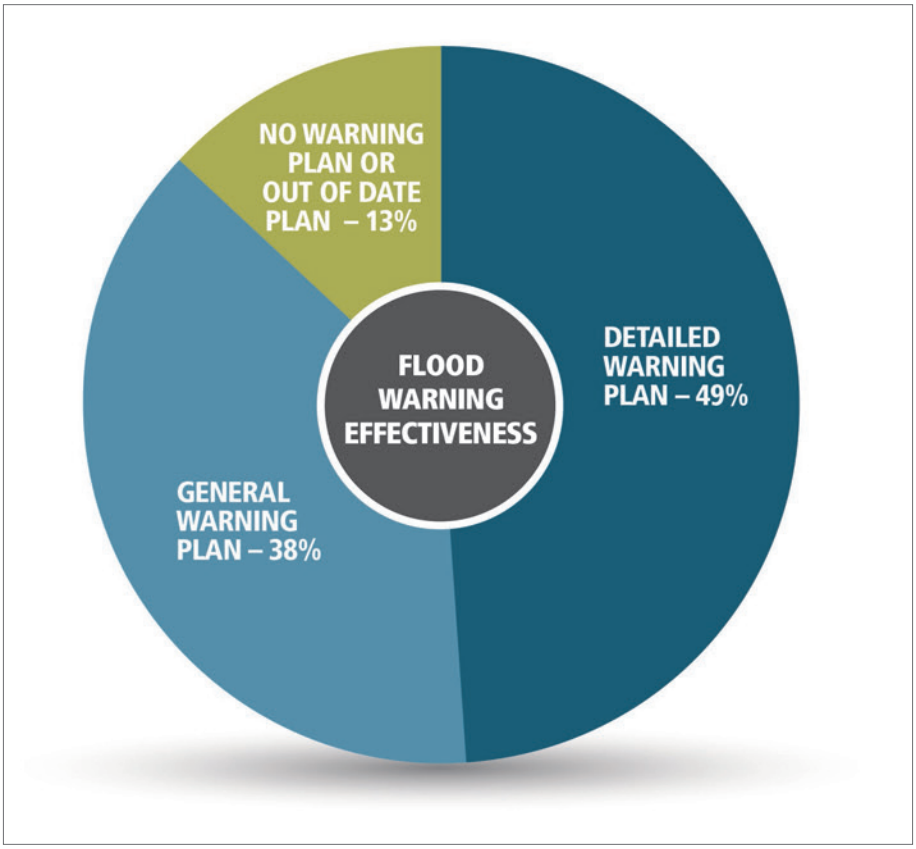
The potential for economic damages associated with levee breach is more than $500B for the portfolio. Economic damage estimates for levees within the portfolio range from more than $40B to less than $1M. Similar to the life loss estimates, there is significant variability in factors across the portfolio that affect economic damages, such as the flooding characteristics due to a levee breach (e.g., depth, velocity and duration) and characteristics of the structures that are inundated (e.g., residential, commercial or industrial structures, single-story or multi-story structures).

VULNERABILITY: THE IMPORTANT ROLE OF EMERGENCY PREPAREDNESS AND LOCAL FLOOD AWARENESS

There are three separate but related factors that are evaluated in a USACE risk assessment to determine how likely it is that people will be in harm's way should a levee breach. The three factors—evacuation planning effectiveness, flood warning effectiveness, and community flood awareness—are evaluated separately but are combined to determine an overall evacuation effectiveness factor. This factor is one component of the estimate for the number of people who are likely to successfully evacuate in an event of a levee breach.

Evacuation Planning Effectiveness

The effectiveness of evacuation planning is one of the factors evaluated in the levee risk assessment. Nearly 40% of levees in the USACE portfolio have either a comprehensive emergency plan or recent evacuation success. For these communities, the local Emergency Management Agency



COMMUNITIES BEHIND ALMOST HALF OF THE PORTFOLIO LEVEES HAVE NO DETAILED FLOOD WARNING PLAN.

(EMA) maintains a warning and/or evacuation plan for the community that contains specific information that would be provided in the case of a flood emergency. That content includes a description of the flood threat, specific information on the locations at risk, what actions the public should take and how to take them (which evacuation routes to take), when the at-risk population should start and complete those actions, and why taking those actions is a good idea. Also, a successful recent evacuation is indicative of an acceptable emergency action plan.

Forty percent of levee systems assessed have an incomplete emergency action plan; the local EMA maintains a warning system or evacuation plan for the threatened community, but it does not have message templates or directions explained in a detailed plan. USACE research indicates that an incomplete emergency action plan is better than no action plan at all, and that minor investments such as tabletop exercises or developing message templates can lead to much more effective execution. Evacuation planning also can be improved by reducing traffic congestion by better identification of evacuation routes and implementation of measures such as contra-flow.

Twenty-three percent (23%) of all levee systems assessed have no evacuation plan. This impacts more than 500,000 people living and working behind USACE portfolio levees.

Flood Warning Effectiveness

Community emergency preparedness also is impacted by the adequacy of a local flood warning plan.

Nearly half of assessed levees are in a community with a detailed flood warning plan. In these communities, the EMA has a written warning plan and standard operating procedure (SOP) for issuing warnings. Responsibility for issuing a warning is clearly defined, warning thresholds that relate the flood threat to the recommended public protective action are in place, and SOP drills are regularly conducted. Additionally, the agency has access to multiple warning systems or channels (e.g., auto-dial telephones, Wireless Emergency Alert, sirens, etc.) that would be used in the case of a major flood.

Approximately 38% of the systems are in communities with a general (multi-hazard) warning plan. These communities have an emergency evacuation plan and general guidance on warning procedures, which may not specifically include flood hazards. These multi-

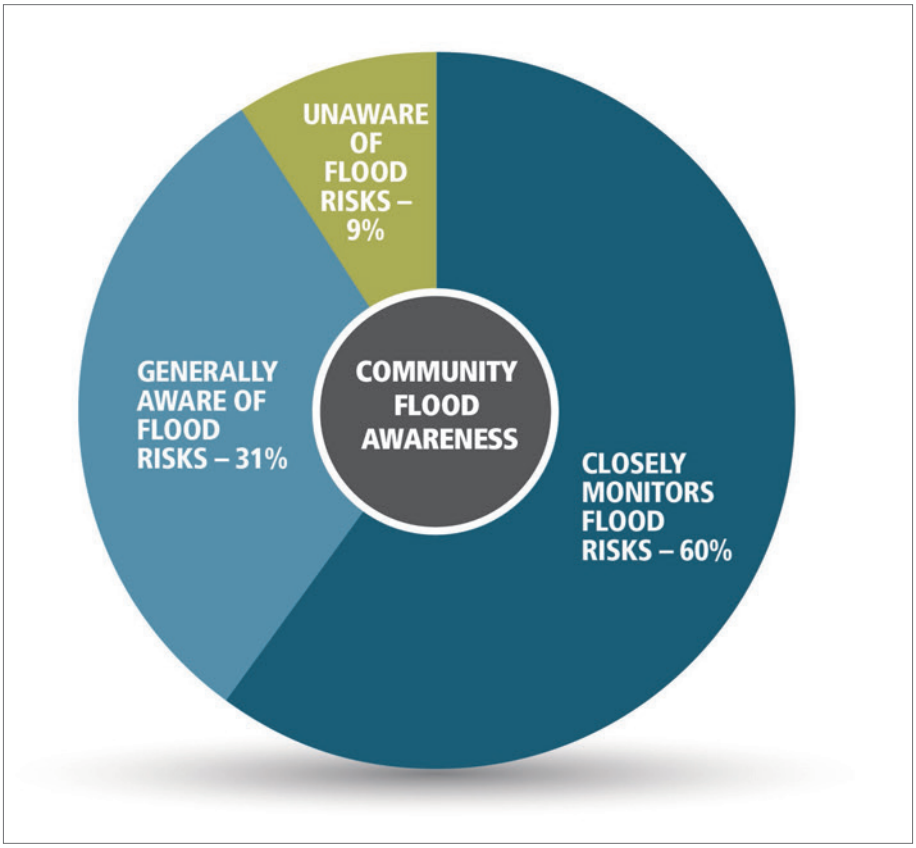
hazard warning plans can be more effective by clearly defining roles and conducting drills. The warning process relies primarily on emergency responders to spread the warning. The procedures are reviewed and updated at regular intervals.

Thirteen percent of assessed levee systems have either no flood warning plan, or their plan is out of date; flood warning procedures in the community either do not exist or are outdated. This impacts more than 600,000 people living and working behind USACE portfolio levees.

Flood warning effectiveness could be improved for nearly half the systems of the USACE portfolio. More than 10 million people live and work behind levees in the USACE portfolio that have some type of warning plan; however, nearly 7 million people live in areas that do not have a detailed warning plan specific to a flood hazard.

Community Flood Awareness

Awareness of flood risk allows communities and individuals to make risk-informed decisions about how to best manage their risk. This can have positive impacts on individual and community preparedness for a flood and potential support for future expenditures needed to operate and maintain or rehabilitate a levee.



COMMUNITIES BEHIND 90% OF THE PORTFOLIO LEVEES HAVE SOME AWARENESS OF FLOOD RISKS ASSOCIATED WITH THE LEVEE.

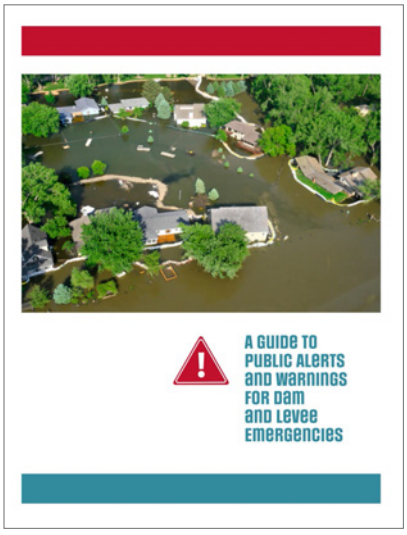
Of those evaluated, 60% of levee systems are in a community that closely monitors flood risk. In these communities, the public is very aware that it could be impacted by a levee breach or overtopping; it is often a topic discussed in local media. Local flood agencies routinely provide public education opportunities related to flooding and the role of the levee system, and they strive to increase awareness and preparedness in the community.

Approximately one-third of levee systems in the portfolio are in communities that are generally aware of flood risk. In these communities, the public is aware of the levee's role in flood risk reduction and generally understands that it is vulnerable to flooding, but there is no ongoing public awareness or education effort on flood awareness and the role of the levees.

In nearly 10% of levee systems, the community is generally unaware that it could be impacted by levee breach or overtopping. Although less than 10% of all levee systems are in communities that are unaware of flood risks, more than 3 million people live and work behind these levee systems. It can be more difficult to raise awareness in more heavily populated areas requiring, large scale communication efforts to

DID YOU KNOW?

The U.S. Army Corps of Engineers (USACE) has engaged with internationally renowned social scientists to better understand how warnings are issued and how they spread through communities that experience severe flooding. The findings from this research will (1) advance knowledge about the public warning process, (2) help improve how future public warnings and evacuations for any hazard are implemented, (3) enable dam and levee owners/ operators to better assess the existing risk posed by their assets, and (4) investigate nonstructural risk reduction measures alongside structural upgrades.



REPORT BY D. S. MILETI PH.D. AND J. H. SORENSEN PH.D. FOR THE USACE RISK MANAGEMENT CENTER, JUNE 5, 2015.

keep a high level of community awareness.

Flood awareness and emergency preparedness play a part in risk management for individuals and communities behind levees. Involved, informed individuals and communities behind levees will be better prepared to take meaningful actions to reduce risks to loss of life (e.g., practicing emergency action plans, warnings, and evacuations) or property (e.g., purchasing flood insurance, floodproofing or elevating structures) and provide adequate revenue for proper levee operation and maintenance. These measures increase public safety and reduce the potential for property losses.

FINDINGS AND DISCUSSION

There is a less comprehensive understanding and set of assessment methodologies regarding the complexities and interrelationships of other types of non-levee performance contributors to risk assessments such as evacuation effectiveness, risks to particularly vulnerable populations, and more comprehensively assessing risks of release of pollutants or harm to the natural environment.

- USACE will continue to support and apply the results of research and knowledge in social science to better understand how warnings are issued and how they spread through communities that experience severe flooding. This research will (1) advance knowledge about the public warning process, (2) help improve how future public warnings and evacuations for any hazard are implemented, (3) enable levee owners to better assess the existing risk posed by their assets, and (4) investigate nonstructural risk reduction measures alongside structural upgrades.
- USACE will continue to develop methods to better estimate life loss and economic damages because of levee breach or malfunction, such as levee breach analysis, breach-specific economic analysis, and breach formation analysis (size and time rate of breach formation). The size of a breach can significantly impact loss of life and economic damages.
- USACE will expand collection and analysis of human behavior observed during and after flood emergencies to compare it to research on evacuation effectiveness.

SECTION 8: ESTIMATING THE COST OF ADDRESSING LEVEE-RELATED RISK IN THE USACE PORTFOLIO

OVERVIEW

This report presents an understanding of the risk and risk drivers in the USACE portfolio. A natural question that follows: How much would it cost to reduce the risk identified in this report? Answering this question helps fulfill the role of USACE to develop approaches, tools, and solutions to support risk-informed decisions for levees within its portfolio. There are several reasons why the answer to that question is important and why a cost estimate has been included as part of this portfolio report:

- First, it helps decision makers at the federal, state, and local level understand the potential design and construction funding needs of the future. Understanding the magnitude of these needs is useful to make informed investment decisions. The cost estimate in this report does not try to indicate who pays (levee sponsor or federal government), but rather is the first attempt at using risk-informed data to estimate potential investment needs to reduce known risks within the portfolio.
- Second, the cost estimate helps to make focused investment decisions in the most cost-effective way to reduce risk. Developing an understanding of what are the most significant cost drivers and what types of risk management measures that effectively reduce risks can be crucial for the prioritization of funds to manage risks.
- Third, the estimate allows for us to identify areas where substantial investments will likely be made so that USACE can prioritize risk assessments, research needs, and guidance updates.
- Fourth, future portfolio cost estimates can be compared with the estimate in this report to provide a relative framework on the effectiveness of risk communication efforts and mitigation measures implemented by levee sponsors and USACE. More detailed risk assessments often result in a smaller future investment need than originally anticipated. The cost estimate also allows for the ability to quantify some of the savings and cost avoidance benefit that is gained through the risk assessment processes.

Although risk assessments are not complete for the entire USACE levee portfolio, the risk assessments completed thus far indicate trends and impacts of risk drivers across the portfolio. By considering the entire USACE portfolio of levee systems and associated leveed areas, the risk across all levee systems can be assessed and risk management measures can be prioritized for implementation to maximize efficiency of risk management.

Risk management measures may include a combination of structural and emergency effectiveness measures that reduce the probability of a levee breach and reduce the potential consequences of a breach.

The cost estimate developed considers: (1) reducing risk of a breach prior to overtopping by implementing structural improvements, (2) reducing risk of breach by overtopping through construction of armored levee sections at breach locations, and (3) improving evacuation effectiveness to reduce consequences. The cost estimate was only completed for the Very

High, High, and Moderate risk levees in the USACE portfolio.

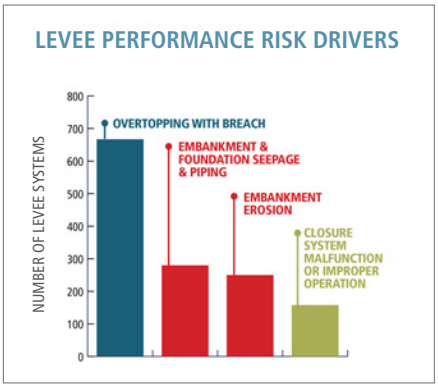
Reducing Risk of Breach Prior to Overtopping. The cost estimate for reducing the risk of breach prior to overtopping for Very High, High, and Moderate risk levees is based on construction of structural improvements to the levees. The structural improvements would be implemented in compliance with USACE design guidelines and would lower the likelihood of breach prior to overtopping due to a risk driver identified from risk assessments. These measures should result in levees that can be loaded to the top without breach occurring. The estimated life loss associated with breach prior to overtopping is 50% more than for overtopping with breach, meaning that life loss potential is reduced significantly if levees can perform when loaded to the top.

Reducing Risk of Overtopping With Breach. Construction of armored overtopping sections developed for the cost estimate does not eliminate flood risk from overtopping, but rather reduces both potential life loss and economic damages by stopping levee breach during overtopping. The benefits of armored overtopping sections have not been quantified, but such structures would certainly decrease the system risk if breach during overtopping does not occur. It is important to note that implementation of structural improvements and armored overtopping sections would not necessarily transform all Very High, High, and Moderate risk levees into Low risk levees, as risk is a complex combination of hazard, performance likelihood, and consequences.

Improving Evacuation Effectiveness to Reduce Consequences. The cost estimate for improving evacuation effectiveness is based on improving gaps in community awareness, warning systems, and evacuation planning that were identified in levee risk assessments. Improved evacuation effectiveness has the benefit of reducing the consequences from flooding. Implementation of both the structural mitigation measures and improvements to evacuation effectiveness used in the cost estimate would not fully eliminate all flood risk associated with the levees; however, such activities would reduce risk to as low a level as possible.

COST ESTIMATION APPROACH AND LIMITATIONS

To calculate cost estimates, scopes of work were developed for 350 individual levee segments with Very High, High, and Moderate risk characterizations. Each scope of work included structural measures to reduce the risk driven by levee breach prior to overtopping failure modes, malfunction of system components, overtopping with levee breach failure modes, and evacuation effectiveness. Based on these scopes of work, a detailed cost estimate was developed for each of these systems to an 80% level of confidence. The team utilized cost risk analysis and USACE Cost Community of Practice standards. Costs were then extrapolated to the remainder of the Very High, High, and Moderate levees in the portfolio. For a detailed description of how the cost estimate was developed and what costs are included, see Appendix D of this report.



TOP FOUR LEVEE PERFORMANCE RISK DRIVERS IN USACE PORTFOLIO, BASED ON OVER 1,600 LEVEE SYSTEMS WITH COMPLETED RISK ASSESSMENTS.

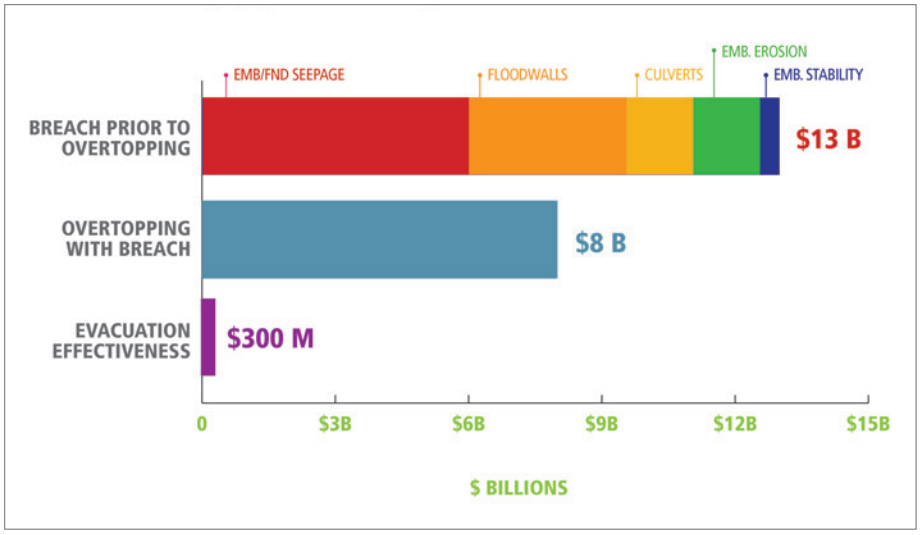
The cost associated with mitigating the risk of levee breach prior to overtopping was developed for the six common failure modes that are evaluated during risk assessments: embankment and foundation

seepage and piping, embankment erosion, embankment stability, floodwall stability, floodwall under seepage, and failure of closure features within the system. These cost estimates were developed with the assumption of necessary remediation or modification to the levee system to prevent breach from any of these failure modes where these failure modes were identified as risk drivers.

The costs associated with addressing levee system risk due to overtopping with levee breach was developed by implementing an armored overtopping section at the most likely overtopping location to prevent levee breach during a 2-foot overtopping event. Preventing levee breach during an overtopping event will help ensure the levee system provides the intended benefits and reduces levee-related flood risks to the leveed area.

RISK MANAGEMENT COMMENTARY:

- The portfolio cost estimate in this report does not address or eliminate all levee-related flood risk, nor does it represent the investment needs for routine operation and maintenance. Routine operation and maintenance costs of levees are not included in the portfolio cost estimate.
- Only deferred maintenance activities that were specifically identified as risk drivers for levees characterized as Very High, High, and Moderate risk levee systems are included in the estimate. This estimate also does not include the cost of inspections and levee screening updates (by the sponsor or USACE), or activities related to constructing new levees or raising existing ones.



ESTIMATED COSTS TO REDUCE BREACH PRIOR TO OVERTOPPING BY KEY FAILURE MODES.

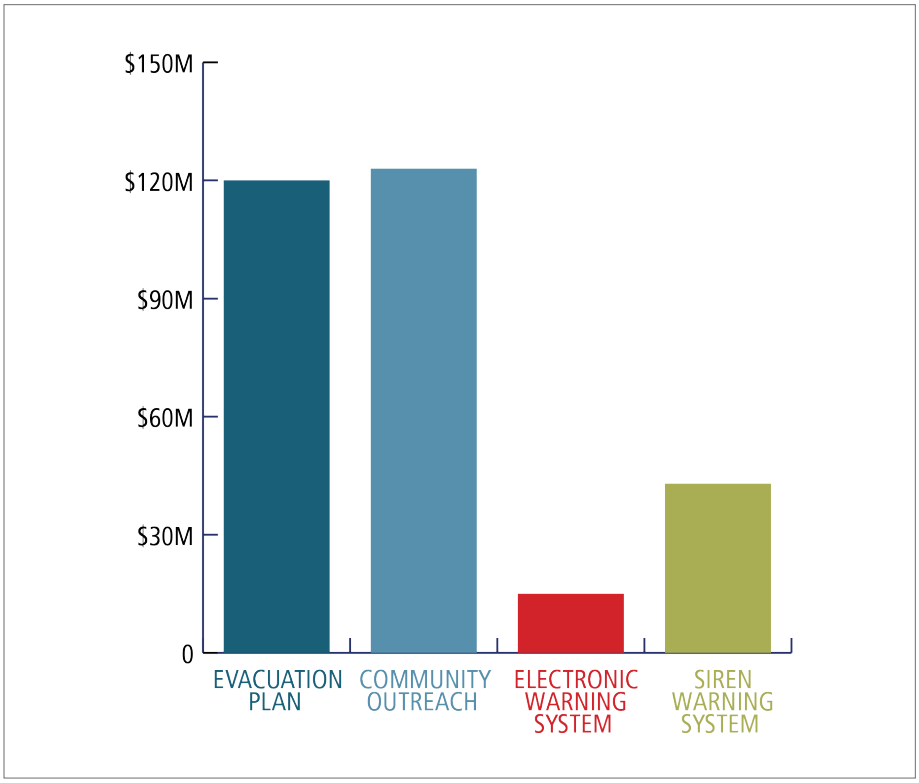
OVERALL COST ESTIMATION

The extrapolated portfolio cost to address risk drivers and improve evacuation effectiveness for Very High, High, and Moderate risk levee systems in the USACE portfolio ranges from $6.5 billion to $38 billion, with an expected cost of about $21 billion. The upper and lower ranges of estimated cost show the uncertainty of the estimate.

The expected cost of $21 billion is broken down into approximately $13 billion for structural improvements to mitigate risk drivers for breach prior to overtopping, approximately $8 billion in armoring of levees to reduce the risk of breach following overtopping, and about $300 million to improve evacuation effectiveness.

RISK MANAGEMENT COMMENTARY:

- Since levee-related flood risks cannot be eliminated and these levee systems have people working and living behind them, a levee breach resulting in inundation of the leveed area could lead to loss of life. The relatively low-cost investment associated with emergency preparedness (improved evacuation effectiveness) will reduce potential life loss in the event



COSTS TO IMPROVE EVACUATION EFFECTIVENESS.

of inundation of the leveed area.

ADDRESSING BREACH PRIOR TO OVERTOPPING FAILURE MODES

The estimated cost to reduce the potential for levee breach prior to overtopping for the USACE portfolio is estimated to be in the range of $4 billion to $27 billion, with an expected cost of about $13 billion. A total of about 2,400 linear miles of levee are estimated to require remediation to address this failure mode.

Embankment and foundation seepage and piping related failure modes, excluding culverts, account for $6 billion of these costs.

Approximately 79% of the cost for mitigation of embankment and foundation seepage failure mode is based on an estimated 225 miles of cutoff wall, 9,800 new or improved relief wells, and 182 miles of new seepage berms to reduce breach prior to overtopping risk in the USACE levee portfolio. These mitigation measures were determined based on applicability of the measure in the local area of the levee.

Remediation of culverts is also a significant cost across the portfolio. The cost to repair or replace culverts, typically an Operation and Maintenance responsibility, was estimated to be about $1.5 billion. These costs are based on repair or replacement of about 2,800 culverts in the USACE portfolio, which represent about 18% of the known culverts in the USACE portfolio; however, there may be as many as 6,400 corrugated metal pipes in the USACE portfolio, and in the long-term all the corrugated metal pipes will require replacement. As such, the actual culvert rehabilitation costs are expected to increase over time.

Structural mitigation of the embankment erosion failure mode is estimated to cost $1.4 billion. Most of the estimated remediation cost is associated with levees in the western half of the nation that are constructed from more erodible materials and/or on erodible foundations, and river systems with high velocity flows.

Floodwalls represent about 3% of the total length of the portfolio, and floodwall stability was a primary risk driving failure mode for only a small number of the systems with floodwalls. However, floodwall stability remediation for the USACE portfolio is estimated to cost $3.5 billion. There are fewer miles of floodwall, but the cost per mile for remediation is considerably higher than for other modes such as embankment erosion or embankment stability. A significant cost for floodwall mitigation includes remediation of existing I-walls.

It is estimated that 22% of the estimated structural mitigation costs to address breach prior to overtopping risk drivers are associated with deferred maintenance activities. These activities range from routine activities (e.g., animal burrow repairs, vegetation management, relief well and toe drain cleaning) to more significant activities such as culvert replacement.

The cost to structurally mitigate closure system malfunction or improper operation was negligible as it is driven by operational rating factors and not the structural condition of the closure structures.

ADDRESSING OVERTOPPING WITH BREACH FAILURE MODES

The estimated cost to reduce the potential for levee breach following overtopping for the USACE portfolio is estimated to be in the range of $3 billion to $11 billion, with an expected cost of about $8 billion. Risk mitigation measures such as structural armoring of the overtopping locations to minimize the potential for breach, controlling the location of the overtopping to reduce consequences, and improved warning and evacuation plans are the types of risk management alternatives that should also be considered for all levees.

Full-scale implementation of structural measures to address overtopping with breach across the portfolio is difficult to achieve. These structural measures would include planned overtopping sections, constructed at locations to minimize consequences as a result of overtopping. For example, the inundation area for most systems can generally be reduced by locating an overtopping section at the downstream portion of the levee. Modifying levees for overtopping may result in directing flood waters toward a particular portion of the community, which society often views as unacceptable. For some levees, high population areas behind the levee may be located near the downstream portion of the levee and siting an overtopping location can be very difficult. The cost for a levee system may be substantially more than estimated because significant levee raising may be required to direct the overtopping to occur at a specific location. Additionally, once a designed overtopping section is constructed there may be a natural tendency to "flood fight" to prevent overtopping along these sections, which can negate the effectiveness of these measures.

MEASURES TO IMPROVE EVACUATION EFFECTIVENESS

The estimated cost to improve evacuation effectiveness, which includes measures such as improved evacuation plans, community outreach, and warning systems, is approximately $300 million. The cost to implement these measures to reduce levee-related flood risk is significantly less than the cost for structural mitigation for breach prior to overtopping and for overtopping with breach. These actions can have a great impact in reducing the consequences of levee-related flooding, even though the economic impact of flooding associated with the various inundation scenarios is not significantly changed by improving flood risk awareness and warning systems. As noted, although improving evacuation effectiveness alone may not change the overall risk characterization of a specific levee, it will certainly reduce life safety risk associated with both breach prior to overtopping and overtopping with breach scenarios.

FINDINGS AND DISCUSSION

The extrapolated portfolio cost to address risk drivers and improve evacuation effectiveness for Very High, High, and Moderate risk levee systems in the USACE

DID YOU KNOW?

USACE Districts and MSCs go through a wide range of budgetary and planning processes to invest in levee infrastructure.

In 2016, more than $700 million was expended to construct flood risk management projects, including new construction and remediation of dams, levees, and channels. Construction and rehabilitation of levee-related infrastructure represents about half of this expenditure figure.

Beyond planning, design, and construction, federal investments in levee infrastructure include activities such as investments in operation and maintenance on federally-operated and maintained projects, levee inventory, inspections and risk assessments on the full USACE portfolio (Inspection of Completed Works), and technical assistance through the Floodplain Management Services and Planning Assistance to States programs.

HURRICANE EVACUATION ROUTE (SOURCE: ISTOCK).

portfolio ranges from $6.5 billion to $38 billion, with an expected cost of about $21 billion. The $21 billion breaks down in the following ways:

- $13 billion for structural improvements to mitigate risk drivers for breach prior to overtopping;
- $8 billion in armoring of levees to reduce the risk of breach due to overtopping; and
- $300 million to improve evacuation effectiveness.

- USACE will work with sponsors to provide information that can improve evacuation effectiveness, particularly since the cost to improve evacuation effectiveness is significantly less than implementation of structural mitigation measures and directly reduces risk to loss of life.
- USACE will update estimated portfolio costs and methodologies to assist decision makers at all levels of government in planning for future design, construction and risk mitigation activities. Understanding what is driving the risk combined with cost estimates help risk managers of all types make focused investment decisions in the most cost-effective way to reduce risk. It improves the ability of managers to weigh options and have community discussions about tradeoffs relative to return on investment. It also provides more information as to the costs of deferred operation and maintenance activities.
- USACE will use cost information to inform research needs and guidance updates with an eye toward not only reducing risk, but lowering assessment, repair, and mitigation cost.

CONCLUSION

Risk assessments provide a deeper understanding of more than 14,000 miles of levees within the USACE levee portfolio across the United States. Results from these risk assessments are being discussed with sponsors and, by sponsors, with communities with the intent that they use them to make cost-effective risk management decisions and raise overall awareness of levee-related risks. Sponsors and communities are just beginning to understand the value and actionable nature of this information.

USACE is already reaping the benefits of risk assessments by incorporating risk concepts into investment and prioritization decisions, including priorities for future or higher-level risk assessments, prioritizing feasibility studies, and prioritization/ sequencing of post-flood levee rehabilitation resources. USACE will continue to apply risk information to improve decision making within the agency. USACE will share this valuable information with sponsors and other community risk managers with an interest in managing risks in their states, tribes, communities, and homes.

Results of risk assessments underline the important roles that states, local communities, and levee sponsors play in managing levee-related flood risk across the country. It is clear from these results that focusing on the levee structure alone will not result in cost-effective risk management, and structural options have to be balanced with other considerations such as environmental and community values. Further, the cost of implementing nonstructural risk management measures such as raising flood risk awareness, evacuation planning, and warning systems is significantly lower than most structural measures that would be expected to improve levee performance. With a focus on life safety, this is generally a recommended investment to manage levee-related flood risk.

Improved understanding of human behavior and evaluation of nonstructural risk management measures, such as evacuation planning and warning systems, will improve the risk characterization of levees and better support effective risk management measures.

Risk assessment is not a one-time activity, but rather is an ongoing responsibility for USACE and levee sponsors to assess and understand the risks associated with levee systems to make informed risk management decisions. Looking at the portfolio, the balance of the risk characterization is expected to shift over time, albeit slowly, as risk management measures, both structural and nonstructural, are implemented. However, even with implementation of risk management measures, risk across the portfolio is still expected to increase somewhat due to increasing flood hazards impacting levees and increasing land use development behind levees.

GULF INTRACOASTAL WATERWAY (GIWW) WEST CLOSURE COMPLEX PUMP STATION IN NEW ORLEANS, LOUISIANA, MAY 2011 (SOURCE: USACE).

Future portfolio reports will help USACE, sponsors, and communities understand the effectiveness and cost-effectiveness of mitigation measures implemented by levee sponsors, quantify savings, and improve the ability to incorporate levee safety needs more effectively into overall public and private investments.

APPENDIX A: FOR MORE INFORMATION

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Data Sources

- National Levee Database, http://nld.usace.army.mil
- USACE Levee Screening Tool

APPENDIX B: LIST OF ACRONYMS AND ABBREVIATIONS

ACE	Annual chance of exceedance in any given year
AOR	Area of Responsibility (e.g., the geographic boundaries of a USACE District or Division)
EC	Engineer Circular
EM	Engineer Manual
ER	Engineer Regulation
FEMA	Federal Emergency Management Agency
HQUSACE	Headquarters of the US Army Corps of Engineers
HSDRRS	Hurricane and Storm Damage Risk Reduction System (in/around New Orleans)
IPET	Interagency Performance Task Force (post Hurricane Katrina)
IRRM	Interim Risk Reduction Measure(s)
LSAC	Levee Safety Action Classification
LSO	Levee Safety Officer
MR&T	Mississippi River and Tributaries
MSC	Major Subordinate Command (also, Division)
NFIP	National Flood Insurance Program
NLD	National Levee Database
NPS	National Park Service
US	United States
USACE	US Army Corps of Engineers
WRDA	Water Resources Development Act(s)
WRRDA	Water Resources Reform & Development Act (of 2014)

APPENDIX C: USACE PORTFOLIO DATASET DEVELOPMENT

DATASET CREATION

The dataset presented in this report is a combination of data from the Levee Screening Tool (LST), higher level risk assessments (e.g. semi quantitative or quantitative risk assessment), the National Levee Database (NLD), and records from the Levee Senior Oversight Group (LSOG) meetings.

The LST dataset, which was downloaded in March 2017, forms the foundation of the data presented in this report. However, significant modifications were made to the data to eliminate screenings that were archived, duplicated, or otherwise inactive. The original data pull had over 20,000 lines of data (screenings) for USACE's approximately 2,700 segments. The overwhelming majority of screenings were duplicates created each time a new LST calculation was performed. After eliminating all calculations prior to version 6, a number of archived screenings needed to be removed. The archived screenings primarily represented segments that have been combined with other segments, eliminated from the portfolio, or recreated in a newer screening in the LST. Multi-purpose levee segments/systems were also a source of duplicated data in the LST. For instance, several New Orleans levees serve as both hurricane risk reduction levees and flood risk reduction levees. Two separate screenings were performed for each segment due to the difference in loading probability and performance of the two design purposes. The lowest risk screening was removed from the dataset for these duplicated segments. The final major modification to the dataset was the elimination of screenings that are not being actively managed. These segments were identified by their lack of data in the LST, and most of these screenings never made it to LSPM approval. Beyond these major modifications to the dataset, only minor corrections were performed as necessary. For example, there were several issues with units. Some districts provided levee elevations in lieu of levee heights. One levee system was identified where the leveed area had been input as acres instead of square miles. Multiple data fields were left blank. All these identified errors were corrected with the most up-to-date information from the LST or corrected manually if updated LST information was not available.

Once the LST dataset was pared down through the process described above, it was supplemented with data from NLD and LSOG notes. From the NLD, segment IDs were cross referenced to obtain project authorizations for the LST dataset, as that information is not included in the LST export data. Additionally, LSOG notes were used to reference the most up-to-date LSAC values that have been approved by the LSOG. The NLD project authorizations and LSOG LSAC values are referenced several times in this report. Anytime LSAC values are mentioned, it is referring to this dataset of LSOG-approved LSAC values.

DATA MANIPULATION

The biggest challenge with getting meaningful information from the dataset is the way the LST handles combined segment and system information. Consequence data is computed in the LST for the entire leveed area. For systems with multiple segments, this results in the populations at risk (PARs) and property values being duplicated for each levee segment. Complicating the issue further is the fact that extremely

LOCAL LEVEE SPONSOR AND USACE MEETING TO DISCUSS POTENTIAL LEVEE IMPROVEMENTS OF A WEST SACRAMENTO LEVEE IN JULY 2014 (SOURCE: USACE).

long systems like the MRL East and West Bank Systems have different, but overlapping, leveed areas for each segment (a compromised levee in Memphis, TN, would affect Greenville, MS, but not vice versa). For this report, the segments with the highest consequence data within a levee system were incorporated in the dataset, with the consequence data for all other segments in the levee system excluded. This allows for accurate reporting on PARs and property values without double-counting for multi-segment systems. Similar calculations were performed to find minimum system evacuation effectiveness, minimum system community awareness, minimum system flood warning effectiveness, system annual chances of exceedance, system leveed areas, and system levee performance rating (e.g., worst rating) information for each of the seven levee performance modes.

APPENDIX D: USACE LEVEE PORTFOLIO COST ESTIMATE APPROACH

PURPOSE

This appendix describes the methodology and approach utilized to estimate a cost for addressing current levee-related risk within the USACE levee portfolio. A portfolio cost estimate provides an improved understanding of the magnitude of investment needs to reduce risk, including factors that significantly influence the cost estimate. This portfolio cost estimate helps inform current and future USACE levee portfolio management decisions and priorities, including the areas of risk assessment, risk management, and risk communication, best practices, and research. The portfolio cost estimate is shared with stakeholders, the research community, and construction and engineering industries to promote the development of innovative technologies and methods to enhance levee safety.

The USACE levee portfolio cost estimate is a rough order of magnitude estimate which aggregates risk information within the USACE levee portfolio to estimate the magnitude and the costs of risk management measures. It is not intended to replace levee-specific risk management plans or cost estimates found in current or future planning studies (e.g., cost shared feasibility studies, major rehabilitation program studies, or other feasibility studies by non-federal entities) on levees within the portfolio.

This appendix describes the approach used to estimate the extent of potential risk reduction measures needed to address risk drivers within the USACE levee portfolio; the approach used to the estimate costs based on the extent of risk reduction measures within the USACE levee portfolio; and sources of uncertainty in the portfolio cost estimate.

INTRODUCTION

The USACE levee portfolio cost estimate represents the costs for addressing current levee-related risk within the portfolio. The portfolio cost estimate focuses on risk drivers for levees classified as Moderate, High and Very High risk, which often require immediate risk reduction actions. The portfolio cost estimate does not include estimates for actions associated with Very Low or Low risk levees, as these levees often do not require immediate risk reduction actions or risk reduction actions are lower priority than higher risk levees within the portfolio. The portfolio cost estimate focuses primarily on risk drivers related to levee performance and life safety consequences.

The portfolio cost estimate relies on the best available information from the National Levee Database (NLD), Levee Safety Program inspections and risk assessments, and completed or ongoing feasibility studies for levees within the portfolio. The NLD provides information on the levee geometric characteristics (e.g., height, length, width, and slopes), levee features and components, and leveed area characteristics (e.g., population density, population at risk, structures exposed, and critical infrastructure). When available, the information from either the screening-level risk assessment or more detailed risk assessments was utilized for the portfolio cost estimate. Although risk assessments are not complete for the entire USACE levee portfolio, the risk assessments completed to date (350 levee segments with Moderate to Very High risk) inform the trends and impacts of

TABLE 1. COMPARISON OF LEVEE HEIGHT TO LEVEE SAFETY ACTION CLASSIFICATION (% IS BASED ON LEVEE LENGTH).

LEVEE HEIGHT (FT)	PERCENTAGE OF THE LEVEE PORTFOLIO WITHIN LEVEE HEIGHT RANGE (%)	PERCENTAGE WITH COMPLETED RISK ASSESSMENTS (%)	PERCENTAGE IDENTIFIED AS MODERATE TO VERY HIGH RISK (%)
< 7	8%	43%	9%
7 – 12.5	40%	57%	34%
12.5 – 17.5	25%	55%	40%
17.5 – 22.5	14%	65%	71%
22.5 – 27.5	6%	95%	91%
< 27.5	6%	94%	95%

risk drivers on the portfolio cost estimate.

The levee portfolio cost estimate approach is similar to the approach utilized for the USACE dam portfolio, which includes over 700 dams. Since 2010, USACE has developed and maintained a dam safety portfolio investment plan which relies on a portfolio cost estimate to inform dam safety portfolio management strategies for the USACE dam portfolio. The dam safety portfolio investment plan is critical in establishing a baseline for planning and execution of major dam modifications, as well as informing other portfolio management decisions. Both the levee portfolio cost estimate and dam portfolio cost estimate include quality assurance processes and similar cost engineering approaches (e.g., costs adjusted to project locations, real estate, utility relocation, and environmental impacts, cost risk analysis approach used, and individual project scopes of work).

RISK REDUCTION MEASURES WITHIN THE PORTFOLIO

In order to develop the portfolio cost estimate, the scope of potential risk reduction measures for the USACE levee portfolio was first identified for the subset of levees with completed risk assessments. The trends and impacts of risk drivers from levees with completed risk assessments was then applied to the remaining subset of levees without completed risk assessments. The subset of levees with completed risk assessments include 350 Moderate, High and Very High risk levee segments with a combined length of over 4,000 miles.

Based on evaluation of trends and impacts of risk drivers for levees with completed risk assessments, levee height was determined to provide an important correlation to risk (Table 1). Based on this correlation, the subset of levees without completed risk assessments were estimated to have about 300 Moderate to Very High risk levee segments with a combined length of almost 3,000 miles.

The incorporation of potential risk reduction measures in the portfolio cost estimate approach

TABLE 2. LIST OF RISK REDUCTION MEASURES FOR LEVEE PERFORMANCE RISK DRIVERS

PERFORMANCE MODE	RISK REDUCTION MEASURE
EMBANKMENT AND FOUNDATION SEEPAGE AND PIPING	■ SEEPAGE BERMS ■ RELIEF WELLS (REPLACEMENT OR REHABILITATION) ■ CUTOFF WALLS ■ VEGETATION REMOVAL ■ EMBANKMENT REPAIR (E.G., ANIMAL BURROWS, ENCROACHMENTS, ETC.) ■ EMBANKMENT/FOUNDATION DRAINS (REPLACEMENT OR REHABILITATION) ■ CULVERT REHABILITATION (E.G., LINING PIPES) ■ CULVERT REPLACEMENT OR ABANDONMENT
EMBANKMENT EROSION	■ WATERSIDE EMBANKMENT ARMORING ■ EMBANKMENT SEEDING ■ STREAM BANK AND CHANNEL REVETMENT
EMBANKMENT STABILITY	■ STABILITY BERMS ■ EMBANKMENT/FOUNDATION DRAINS (REPLACEMENT OR REHABILITATION) ■ VEGETATION REMOVAL ■ EMBANKMENT REPAIR (E.G., ANIMAL BURROWS, ENCROACHMENTS, ETC.) ■ SOIL STABILIZATION – EMBANKMENT/FOUNDATION ■ EMBANKMENT REPLACEMENT (E.G., EXISTING SLIDE ZONES)
FLOODWALL UNDER SEEPAGE AND PIPING	■ RELIEF WELLS (REPLACEMENT OR REHABILITATION) ■ CUTOFF WALLS ■ VEGETATION REMOVAL ■ ENCROACHMENT RELOCATION ■ FOUNDATION DRAINS (REPLACEMENT OR REHABILITATION)
FLOODWALL STABILITY	■ FLOODWALL REPLACEMENT (E.G., I-WALLS TO T-WALLS, ETC.) ■ FOUNDATION DRAINS (REPLACEMENT OR REHABILITATION) ■ VEGETATION REMOVAL ■ ENCROACHMENT RELOCATION ■ SOIL STABILIZATION – FOUNDATION
LEVEE CLOSURES	■ REMOVAL OR REPLACEMENT

was developed by USACE levee subject matter experts in geotechnical engineering, structural engineering, geologists, stream bank erosion, hydraulic engineering and cost engineering. Other subject matter experts in environmental assessment, real estate acquisition, emergency planning, risk management, and data management provided input into the portfolio cost estimate approach. The selection of risk reduction technology type for levee performance measures was based on information provided in the risk characterization of the levee and utilized best practices and engineering judgment of the subject matter experts.

Risk Reduction Measures Associated with Levee Performance during Overtopping

Levee performance risk drivers includes risk drivers associated with levee breach prior to and during levee overtopping. Levees, in general, are not designed for overtopping and breach during overtopping is a hazard. The factors that affect the likelihood of levee breach due to overtopping include duration of the overtopping event, the size of the leveed area versus overtopping flows, the geometry of the levee embankment, and erosion resistance of the levee embankment. These factors were considered when evaluating appropriate risk reduction

measures for overtopping with breach.

Unable to consider all factors that influence levee performance during overtopping, cost estimates were developed based on an armored overtopping reach of the levee that would reduce risk. Armoring the entire length of each levee system is not a cost effective risk reduction measure for many levees. In conjunction with the USACE Hydrologic Engineering Center and USACE guidance regarding managing overtopping of levee systems (Engineering and Construction Bulletin 2017-15), a simplified methodology was developed that utilizes available levee information from the screening-level risk assessments to estimate the length and type of armoring required for each levee. Factors that impacted the estimated armoring length is based on the relative length of the adjacent stream or river, the annual chance of exceedance (ACE) of overtopping for the levee, the levee material type, and the duration of the flood loading. Cost estimates were developed for armoring the entire levee crest width, the landside slope, and a limited distance beyond landside levee toe. Since the costs for armoring levees to reduce overtopping related risks are driven more by the length of levee that is armored versus the actual armoring type, only two armoring types (turf reinforcement mats and concrete overflow sections) were considered in the portfolio cost estimate.

Levee raises were not utilized in the portfolio cost estimate as a risk reduction measure associated with overtopping, as levee raises often require congressional authorization.

Risk Reduction Measures Associated with Levee Performance Prior to Overtopping

For most of the USACE levee portfolio, screening-level risk assessments were the primary source of information to determine risk drivers associated with breach prior to levee overtopping. Risk drivers for each levee was identified based on screening-level risk assessment evaluation of six levee performance modes:

- Embankment and foundation seepage and piping;
- Embankment erosion;
- Embankment stability;
- Floodwall under seepage and piping;
- Floodwall stability; and
- Levee closures.

For each levee performance mode identified as either "Moderate Likelihood" or "High Likelihood," risk reduction measures was developed to address each levee performance mode.

The screening-level risk assessment was used to delineate the critical reaches for remediation. The type of risk reduction measure selected for the cost estimate depends on the embankment and foundation conditions as well as potential for environmental and real estate impacts. Risk reduction measures that were used for levee performance risk drivers in the portfolio cost estimate are shown in Table 2.

Risk Reduction Measures Associated with Life Safety Consequences

Risk reduction measures to reduce life safety consequences focuses on improvements to evacuation effectiveness within the leveed area, and is intended to reduce the loss of life in an event of a levee breach. Measures improving evacuation effectiveness includes warning systems, evacuation planning, and community awareness measures. Risk reduction measures to reduce economic damages or damages to property through flood proofing, buyouts, and relocations were not considered in the cost estimate. For each levee, screening-level risk assessment ratings of evacuation effectiveness determined whether additional risk reduction measures were needed. Risk reduction measures were included in the portfolio costs estimate when the screening-level risk assessment ratings of warning systems,

evacuation planning, or community awareness within the leveed area were identified as "Unacceptable" and "Minimally Acceptable." The risk reduction measures include installation of warning systems (sirens, reverse 911, text messaging, etc.), community outreach efforts, and improved evacuation planning (e.g., breach modeling and inundation mapping, emergency action plan, etc.).

COST ESTIMATES FOR RISK REDUCTION MEASURES WITHIN THE PORTFOLIO

Cost estimates for risk reduction measures within the portfolio were completed by USACE cost engineers for each levee segment based on risk reduction measure and risk driver (Table 2). Cost estimates incorporated a cost risk analysis based on rating of cost contingency factors such as scope and technical risks, construction risks, contract acquisition strategy, and external risks. In addition, real estate impacts based on urban or rural designated areas along the levee system were considered in the cost analysis and estimation.

The USACE Civil Works Cost Engineering Center of Expertise performed oversight and quality assurance on the overall cost engineering approach, including unit prices used cost estimates. Each cost estimate of risk reduction measures went through an internal Quality Control (QC) review perform by a senior subject matter expert in levee safety and cost engineering to ensure consistency and quality. Internal QC controls were tracked and evaluated throughout the scope and cost estimating effort.

Per USACE regulations (Engineering Regulation 1110-2-1302), the detail of cost estimates developed is commensurate to the level of detail in the scope of work that forms the basis of the estimate. Scopes of work for risk reduction measures for each levee are considered preliminary in nature; therefore the cost estimates are considered parametric in nature (Class 5). The Class 5 estimates are similar to a reconnaissance estimate. Cost estimates are developed utilizing a combination of USACE cost estimating software Micro-Computer Aided Cost Estimating System second generation (MII), Crystal Ball Cost Risk Analysis program, and Microsoft Excel. The major portions of the cost estimate are described below.

Unit Price Development

Unit prices for risk reduction measures were developed based on previous cost estimates, bid results of past USACE projects of similar scope, USACE Dam Safety Investment Plan unit pricing, or built from other sources of information. National pricing is used to create each unit price. Once a unit price is developed, it is applied to similar risk reduction measures. Cost estimates take into account the general location of the levee by making adjustments to the national pricing using Civil Works Construction Cost Index System State Adjustment Factors.

Markups and Subcontracting Assumptions

The percentage of each project performed by subcontractors makes a significant impact in costs. For the portfolio cost estimate, it is assumed the major construction feature is performed by the prime contractor. The remaining specialized work is assumed to be performed by subcontractors.

The following overhead and profit markups are assumed: job office overhead, 15%; home office overhead, 10%; profit, 10%; Bond, 1%.

Environmental Costs

Cost estimates for environmental factors, including statutorily mandated mitigation, are calculated based on a percentage of construction costs. Environmental-related construction costs from past USACE projects are used as a basis for the percentages. Several levee construction projects in the USACE Sacramento District and USACE Kansas City District

were considered when evaluating the impacts of environmental costs associated with risk reduction measures. Based on past projects, environmental construction cost factors of 13% were used for levees within the western portion of the U.S. and 4% for the rest of the Nation. Environmental labor costs, including labor for the NEPA process, are included in the Planning, Engineering, and Design and Construction Management costs, not the environmental cost estimates. Environmental costs include: construction of environmental mitigation; temporary erosion control; and permitting.

Utility Relocations and Real Estate Costs

Costs for utility relocations and real estate costs associated with risk reduction measures are based on a percentage of construction costs. These percentages are based on historic data on USACE projects of similar scope. Separate percentages are used for rural and urban construction locations. In the cost estimate, utility cost factors are 5% of construction costs in urban areas and 1% in rural areas. Real estate cost factors are 8% in urban areas and 3% in rural areas.

Planning, Engineering, Design and Construction Management Costs

Cost for planning, engineering, design, and construction management labor are based on a percentage of construction costs. These percentages are based on historic data on USACE projects of similar scope. Labor costs in this category include all NEPA-related labor costs, along with other standard planning, engineering and design costs. Planning, engineering and design costs range from 15% on large projects to 30% on risk reduction measures less than $1 million. Construction management labor is 8% for all risk reduction measures.

Cost Contingency

Contingency costs on risk reduction measures with rather rough scopes typically make up a significant percentage of the total cost estimate due to the unknowns and large amount of uncertainty. A simplified cost risk analysis was performed on each levee segment. A confidence value of 80% is used to determine the contingency on each levee segment using Crystal Ball Cost Risk Analysis software. The following risks are taken into consideration:

- Scope/Technical Risks (-25% to +60% of base estimate)
  - Project specific (high, medium, low)
  - Risk based on scope confidence, real estate, environmental, and utility relocations
- Construction Risks (0% to +20% of base estimate)
  - Project specific (high, medium, low)
  - Urban or rural setting, and required water diversions
- Contract Acquisition Strategy (0% to +30% of base estimate)
  - Not project specific, same range run for all projects
  - Includes contracting pool (multiple award task order contract, small business, etc.) and number of contracts
- External Risks (-5% to +15% of base estimate)
  - Not project specific, same range run for all projects
  - Includes delays due to funding issues, force majeure, and market conditions

UNCERTAINTY IN THE PORTFOLIO COST ESTIMATE

The uncertainty in the portfolio cost estimate are influenced by number of factors:

- Risk information for the portfolio was not complete; total portfolio risk had to be extrapolated and estimated based on trends in completed risk assessments.

- Screening level risk assessments, which is the primary source of risk information, provide information regarding the "weakest link" in the levee and often do not identify the full extent of performance risk drivers within the levee (e.g., number of pipes that have similar ratings as the ones rated, how many linear feet along the levee alignment require seepage mitigation, etc.).
- The preliminary nature of the cost estimates (classified as Class 5 according to USACE cost estimating nomenclature).
- USACE or sponsors may have already addressed some of the identified performance risk drivers since the risk assessment was conducted.
- Additional risk drivers may have been identified since completion of the risk assessment.

The portfolio cost estimate was calculated by summing the 80% confidence cost estimate addressing risk factors for each levee segment. The 80% confidence estimate is the estimated cost that a particular project would have an 80% chance of not exceeding. However, a range of cost is presented in this report to illustrate the uncertainty associated with the cost estimate; a relatively small percentage of levees control a significant percentage of the portfolio cost estimate.

As risk assessments are completed or updated, USACE will incorporate this updated risk information into the portfolio cost estimate. This will reduce the uncertainty in the portfolio cost estimate. Future updates to portfolio cost estimate will also help to identify the effectiveness of the risk management measures that have been implemented since the initial portfolio estimate.

APPENDIX E: SNAPSHOT OF LEVEE INFORMATION FOR EACH U.S. STATE AND TERRITORY

OVERTOPPING OF THE L-550 LEVEE IN ATCHISON COUNTY, MISSOURI DURING A MISSOURI RIVER FLOOD, JUNE 2011(SOURCE: USACE).

Levee inventory information on USACE Portfolio levees and levees outside the USACE portfolio provides a snapshot of the population, critical infrastructure, and properties in leveed areas across the United States. This information is summarized in state-by-state summaries.

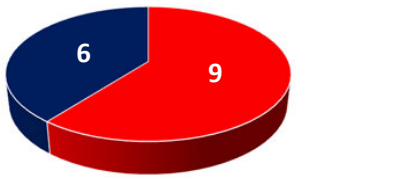
For more information, please visit the National Levee Database, http://nld.usace.army.mil.

Levees within U.S. Army Corps of Engineers (USACE) authority in Alabama*

Number of USACE levee systems:	5
Total miles of USACE levees:	9
Population:	2,600

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Alabama



Estimated Population and Property Value for three USACE levee systems near key cities in Alabama:

Levee System	City	Population	Property Value ($, Billion)
Prattville Continental Gin Company Protected Area	Prattville	1,130	$0.1
Elba Protected Area	Elba	795	$0.1
Northport Levee Protected Area	Tuscaloosa	699	$0.08

Source: National Levee Database

Known levees not within USACE authority in Alabama*

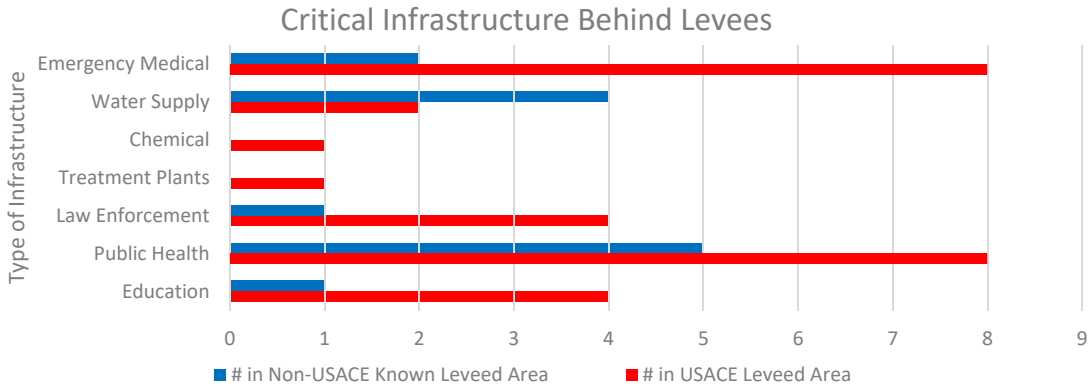
Number of non-USACE known levee systems:	8
Total miles of non-USACE known levees:	6
Population:	570

(*Estimated number of people who live behind non-USACE known levees*)

Image: Northport Levee Protected Area Tuscaloosa, Alabama

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Alabama. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: May 25, 2017**

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4155 Clay Street, Vicksburg, Mississippi 39183
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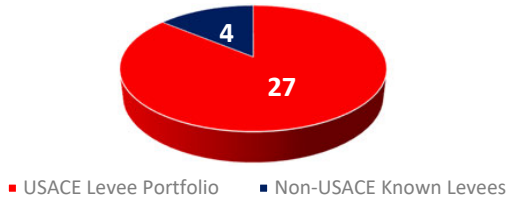
Levees within U.S. Army Corps of Engineers (USACE) authority in Alaska*

Number of USACE levee systems:	6
Total miles of USACE levees:	27
Population:	23,550

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Alaska



Estimated Population and Property Value for three USACE levee systems near key cities in Alaska:

Levee System	City	Population	Property Value ($, Billion)
Tanana River Levee	Fairbanks	19,400	$2.2
Skagway River Levee	Skagway	3,600	$0.2
Aniak Levee	Aniak	270	$0.01

Source: National Levee Database

Known levees not within USACE authority in Alaska*

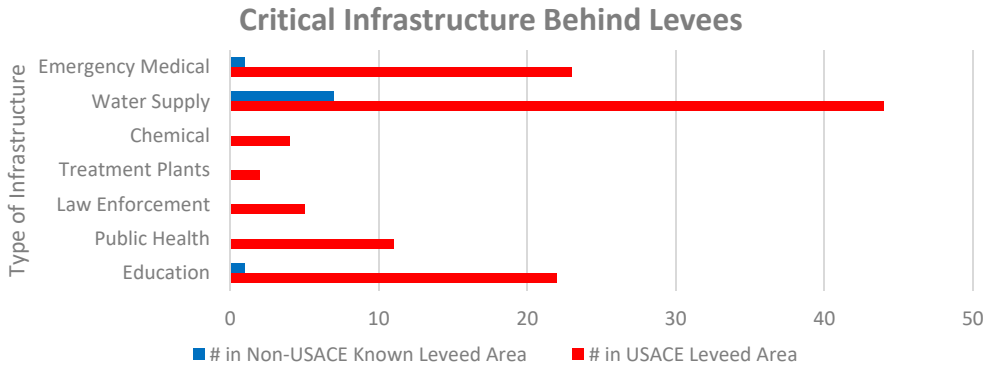
Number of non-USACE known levee systems:	1
Total miles of non-USACE known levees:	4
Population:	0

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Alaska. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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4155 Clay Street, Vicksburg, Mississippi 39183
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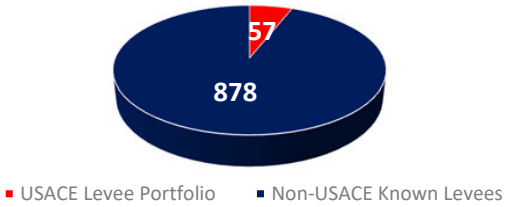
ARIZONA
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Arizona*

Number of USACE levee systems:	38
Total miles of USACE levees:	57
Population:	77,900

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Arizona



Estimated Population and Property Value for three USACE levee systems near key cities in Arizona:

Levee System	City	Population	Property Value ($, Billion)
Indian Bend Wash 4	Scottsdale	24,700	$2.8
Tucson Diversion Channel 6	Tucson	17,800	$1.9
Indian Bend Wash 1	Scottsdale	6,800	$0.3

Source: National Levee Database

Known levees not within USACE authority in Arizona*

Number of non-USACE known levee systems:	313
Total miles of non-USACE known levees:	878
Population:	472,400

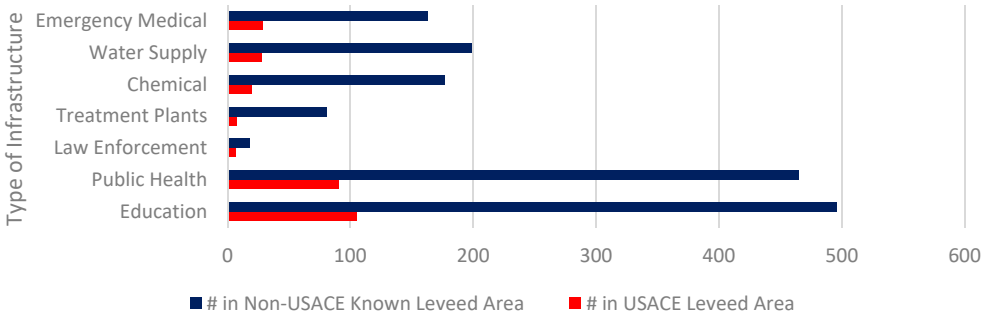
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Arizona. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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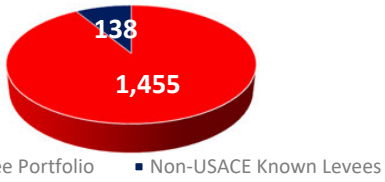
Levees within U.S. Army Corps of Engineers (USACE) authority in Arkansas*

Number of USACE levee systems:	52
Total miles of USACE levees:	1,455
Population:	560,900

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Arkansas



Estimated Population and Property Value for three USACE levee systems near key cities in Arkansas:

Levee System	City	Population	Property Value ($, Billion)
AR-LA MS River	Pine Bluff	200,700	$20.9
Commerce-St. Francis River System	Jonesboro	197,500	$22.5
Big Lake and St. Francis River East System	West Memphis	70,200	$9.7

Source: National Levee Database

Known levees not within USACE authority in Arkansas*

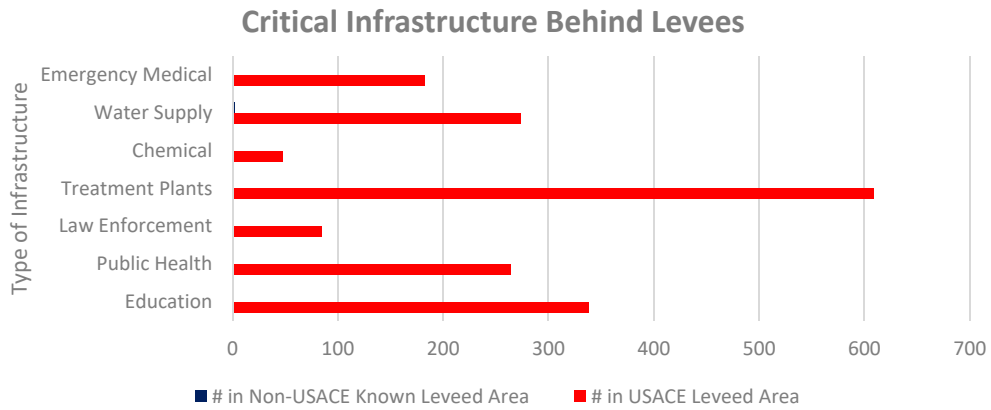
Number of non-USACE known levee systems:	51
Total miles of non-USACE known levees:	138
Population:	455

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in USACE Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Arkansas. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: July 11, 2017**

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CALIFORNIA
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

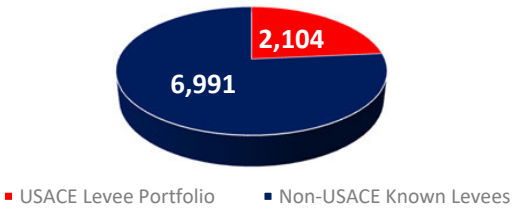
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in California*

Number of USACE levee systems:	284
Total miles of USACE levees:	2,104
Population:	4,774,885

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in California



Estimated Population and Property Value for three USACE levee systems near key cities in California:

Levee System	City	Population	Property Value ($, Billion)
Santa Ana River 1	Los Angeles	832,672	$113.3
Los Angeles River/Compton Creek 2	Los Angeles	464,063	$28.9
Sacramento and Elk Grove	Sacramento	439,491	$69.9

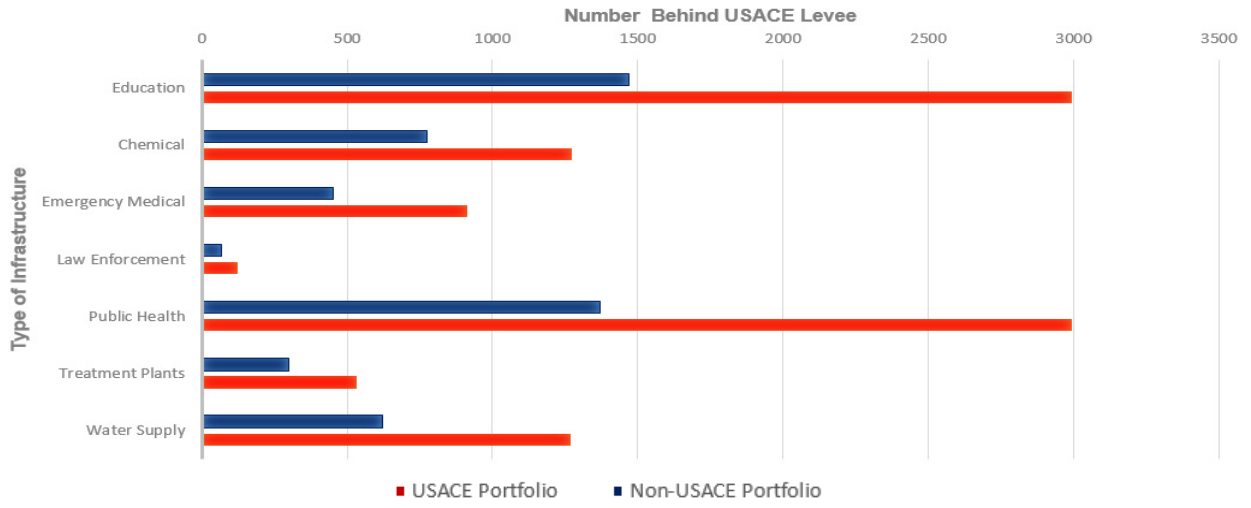
Source: National Levee Database

Known levees not within USACE authority in California*

Number of non-USACE known levee systems:	3,144
Total miles of non-USACE known levees:	6,991
Population:	2,458,136

(*Estimated number of people who live behind non-USACE known levees*)

Image: Levee in USACE inventory



*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: December 21, 2017**

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4155 Clay Street, Vicksburg, Mississippi 39183
TEL: 601-631-5053, http://www.mvk.usace.army.mil

COLORADO

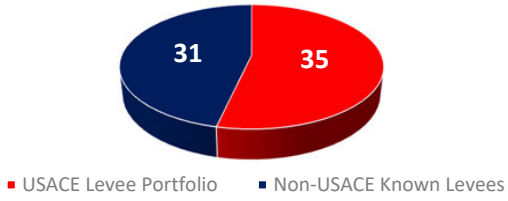
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Colorado*

Number of USACE levee systems:	22
Total miles of USACE levees:	35
Population:	22,700

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Colorado



Estimated Population and Property Value for three USACE levee systems near key cities in Colorado:

Levee System	City	Population	Property Value ($, Billion)
Colorado Springs, Templeton Gap Floodway, S.Levee	Colorado Springs	7,800	$1.1
Alamosa Levees, Rio Grande, Right Levee	Alamosa	6,400	$1.2
Las Animas, Arkansas River, South Levee (Right)	Las Animas	3,100	$0.3

Source: National Levee Database

Known levees not within USACE authority in Colorado*

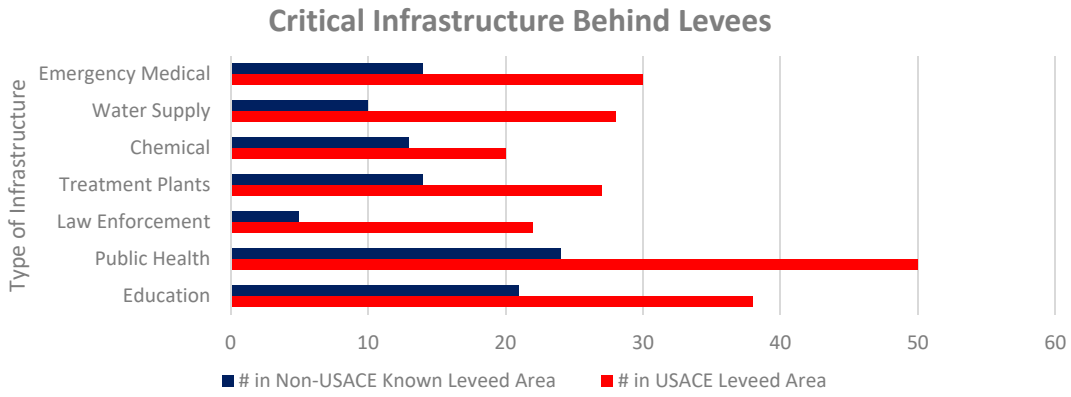
Number of non-USACE known levee systems:	46
Total miles of non-USACE known levees:	31
Population:	6,900

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Colorado. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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CONNECTICUT
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

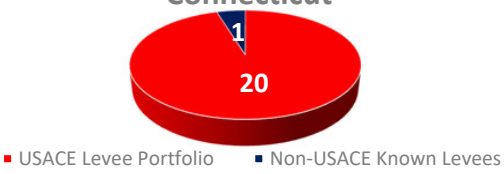
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Connecticut*

Number of USACE levee systems:	20
Total miles of USACE levees:	20
Population:	19,600

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Connecticut



Estimated Population and Property Value for three USACE levee systems near key cities in Connecticut:

Levee System	City	Population	Property Value ($, Billion)
CT River RB Hartford, CT	Hartford	6,900	$1.5
Stamford HSPP, CT	Stamford	5,900	$1.1
CT Riv LB & Hockanum Riv RB East Hartford, CT	East Hartford	4,000	$0.8

Source: National Levee Database

Known levees not within USACE authority in Connecticut*

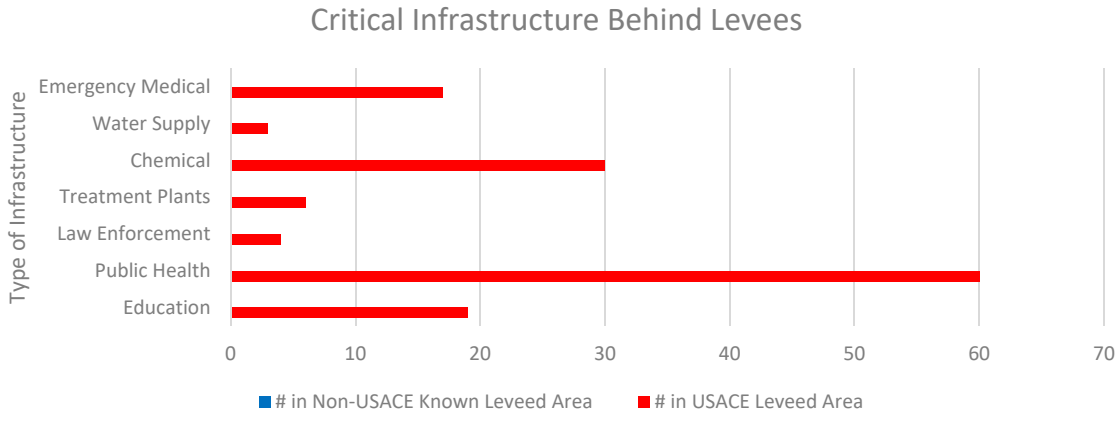
Number of non-USACE known levee systems:	4
Total miles of non-USACE known levees:	1
Population:	168

(*Estimated number of people who live behind non-USACE known levees*)

Image: Embankment Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Connecticut. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of June 3, 2017**

U.S. ARMY CORPS OF ENGINEERS, VICKSBURG DISTRICT
4155 Clay Street, Vicksburg, Mississippi 39183
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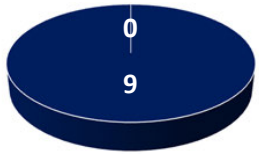
Levees within U.S. Army Corps of Engineers (USACE) authority in Delaware*

Number of USACE levee systems:	0
Total miles of USACE levees:	0
Population:	0

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Delaware



Estimated Population and Property Value for three USACE levee systems near key cities in Delaware:

Levee System	City	Population	Property Value ($, Billion)
NA	NA	NA	$0

Source: National Levee Database

Known levees not within USACE authority in Delaware*

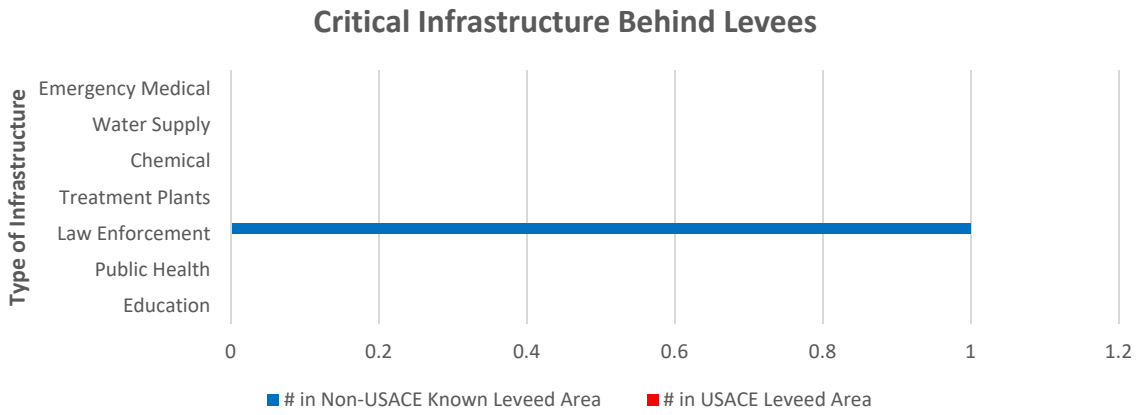
Number of non-USACE known levee systems:	7
Total miles of non-USACE known levees:	9
Population:	170

(*Estimated number of people who live behind non-USACE known levees*)

Image: Embankment Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Delaware. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 3, 2017**

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DISTRICT OF COLUMBIA

SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

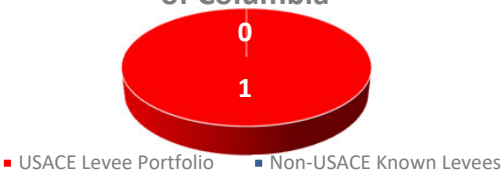
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in District of Columbia*

Number of USACE levee systems:	2
Total miles of USACE levees:	1
Population:	24,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in District of Columbia



Estimated Population and Property Value for three USACE levee systems near key cities in District of Columbia:

Levee System	City	Population	Property Value ($, Billion)
District of Columbia	District of Columbia	22,000	$2.9
Anacostia	Anacostia	1.900	$0.2

Source: National Levee Database

Known levees not within USACE authority in District of Columbia*

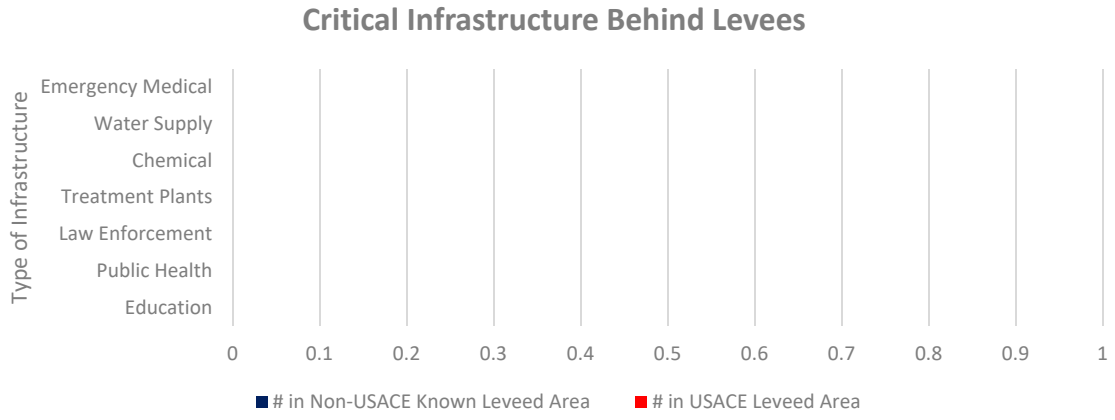
Number of non-USACE known levee systems:	0
Total miles of non-USACE known levees:	0
Population:	0

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the District of Columbia. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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4155 Clay Street, Vicksburg, Mississippi 39183
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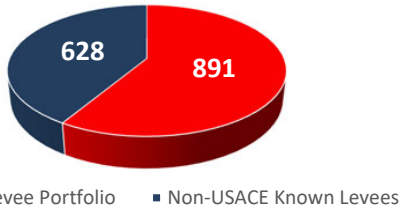
FLORIDA
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Florida*

Number of USACE levee systems:	79
Total miles of USACE levees:	891
Population:	767,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Florida



Estimated Population and Property Value for three USACE levee systems near key cities in Florida:

Levee System	City	Population	Property Value ($, Billion)
East Coast Protective Levees, L-36, L-35	Miami	235,000	$30.6
L-31 North	Miami	154,000	$15.5
East Coast Protection Levees, L-40, L-85, STA-1E	Miami	115,000	$15.8

Source: National Levee Database

Known levees not within USACE authority in Florida*

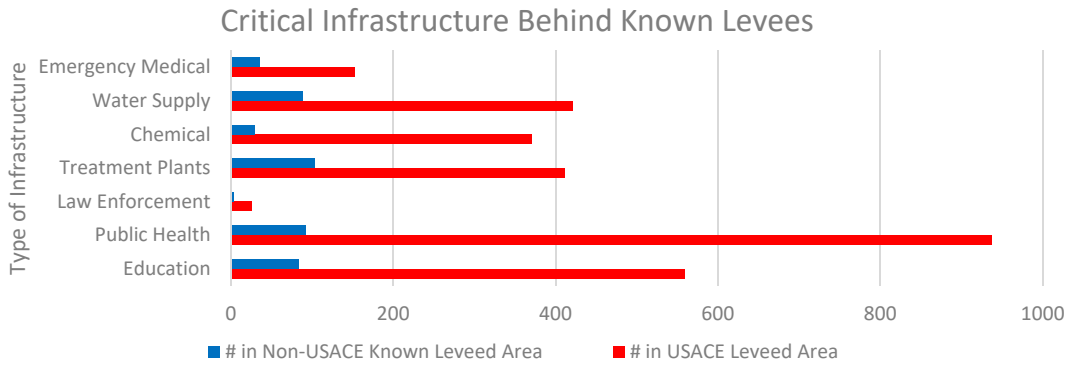
Number of non-USACE known levee systems:	158
Total miles of non-USACE known levees:	628
Population:	92,000

(*Estimated number of people who live behind non-USACE known levees*)

Image: L-31W Canal and Levee South Dade, Florida

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Florida. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: May 24, 2017**

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GEORGIA

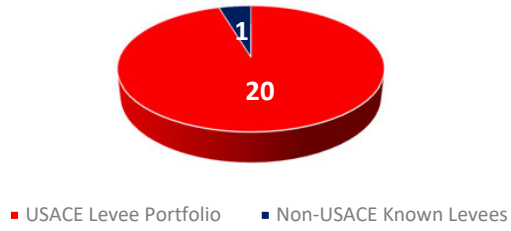
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Georgia*

Number of USACE levee systems:	4
Total miles of USACE levees:	20
Population:	21,667

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Georgia



Estimated Population and Property Value for three USACE levee systems near key cities in Georgia:

Levee System	City	Population	Property Value ($, Billion)
Augusta Levee	Augusta	19,200	$3.2
Rome Levee System	Rome	2,100	$0.3
Macon Levee	Macon	213	$0.08

Source: National Levee Database

Known levees not within USACE authority in Georgia*

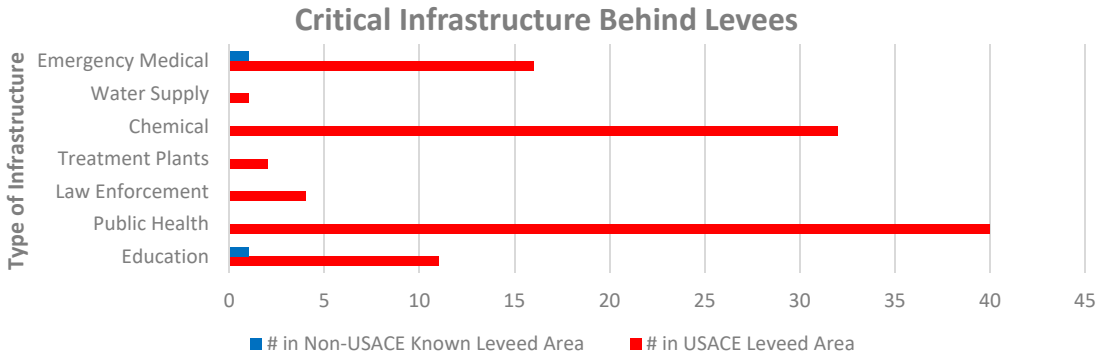
Number of non-USACE known levee systems:	1
Total miles of non-USACE known levees:	1
Population:	389

(*Estimated number of people who live behind non-USACE known levees*)

Image: Augusta Levee and Riverwalk Augusta, Georgia

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Georgia. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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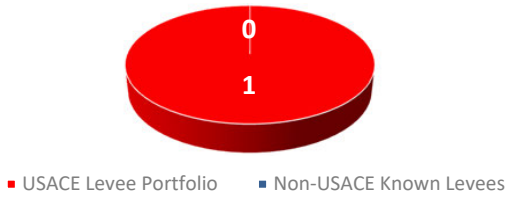
4155 Clay Street, Vicksburg, Mississippi 39183
TEL: 601-631-5053, http://www.mvk.usace.army.mil

Levees within U.S. Army Corps of Engineers (USACE) authority in Guam*

Number of USACE levee systems:	2
Total miles of USACE levees:	1
Population:	251

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Guam



Estimated Population and Property Value for three USACE levee systems near key cities in Guam:

Levee System	City	Population	Property Value ($, Million)
Namo River Left Bank, Levee and Channel (NRLB)	Agana	251	$18

Source: National Levee Database

Known levees not within USACE authority in Guam*

Number of non-USACE known levee systems:	1
Total miles of non-USACE known levees:	0
Population:	0

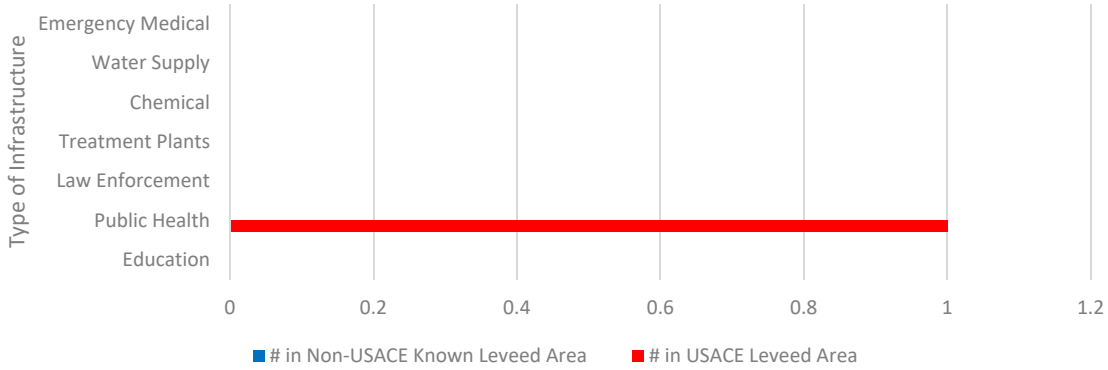
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in Guam. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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HAWAII

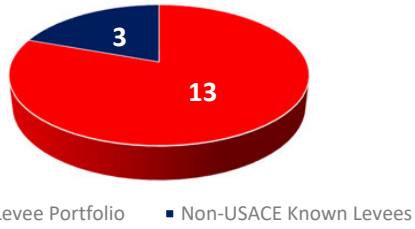
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Hawaii*

Number of USACE levee systems:	25
Total miles of USACE levees:	13
Population:	23,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Hawaii



Estimated Population and Property Value for three USACE levee systems near key cities in Hawaii:

Levee System	City	Population	Property Value ($, Billion)
Kawainui Marsh – 6850lf, Lev Floodwall, Oneawa Ch	Kailua	13,800	$2.5
Iao Stream – A,B,C,D,E,H,I,Chnl and Revt X RB	Kahului	2,900	$0.6
Wailoa Stream RB – Diversion Lev 1,2,3,4, and Chnl	Hilo	1,500	$0.3

Source: National Levee Database

Known levees not within USACE authority in Hawaii*

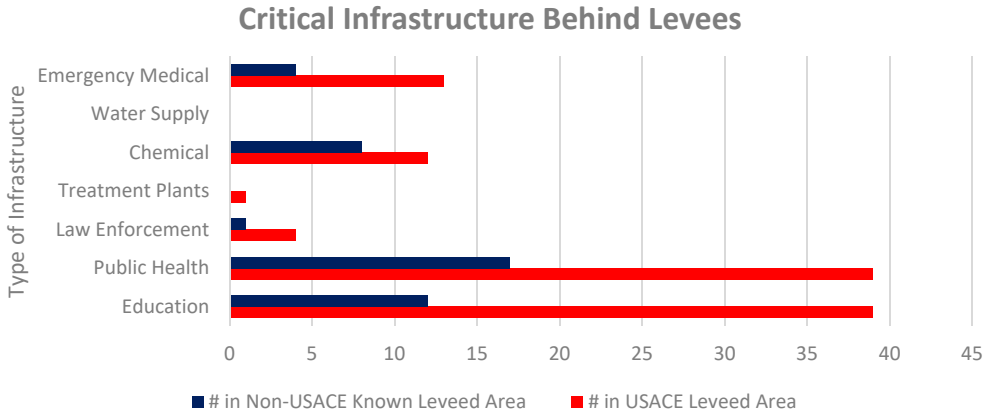
Number of non-USACE known levee systems:	8
Total miles of non-USACE known levees:	3
Population:	6,900

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Hawaii. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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IDAHO

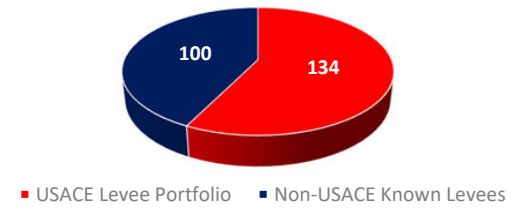
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Idaho*

Number of USACE levee systems:	96
Total miles of USACE levees:	134
Population:	19,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Idaho



Estimated Population and Property Value for three USACE levee systems near key cities in Idaho:

Levee System	City	Population	Property Value ($, Million)
Heise Roberts 1 (Left Bank)	Rigby	4,400	$337.5
Coeur D' Alene	Coeur D' Alene	2,500	$54.1
Blackfoot 1 (Rt. Bank, Rt. Bank Diver Blackfoot	Blackfoot	2,300	$294.2

Source: National Levee Database

Known levees not within USACE authority in Idaho*

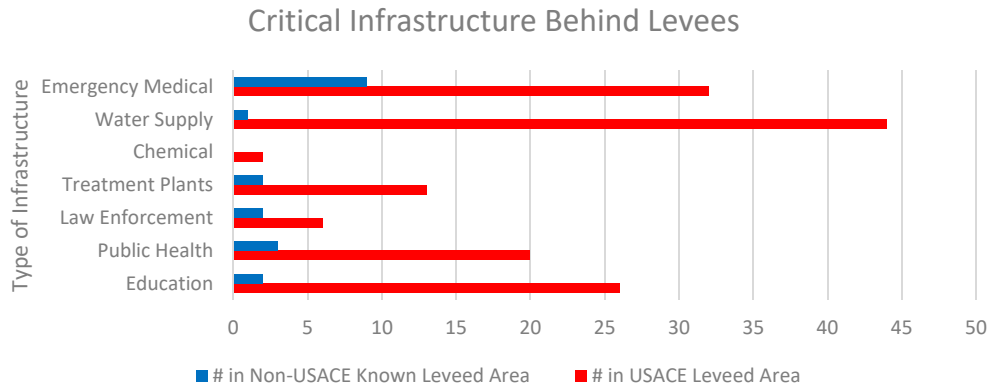
Number of non-USACE known levee systems:	47
Total miles of non-USACE known levees:	100
Population:	1,600

(*Estimated number of people who live behind non-USACE known levees*)

Image: Coeur D' Alene Levee
Coeur D' Alene, Idaho

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Idaho. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: May 24, 2017**

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ILLINOIS
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

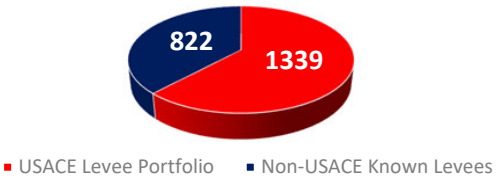
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Illinois*

Number of USACE levee systems:	134
Total miles of USACE levees:	1,339
Population:	193,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Illinois



Estimated Population and Property Value for three USACE levee systems near key cities in Illinois:

Levee System	City	Population	Property Value ($, Billion)
Metro East and Chain of Rocks System	Madison	106,000	$13.5
Wood River D&LD Lower	Roxana	17,800	$2.3
Sid Simpson Flood Control Project	Beardstown	7,000	$0.6

Source: National Levee Database

Known levees not within USACE authority in Illinois*

Number of non-USACE known levee systems:	447
Total miles of non-USACE known levees:	822
Population:	22,700

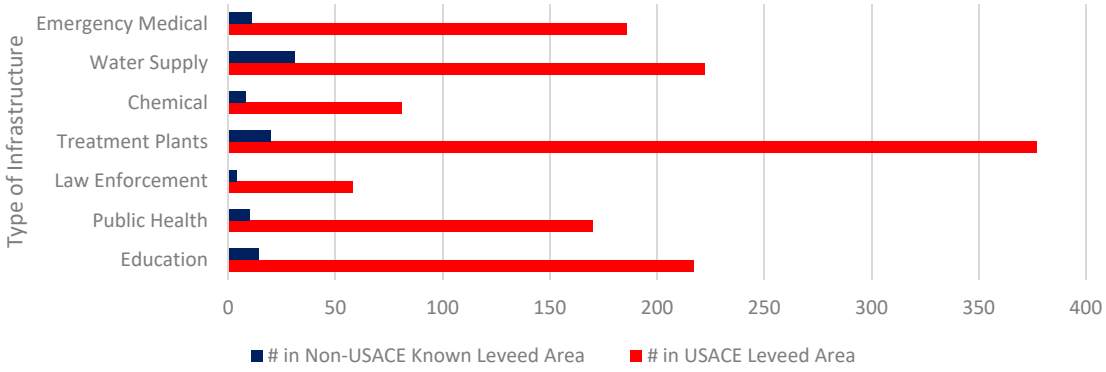
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in USACE Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Illinois. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 28, 2017**

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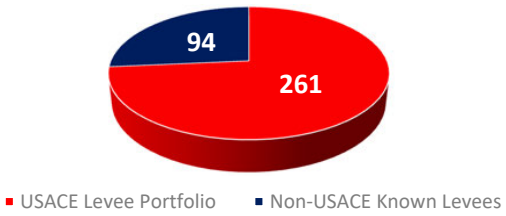
Levees within U.S. Army Corps of Engineers (USACE) authority in Indiana*

Number of USACE levee systems:	40
Total miles of USACE levees:	261
Population:	169,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Indiana



Estimated Population and Property Value for three USACE levee systems near key cities in Indiana:

Levee System	City	Population	Property Value ($, Billion)
Evansville LFPP	Evansville	62,600	$10.9
Jeffersonville – Clarksville LFPP	Clarksville	21,100	$3.7
Hammond	Hammond	17,500	$2.0

Source: National Levee Database

Known levees not within USACE authority in Indiana*

Number of non-USACE known levee systems:	77
Total miles of non-USACE known levees:	94
Population:	23,400

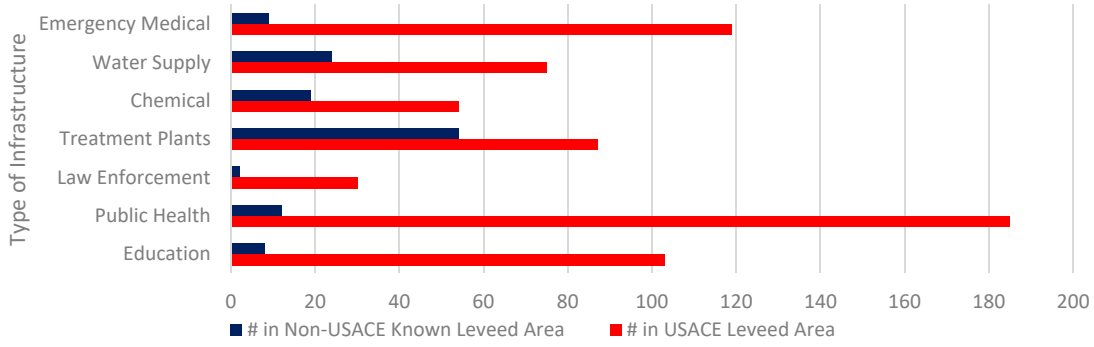
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Indiana. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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IOWA

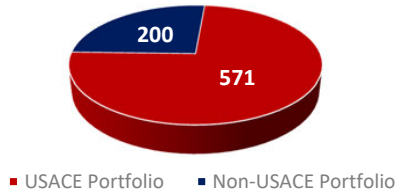
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Iowa*

Number of USACE levee systems:	95
Total miles of USACE levees:	571
Population:	127,000

(*Estimated number of people who live behind USACE known levees*)

Levee Miles in Iowa



Estimated Population and Property Value for three USACE levee systems near key cities in Iowa:

Levee System	City	Population	Property Value ($, Billion)
L-627 MO River LB & Indian Creek Rt. Bank	Council Bluffs	24,500	$2.8
Des Moines, DM II RDB Des Moines/Raccoon Rivers	Des Moines	21,600	$2.6
Waterloo & Evansdale, IA LDB Cedar River	Waterloo	13,900	$1.4

Source: National Levee Database

Known levees not within USACE authority in Iowa*

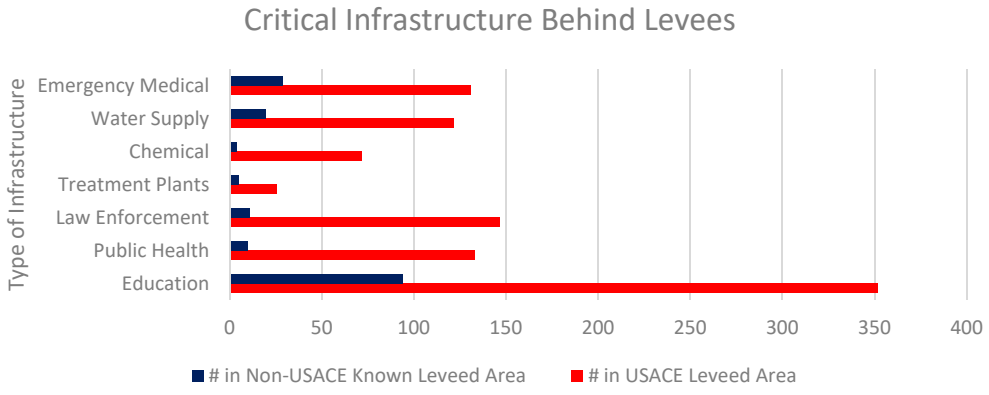
Number of non-USACE known levee systems:	91
Total miles of non-USACE known levees:	200
Population:	12,200

(*Estimated number of people who live behind non-USACE known levees*)

Image: Des Moines Levee
Des Moines, Iowa

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Iowa. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 28, 2017**

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KANSAS

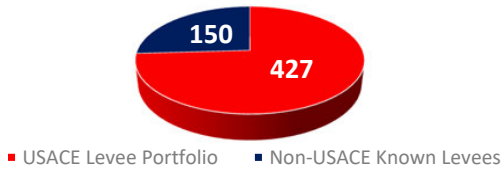
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Kansas*

Number of USACE levee systems:	78
Total miles of USACE levees:	427
Population:	395,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Kansas



Estimated Population and Property Value for three USACE levee systems near key cities in Kansas:

Levee System	City	Population	Property Value ($, Billion)
WVC Big Slough Levee D/WVC Riverside Levee, P,R,S	Wichita	169,000	$18.0
WVC Big Slough Levee C North	Wichita	59,500	$5.3
Salina, KS FPP	Salina	42,300	$4.5

Source: National Levee Database

Known levees not within USACE authority in Kansas*

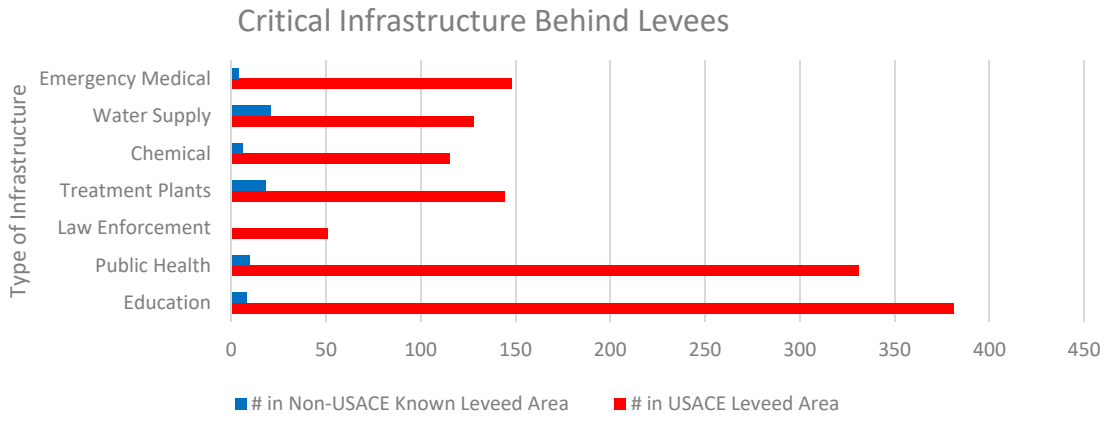
Number of non-USACE known levee systems:	86
Total miles of non-USACE known levees:	150
Population:	11,650

(*Estimated number of people who live behind non-USACE known levees*)

Image: Wichita Levee
Wichita, Kansas

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Kansas. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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KENTUCKY

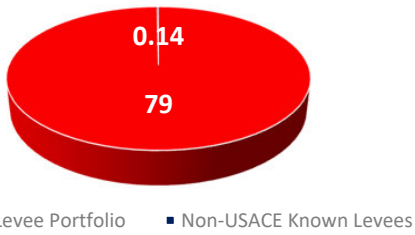
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Kentucky*

Number of USACE levee systems:	31
Total miles of USACE levees:	79
Population:	267,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Kentucky



Estimated Population and Property Value for three USACE levee systems near key cities in Kentucky:

Levee System	City	Population	Property Value ($, Billion)
Louisville Metro Leveed Area	Louisville	211,100	$33.8
Paducah Leveed Area (LFPP)	Paducah	19,500	$3.3
Covington Leveed Area (LFPP)	Covington	7,500	$1.4

Source: National Levee Database

Known levees not within USACE authority in Kentucky*

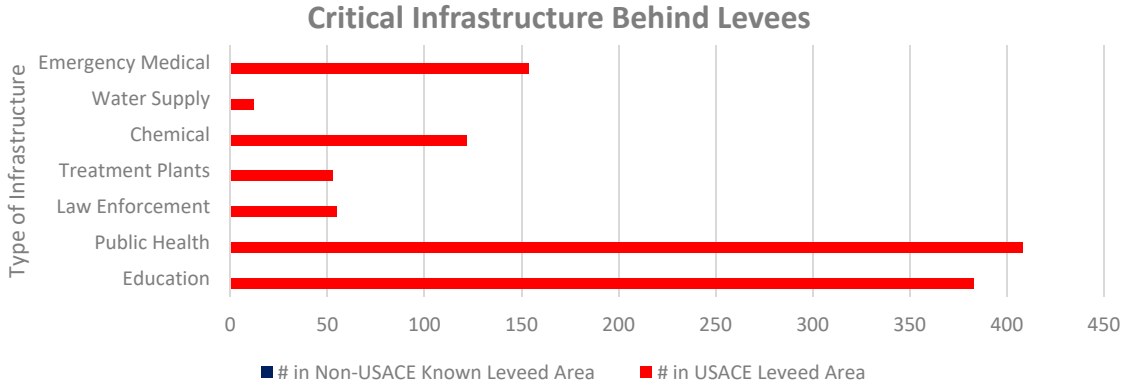
Number of non-USACE known levee systems:	1
Total miles of non-USACE known levees:	0.14
Population:	1

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Kentucky. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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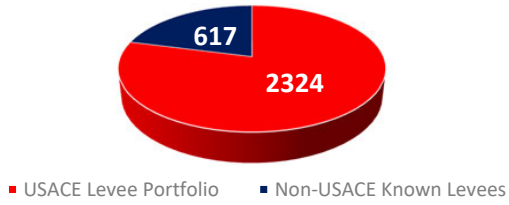
Levees within U.S. Army Corps of Engineers (USACE) authority in Louisiana*

Number of USACE levee systems:	47
Total miles of USACE levees:	2,324
Population:	2,100,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Louisiana



Estimated Population and Property Value for three USACE levee systems near key cities in Louisiana:

Levee System	City	Population	Property Value ($, Billion)
New Orleans East Bank	New Orleans	457,300	$79.6
Mississippi River East Bank	Gonzales	366,700	$49.4
New Orleans West Bank	New Orleans	212,900	$26.0

Source: National Levee Database

Known levees not within USACE authority in Louisiana*

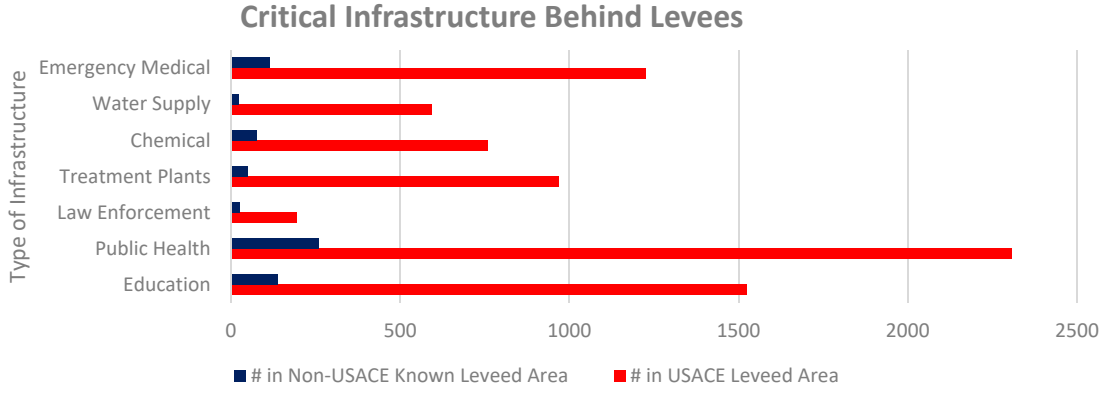
Number of non-USACE known levee systems:	138
Total miles of non-USACE known levees:	617
Population:	367,600

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Louisiana. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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MAINE

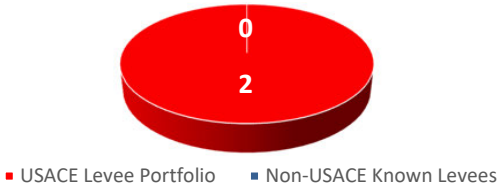
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Maine*

Number of USACE levee systems:	5
Total miles of USACE levees:	2
Population:	427

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Maine



Estimated Population and Property Value for three USACE levee systems near key cities in Maine:

Levee System	City	Population	Property Value ($, Billion)
Saint John River RB Fish Riv LB	Fort Kent	189	$0.1
Aroostook River RB	Fort Fairfield	107	$0.01
Sebasticook River LB	Hartland	69	$0.001

Source: National Levee Database

Known levees not within USACE authority in Maine*

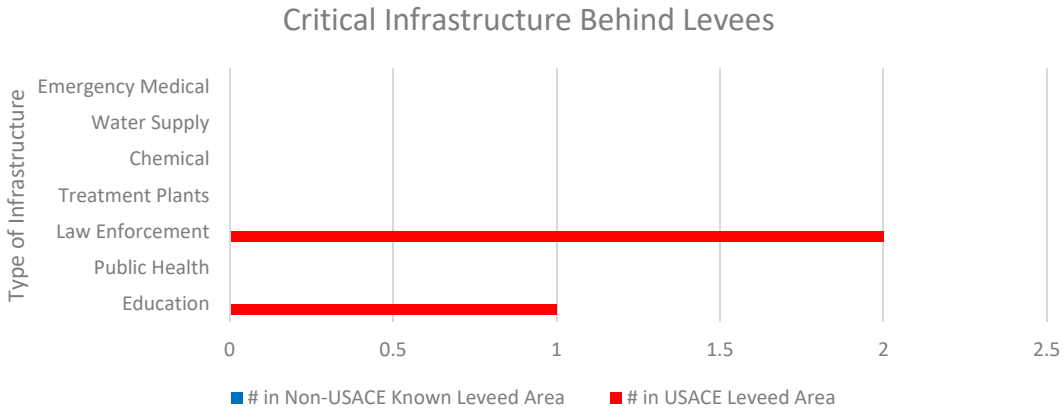
Number of non-USACE known levee systems:	0
Total miles of non-USACE known levees:	0
Population:	0

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Maine. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 5, 2017**

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4155 Clay Street, Vicksburg, Mississippi 39183
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MARYLAND

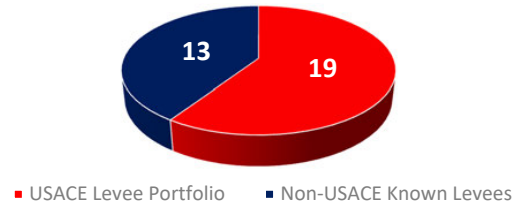
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Maryland*

Number of USACE levee systems:	11
Total miles of USACE levees:	19
Population:	11,099

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Maryland



Estimated Population and Property Value for three USACE levee systems near key cities in Maryland:

Levee System	City	Population	Property Value ($, Billion)
Cumberland Levee	Cumberland	2,600	$0.6
Hyattsville Riverdale	Hyattsville	2,100	$0.2
Atlantic Coast of Maryland Shoreline Protection	Ocean City	2,000	$1.3

Source: National Levee Database

Known levees not within USACE authority in Maryland*

Number of non-USACE known levee systems:	17
Total miles of non-USACE known levees:	13
Population:	4,500

(*Estimated number of people who live behind non-USACE known levees*)

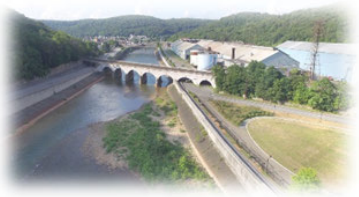
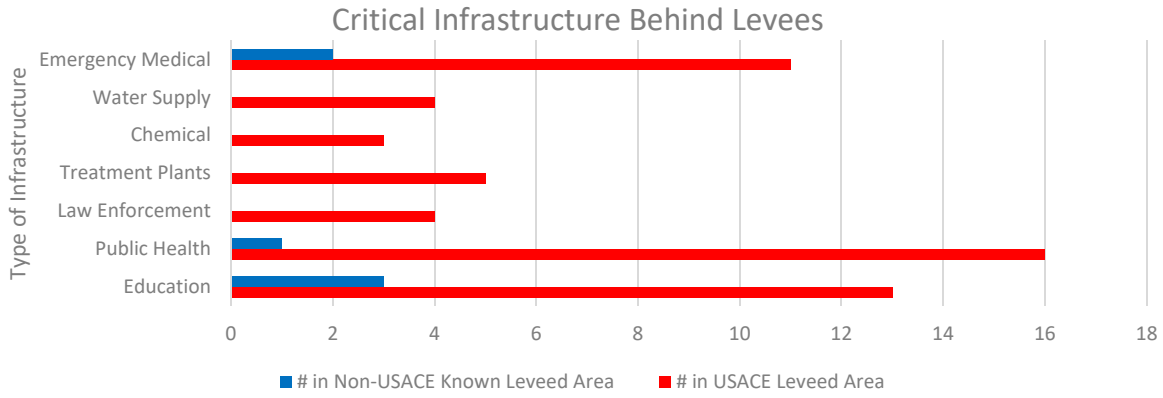


Image: Cumberland Levee
Cumberland, Maryland

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Maryland. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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MASSACHUSETTS
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

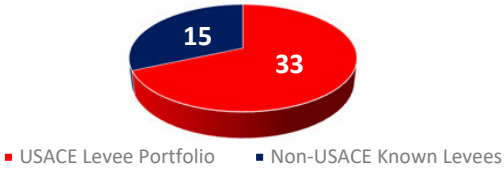
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Massachusetts*

Number of USACE levee systems:	40
Total miles of USACE levees:	33
Population:	52,100

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Massachusetts



Estimated Population and Property Value for three USACE levee systems near key cities in Massachusetts:

Levee System	City	Population	Property Value ($, Billion)
New Bedford HSPP, MA	New Bedford	12,500	$2.7
Chicopee Riv RB & CT Riv LB Chicopee, MA	Hampden	7,400	$1.0
Mill Riv LB, Mill Riv Div, Smith CollNorthamp, MA	Northampton	6,100	$1.2

Source: National Levee Database

Known levees not within USACE authority in Massachusetts*

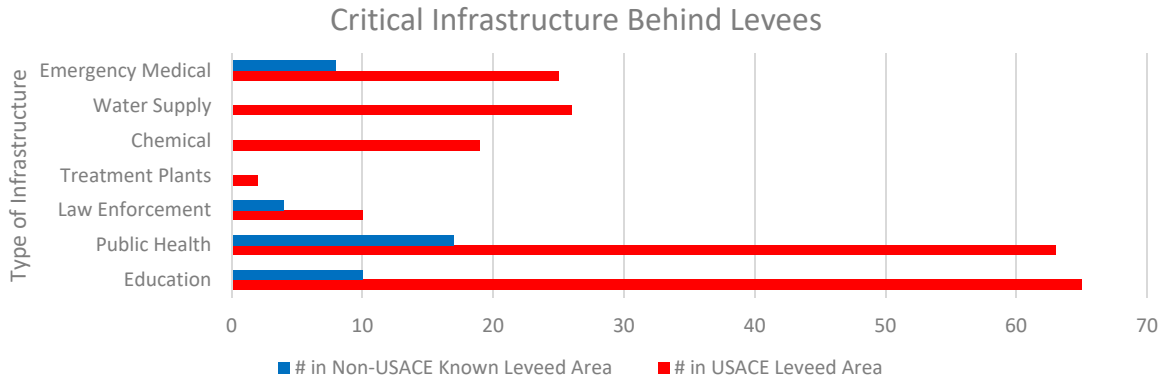
Number of non-USACE known levee systems:	19
Total miles of non-USACE known levees:	15
Population:	6,400

(*Estimated number of people who live behind non-USACE known levees*)

Image: New Bedford HSPP
New Bedford, Massachusetts

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Massachusetts. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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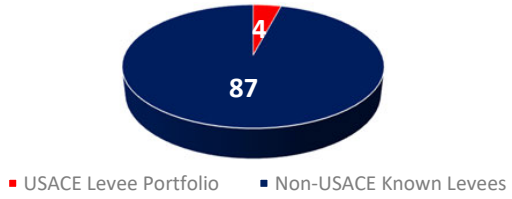
Levees within U.S. Army Corps of Engineers (USACE) authority in Michigan*

Number of USACE levee systems:	9
Total miles of USACE levees:	4
Population:	2,400

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Michigan



Estimated Population and Property Value for three USACE levee systems near key cities in Michigan:

Levee System	City	Population	Property Value ($, Billion)
Battle Creek, East Bank	Battle Creek	1,300	$0.3
Sebewaing River, North Bank	Sebewaing	463	$0.2
Sebewaing River, South Bank	Sebewaing	310	$0.05

Source: National Levee Database

Known levees not within USACE authority in Michigan*

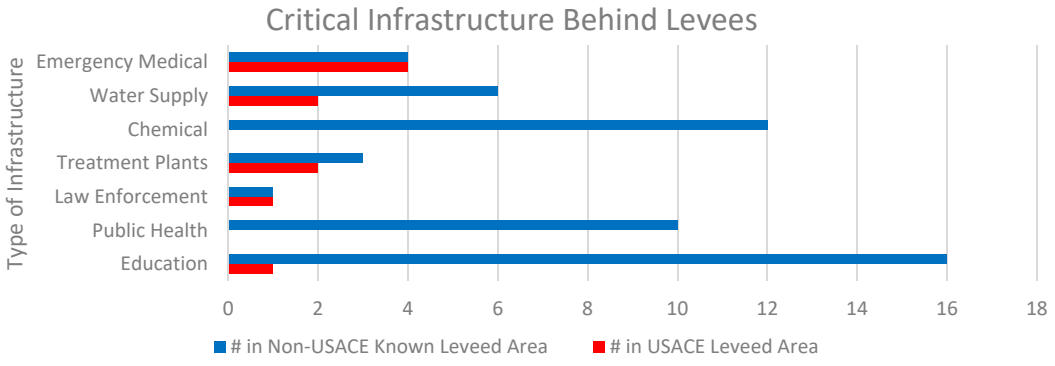
Number of non-USACE known levee systems:	52
Total miles of non-USACE known levees:	87
Population:	13,400

(*Estimated number of people who live behind non-USACE known levees*)

Image: Sebewaing River Levee
Sebewaing, Michigan

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Michigan. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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MINNESOTA
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

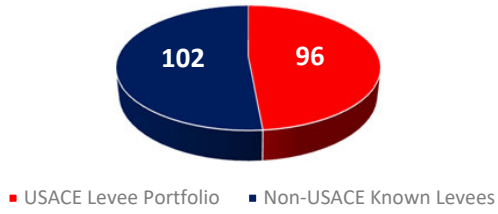
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Minnesota*

Number of USACE levee systems:	57
Total miles of USACE levees:	96
Population:	53,600

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Minnesota



Estimated Population and Property Value for three USACE levee systems near key cities in Minnesota:

Levee System	City	Population	Property Value ($, Billion)
Mississippi River Winona City & Prairie Island	Winona	15,700	$3.0
Redwood River Marshall Right Bank Upstream	Marshall	5,200	$0.6
Red River of the North East Grand Forks	Grand Forks	4,800	$0.7

Source: National Levee Database

Known levees not within USACE authority in Minnesota*

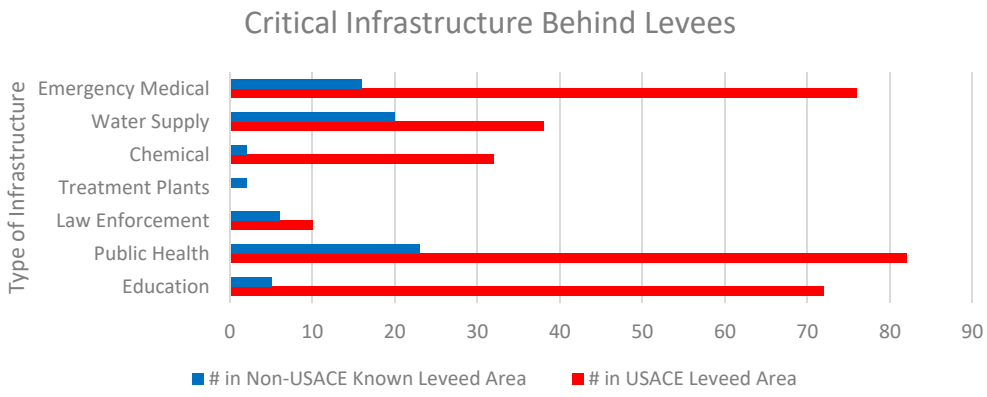
Number of non-USACE known levee systems:	84
Total miles of non-USACE known levees:	102
Population:	9,000

(*Estimated number of people who live behind non-USACE known levees*)

Image: Winona Levee
Winona, Minnesota

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Minnesota. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: May 24, 2017**

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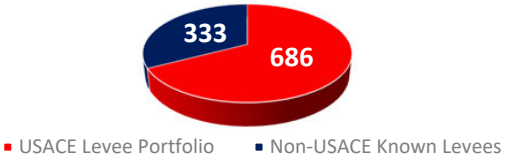
Levees within U.S. Army Corps of Engineers (USACE) authority in Mississippi*

Number of USACE levee systems:	25
Total miles of USACE levees:	686
Population:	295,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Mississippi



Estimated Population and Property Value for three USACE levee systems near key cities in Mississippi:

Levee System	City	Population	Property Value ($, Billion)
Yazoo Delta Levee Memphis-Rosedale Sys (MS East)	Greenville	191,600	$16.9
Yazoo, Backwater-Yazoo River RB	Anguilla	29,200	$3.2
Greenwood MS, East	Greenwood	23,800	$1.7

Source: National Levee Database

Known levees not within USACE authority in Mississippi*

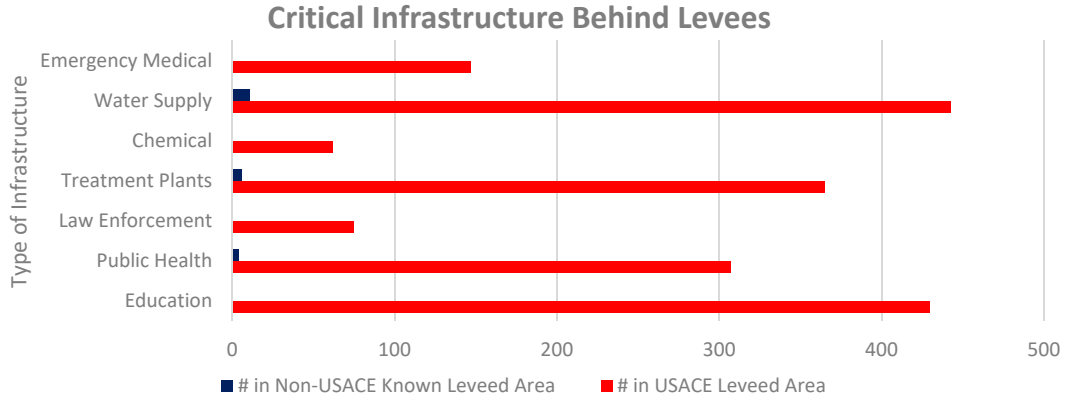
Number of non-USACE known levee systems:	98
Total miles of non-USACE known levees:	333
Population:	4,200

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Mississippi. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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MISSOURI
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

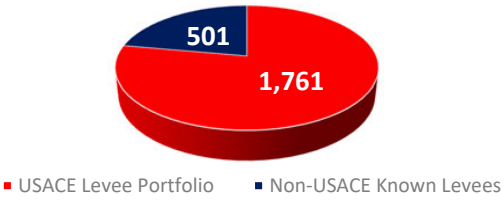
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Missouri*

Number of USACE levee systems:	154
Total miles of USACE levees:	1,761
Population:	293,300

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Missouri



Estimated Population and Property Value for three USACE levee systems near key cities in Missouri:

Levee System	City	Population	Property Value ($, Billion)
Commerce, MO – St. Francis River	Holland	197,500	$22.5
St. Francis east to Big Lake West	Senath	23,800	$2.5
North Kansas City Levee Unit	North Kansas City	19,600	$2.7

Source: National Levee Database

Known levees not within USACE authority in Missouri*

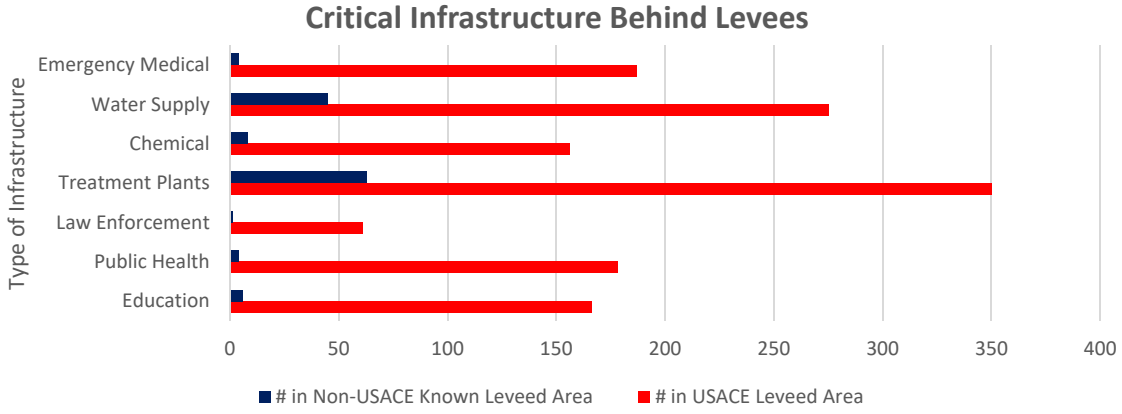
Number of non-USACE known levee systems:	192
Total miles of non-USACE known levees:	501
Population:	3,042

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Missouri. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: July 23, 2017**

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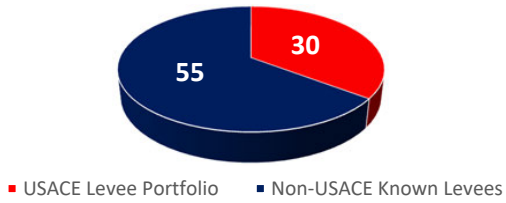
MONTANA
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Montana*

Number of USACE levee systems:	29
Total miles of USACE levees:	30
Population:	9,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Montana



Estimated Population and Property Value for three USACE levee systems near key cities in Montana:

Levee System	City	Population	Property Value ($, Billion)
Havre Milk River Rt. Bank	Havre	2,000	$0.3
Forsyth Yellowstone Rt. Bank	Forsyth	1,700	$0.2
Great Falls Sun River Lt. Bank	Great Falls	1,200	$0.1

Source: National Levee Database

Known levees not within USACE authority in Montana*

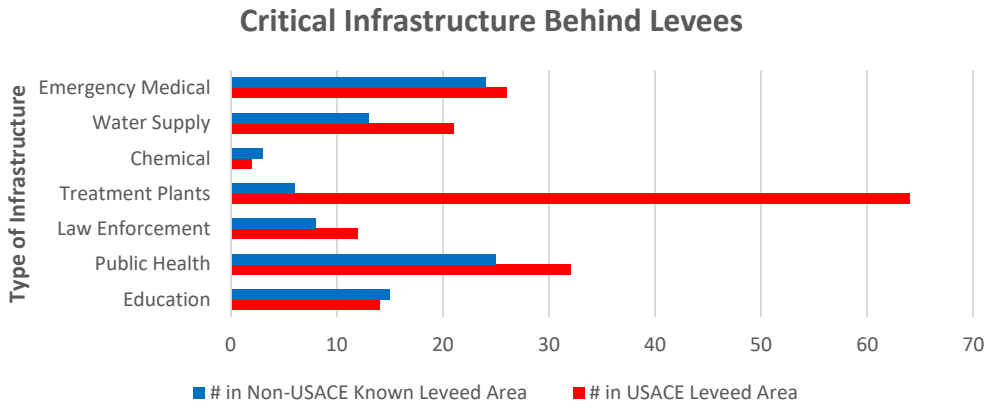
Number of non-USACE known levee systems:	51
Total miles of non-USACE known levees:	55
Population:	14,800

(*Estimated number of people who live behind non-USACE known levees*)

Image: Forsyth Yellowstone Levee Forsyth, Montana

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Montana. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: May 24, 2017**

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NEBRASKA
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

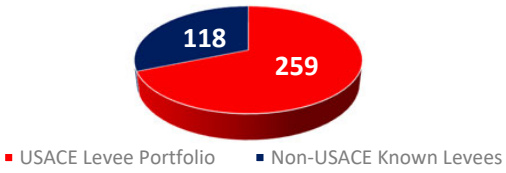
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Nebraska*

Number of USACE levee systems:	80
Total miles of USACE levees:	259
Population:	42,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Nebraska



Estimated Population and Property Value for three USACE levee systems near key cities in Nebraska:

Levee System	City	Population	Property Value ($, Billion)
Norfolk Elkhorn Right Bank	Norfolk	10,000	$1.4
Grand Island Wood River Left Bank	Grand Island	7,500	$0.8
Columbus Loup River Left Bank	Columbus	3,000	$0.3

Source: National Levee Database

Known levees not within USACE authority in Nebraska*

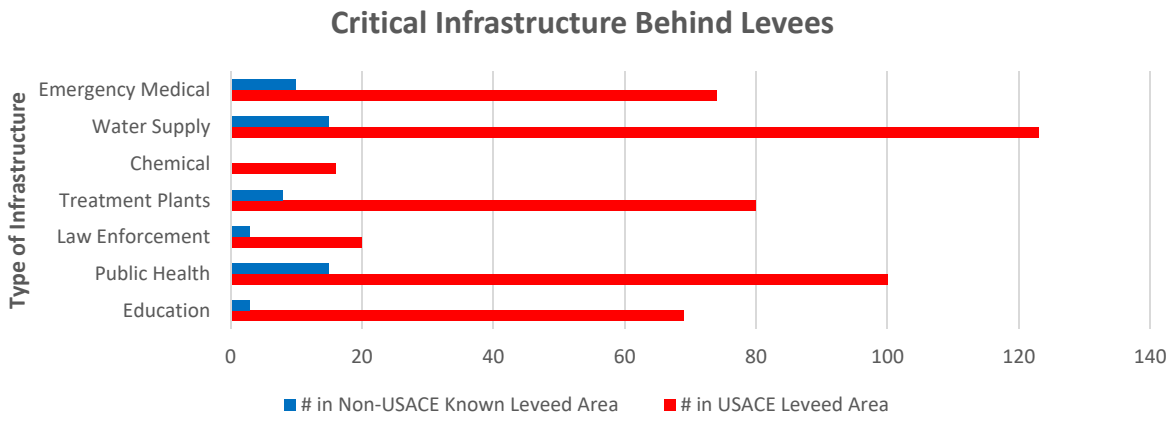
Number of non-USACE known levee systems:	60
Total miles of non-USACE known levees:	118
Population:	6,700

(*Estimated number of people who live behind non-USACE known levees*)

Image: Wood River Levee
Grand Island, Nebraska

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Nebraska. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of June 2, 2017**

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NEVADA

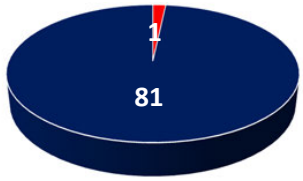
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Nevada*

Number of USACE levee systems:	1
Total miles of USACE levees:	1
Population:	2,400

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Nevada



Estimated Population and Property Value for three USACE levee systems near key cities in Nevada:

Levee System	City	Population	Property Value ($, Billion)
Reese River at Battle Mountain, NV	Battle Mountain	2,400	$0.3

Source: National Levee Database

Known levees not within USACE authority in Nevada*

Number of non-USACE known levee systems:	31
Total miles of non-USACE known levees:	81
Population:	36

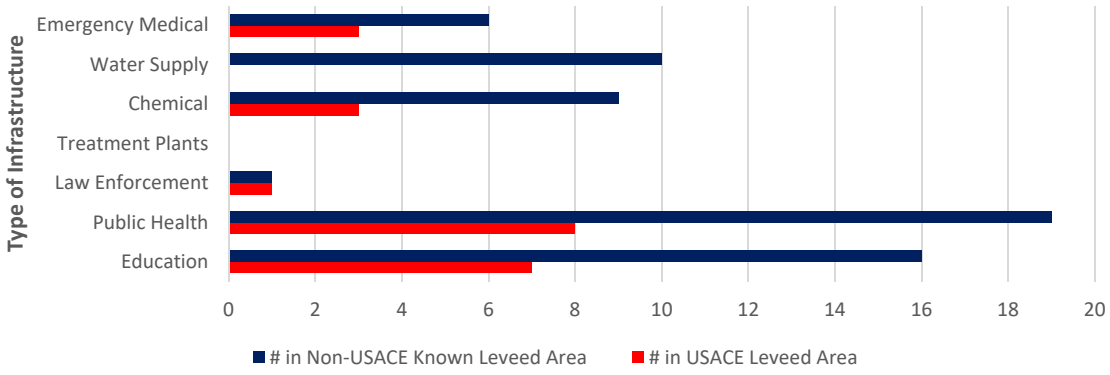
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Nevada. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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NEW HAMPSHIRE
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

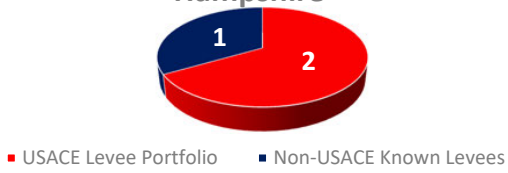
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in New Hampshire*

Number of USACE levee systems:	4
Total miles of USACE levees:	2
Population:	5,400

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in New Hampshire



Estimated Population and Property Value for three USACE levee systems near key cities in New Hampshire:

Levee System	City	Population	Property Value ($, Billion)
Beaver Bk Dam and Levees, Downtown Cl	Keene	5,200	$0.8
Cocheco River LB-Farmington, NH	Farmington	126	$0.06
Nashua Local Protection Project	Nashua	97	$0.06

Source: National Levee Database

Known levees not within USACE authority in New Hampshire*

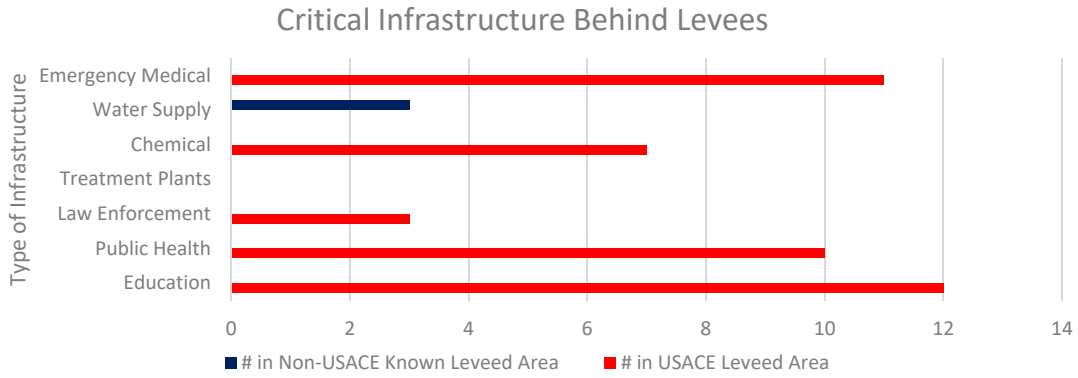
Number of non-USACE known levee systems:	3
Total miles of non-USACE known levees:	1
Population:	1

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of New Hampshire. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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Levees within U.S. Army Corps of Engineers (USACE) authority in New Jersey*

Number of USACE levee systems:	9
Total miles of USACE levees:	11
Population:	19,000

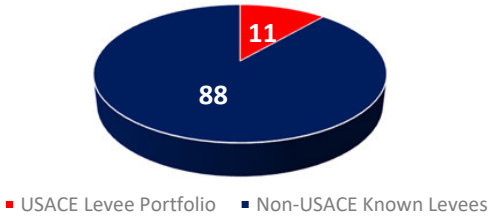
(*Estimated number of people who live behind USACE known levees*)

Estimated Population and Property Value for three USACE levee systems near key cities in New Jersey:

Levee System	City	Population	Property Value ($, Billion)
Raritan Bay and Sandy Hook Bay	Keansburg	12,000	$1.8
Elizabeth River Left Bank South	Elizabeth	2,600	$0.3
Elizabeth River Right Bank South	Elizabeth	2,500	$0.2

Source: National Levee Database

Number of Levees Miles in New Jersey



Known levees not within USACE authority in New Jersey*

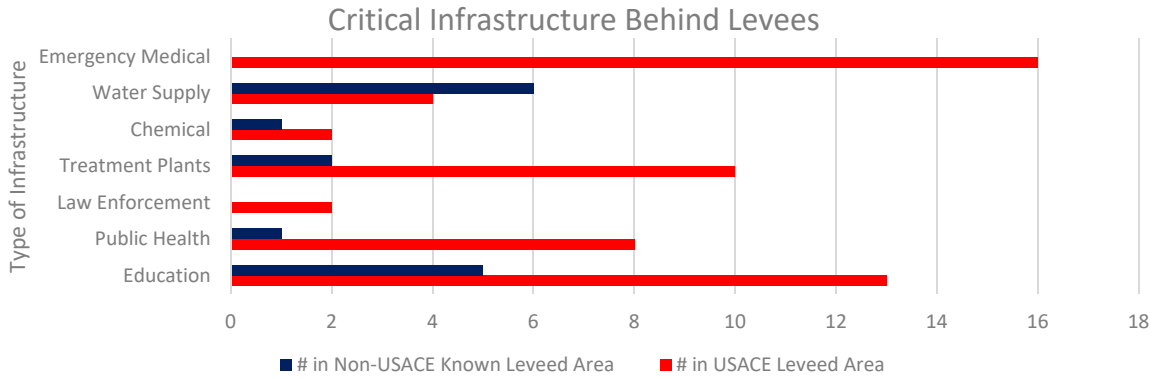
Number of non-USACE known levee systems:	107
Total miles of non-USACE known levees:	88
Population:	2,100

(*Estimated number of people who live behind non-USACE known levees*)

Image: Elizabeth River Right Bank Levee Elizabeth, New Jersey

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of New Jersey. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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NEW MEXICO
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

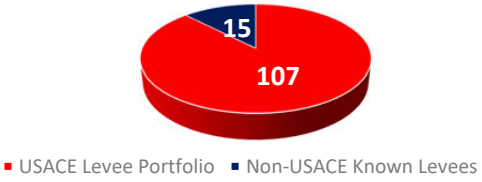
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in New Mexico*

Number of USACE levee systems:	39
Total miles of USACE levees:	80
Population:	133,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in New Mexico



Estimated Population and Property Value for three USACE levee systems near key cities in New Mexico:

Levee System	City	Population	Property Value ($, Billion)
Alb. Middle Rio Grande, East Levee	Albuquerque	63,400	$7.6
Alb. Middle Rio Grande, West Levee	Albuquerque	38,900	$2.9
Socorro Diversion Channel, Right Levee	Socorro	7,100	$0.7

Source: National Levee Database

Known levees not within USACE authority in New Mexico*

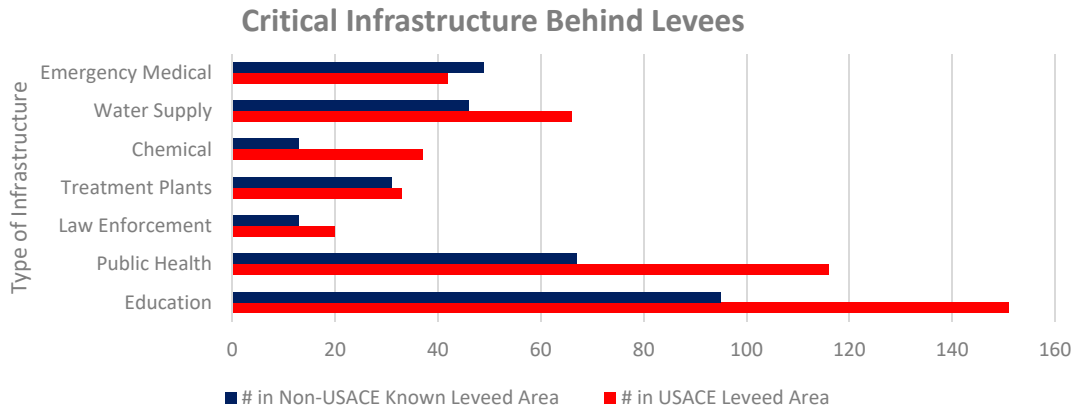
Number of non-USACE known levee systems:	177
Total miles of non-USACE known levees:	478
Population:	137,200

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of New Mexico. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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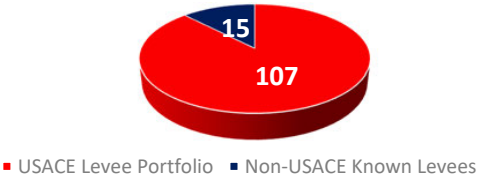
Levees within U.S. Army Corps of Engineers (USACE) authority in New York*

Number of USACE levee systems:	73
Total miles of USACE levees:	107
Population:	88,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in New York



Estimated Population and Property Value for three USACE levee systems near key cities in New York:

Levee System	City	Population	Property Value ($, Billion)
North Elmira	North Elmira	11,900	$2.4
Northeast Binghamton	Binghamton	6,200	$2.3
South Elmira	South Elmira	12,600	$1.4

Source: National Levee Database

Known levees not within USACE authority in New York*

Number of non-USACE known levee systems:	35
Total miles of non-USACE known levees:	15
Population:	12,100

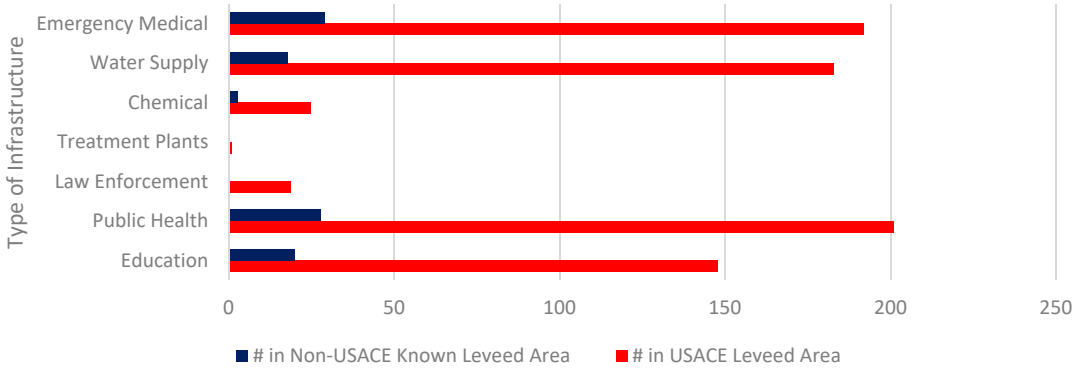
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of New York. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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4155 Clay Street, Vicksburg, Mississippi 39183
TEL: 601-631-5053, http://www.mvk.usace.army.mil

NORTH CAROLINA
SUMMARY OF LEVEE INFORMATION

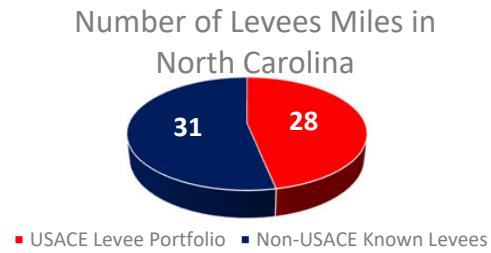
U.S. ARMY CORPS OF ENGINEERS

BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in North Carolina*

Number of USACE levee systems:	13
Total miles of USACE levees:	28
Population:	539

(*Estimated number of people who live behind USACE known levees*)



Estimated Population and Property Value for three USACE levee systems near key cities in North Carolina:

Levee System	City	Population	Property Value ($, Million)
Princeville Dike	Princeville	286	$72.3
White Oak Dike	East Arcadia	137	$11.5
Deep Creek FCP	Speed	29	$7.9

Source: National Levee Database

Known levees not within USACE authority in North Carolina*

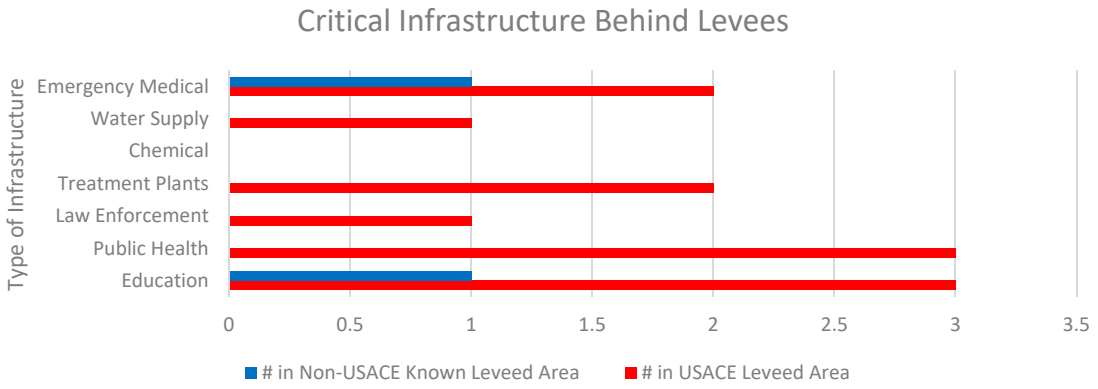
Number of non-USACE known levee systems:	5
Total miles of non-USACE known levees:	31
Population:	31

(*Estimated number of people who live behind non-USACE known levees*)

Image: Princeville Dike
Princeville, North Carolina

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of North Carolina. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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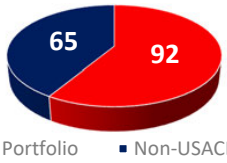
NORTH DAKOTA
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in North Dakota*

Number of USACE levee systems:	28
Total miles of USACE levees:	92
Population:	92,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in North Dakota



Estimated Population and Property Value for three USACE levee systems near key cities in North Dakota:

Levee System	City	Population	Property Value ($, Billion)
Red River of the North Grand Forks	Grand Forks	47,900	$6.1
Sheyenne River West Fargo	West Fargo	17,400	$1.5
Sheyenne River Horace to West Fargo	West Fargo	8,800	,,$0.2

Source: National Levee Database

Known levees not within USACE authority in North Dakota*

Number of non-USACE known levee systems:	52
Total miles of non-USACE known levees:	65
Population:	11,500

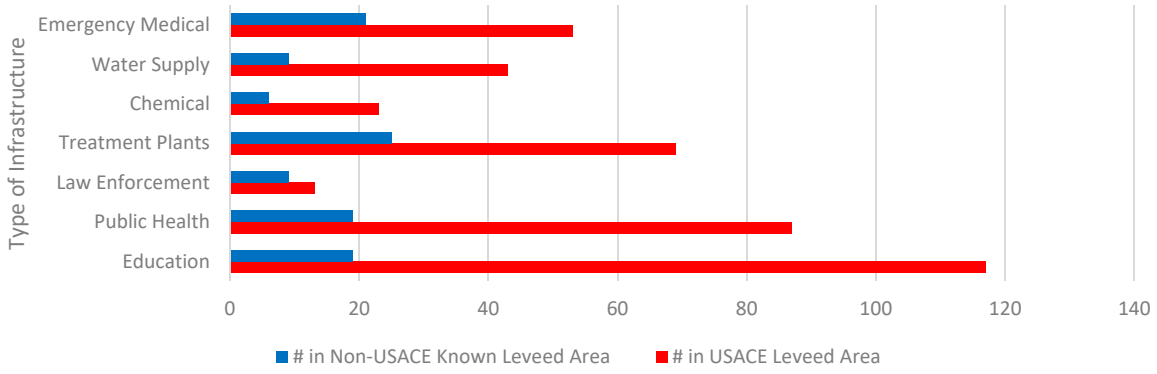
(*Estimated number of people who live behind non-USACE known levees*)

Image: Embankment Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of North Dakota. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 3, 2017**

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OHIO

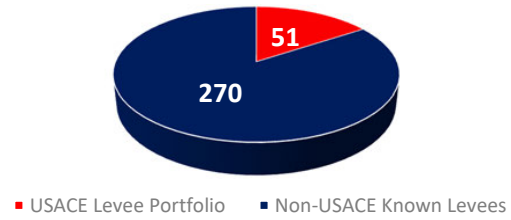
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Ohio*

Number of USACE levee systems:	29
Total miles of USACE levees:	51
Population:	52,900

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Ohio



Estimated Population and Property Value for three USACE levee systems near key cities in Ohio:

Levee System	City	Population	Property Value ($, Billion)
West Columbus, OH, LPP	Columbus (West)	12,800	$2.0
Portsmouth-New Boston, OH, LPP	Portsmouth	10,100	$1.8
Cincinnati LFPP	Cincinnati	7,200	$2.1

Source: National Levee Database

Known levees not within USACE authority in Ohio*

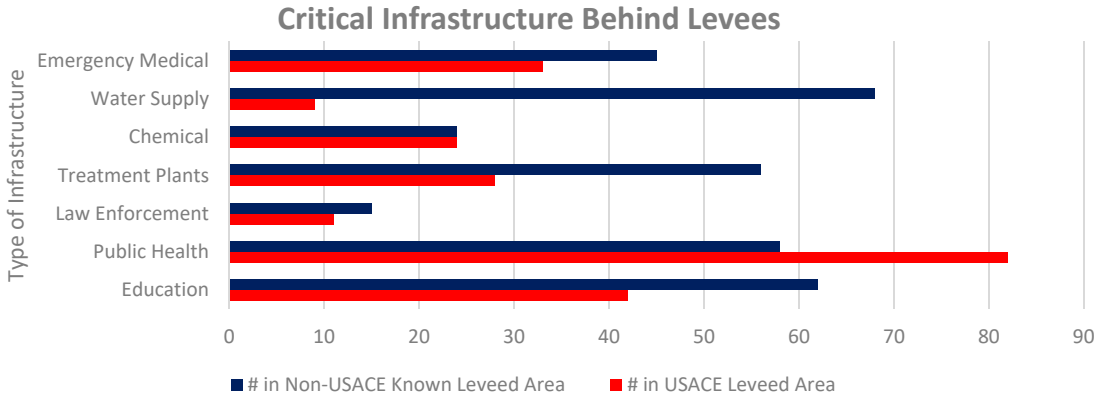
Number of non-USACE known levee systems:	229
Total miles of non-USACE known levees:	270
Population:	42,500

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Ohio. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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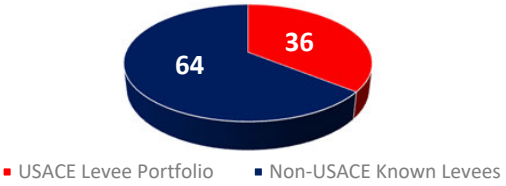
Levees within U.S. Army Corps of Engineers (USACE) authority in Oklahoma*

Number of USACE levee systems:	9
Total miles of USACE levees:	36
Population:	14,200

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Oklahoma



Estimated Population and Property Value for three USACE levee systems near key cities in Oklahoma:

Levee System	City	Population	Property Value ($, Billion)
Jenks Levee	Jenks	3,000	$0.4
Tulsa-West Tulsa Levee – Levee C	Tulsa	3,800	$0.5
Tulsa-West Tulsa Levee – Levee A and B	Tulsai	5,800	$1.1

Source: National Levee Database

Known levees not within USACE authority in Oklahoma*

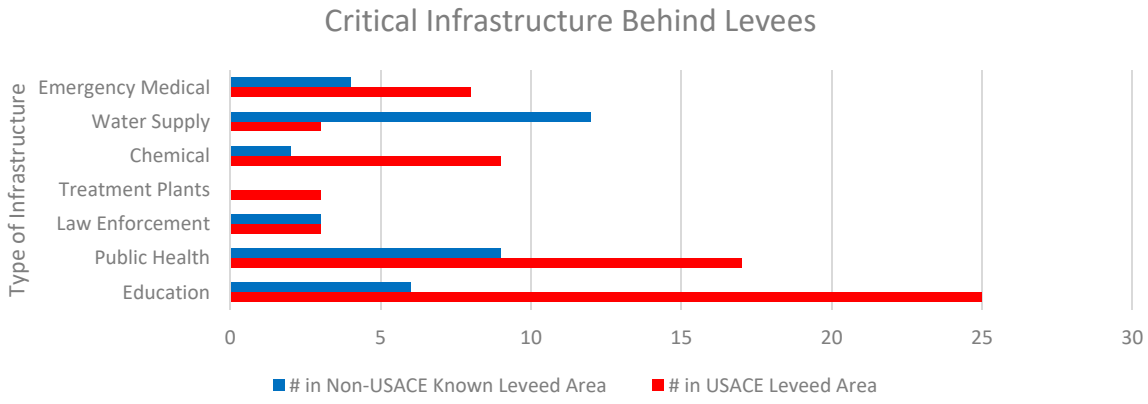
Number of non-USACE known levee systems:	72
Total miles of non-USACE known levees:	64
Population:	2,800

(*Estimated number of people who live behind non-USACE known levees*)

Image: Embankment Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Oklahoma. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 3, 2017**

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OREGON

SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

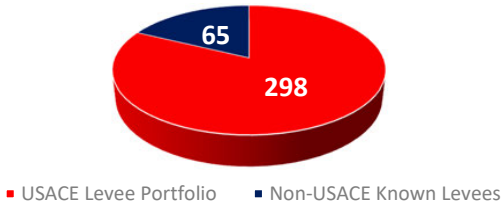
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Oregon*

Number of USACE levee systems:	137
Total miles of USACE levees:	298
Population:	33,800

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Oregon



Estimated Population and Property Value for three USACE levee systems near key cities in Oregon:

Levee System	City	Population	Property Value ($, Billion)
Multnomah Protected Area – West	Portland	10,300	$1.6
Milton-Freewater 1 (Left Bank Lower)	Milton-Freewater	5,800	$0.7
Peninsula DD No. 2 Protected Area	Portland	3,200	$0.7

Source: National Levee Database

Known levees not within USACE authority in Oregon*

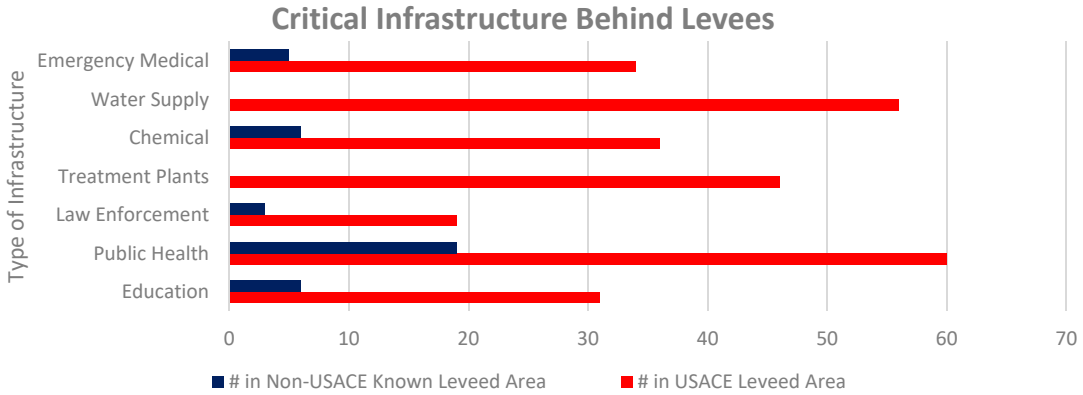
Number of non-USACE known levee systems:	102
Total miles of non-USACE known levees:	65
Population:	5,500

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Oregon. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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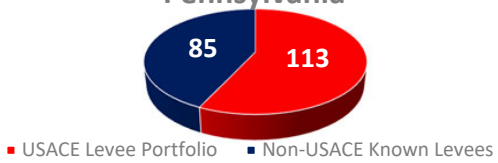
PENNSYLVANIA
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Pennsylvania*

Number of USACE levee systems:	97
Total miles of USACE levees:	113
Population:	93,900

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Pennsylvania



Estimated Population and Property Value for three USACE levee systems near key cities in Pennsylvania:

Levee System	City	Population	Property Value ($, Billion)
Kingston to Exeter	Kingston	26,200	$3.7
Wilkes-Barre-Hanover Township	Wilkes-Barre	17,600	$3.2
Northeast Williamsport	Williamsport	5,100	$2.7

Source: National Levee Database

Known levees not within USACE authority in Pennsylvania*

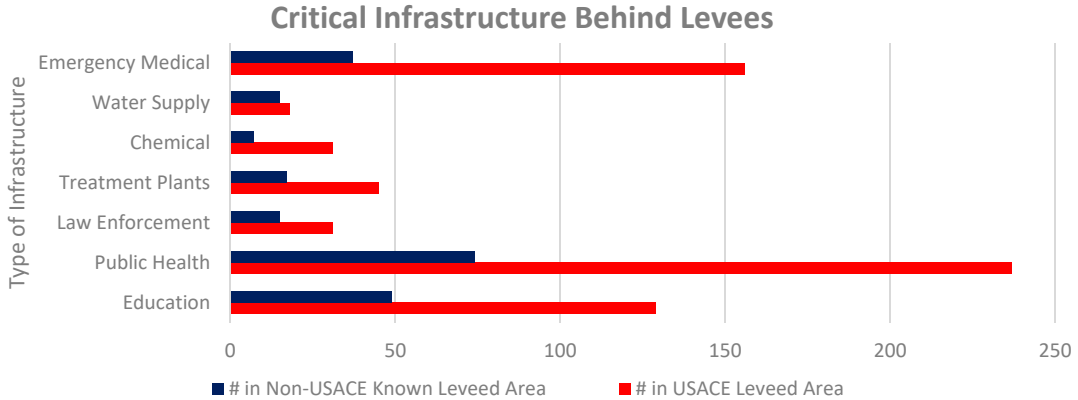
Number of non-USACE known levee systems:	117
Total miles of non-USACE known levees:	85
Population:	109,900

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Pennsylvania. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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PUERTO RICO
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

BUILDING STRONG

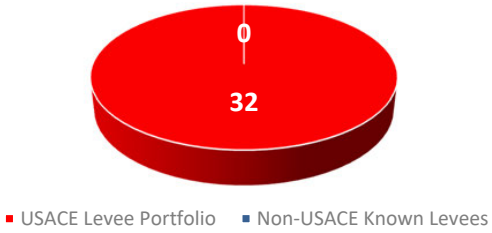
Levees within U.S. Army Corps of Engineers (USACE) authority in Puerto Rico*

Number of USACE levee systems:	13
Total miles of USACE levees:	32
Population:	82,800

(*Estimated number of people who live behind USACE known levees*)

Estimated Population and Property Value for three USACE levee systems near key cities in Puerto Rico:

Number of Levees Miles in Puerto Rico



Levee System	City	Population	Property Value ($, Billion)
Portugues West	Playa	30,800	$2.1
Portugues and Bucana	Machuelo Abajo	26,200	$1.7
Bucana East	Bucana East	9,500	$0.6

Source: National Levee Database

Known levees not within USACE authority in Puerto Rico*

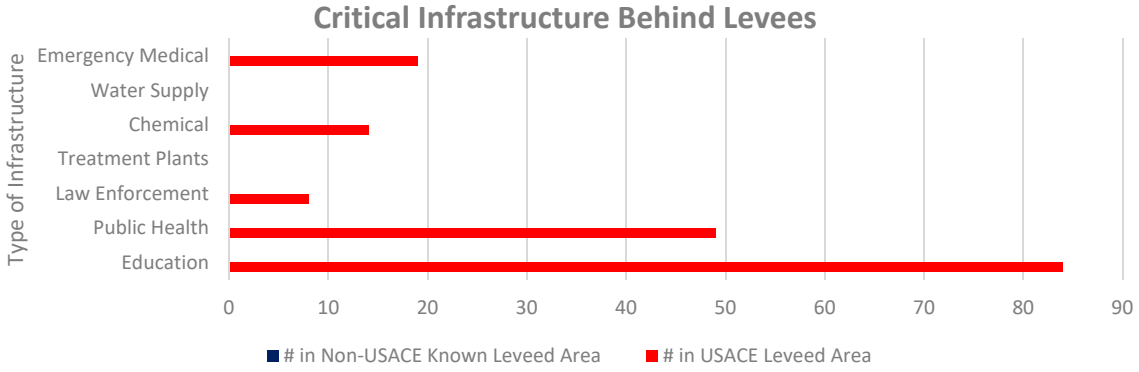
Number of non-USACE known levee systems:	0
Total miles of non-USACE known levees:	0
Population:	0

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in Puerto Rico. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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RHODE ISLAND
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

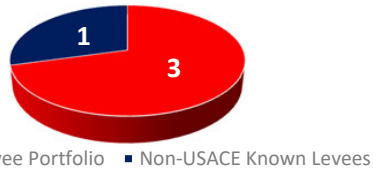
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Rhode Island*

Number of USACE levee systems:	5
Total miles of USACE levees:	3
Population:	9,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Rhode Island



Estimated Population and Property Value for three USACE levee systems near key cities in Rhode Island:

Levee System	City	Population	Property Value ($, Billion)
Fox Point HSPP, Providence, RI	Providence	8,600	$3.7
Lower Woonsocket Blackstone LB, Mill & Peters Riv	Woonsocket	636	$0.2
Lower Woonsocket Blackstone Riv RB	Social	358	$0.07

Source: National Levee Database

Known levees not within USACE authority in Rhode Island*

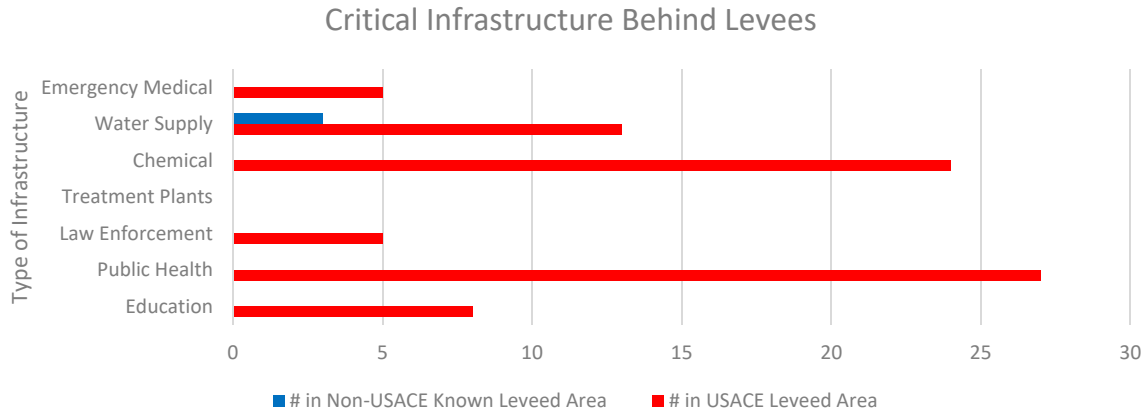
Number of non-USACE known levee systems:	4
Total miles of non-USACE known levees:	1
Population:	23

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Rhode Island. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 5, 2017**

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SOUTH CAROLINA
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

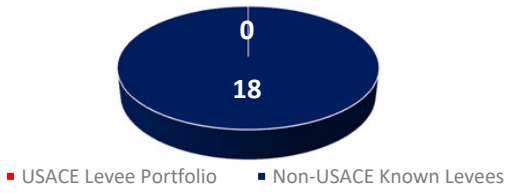
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in South Carolina*

Number of USACE levee systems:	0
Total miles of USACE levees:	0
Population:	0

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in South Carolina



Estimated Population and Property Value for three USACE levee systems near key cities in South Carolina:

Levee System	City	Population	Property Value ($, Billion)
No USACE levee systems	NA	NA	

Source: National Levee Database

Known levees not within USACE authority in South Carolina*

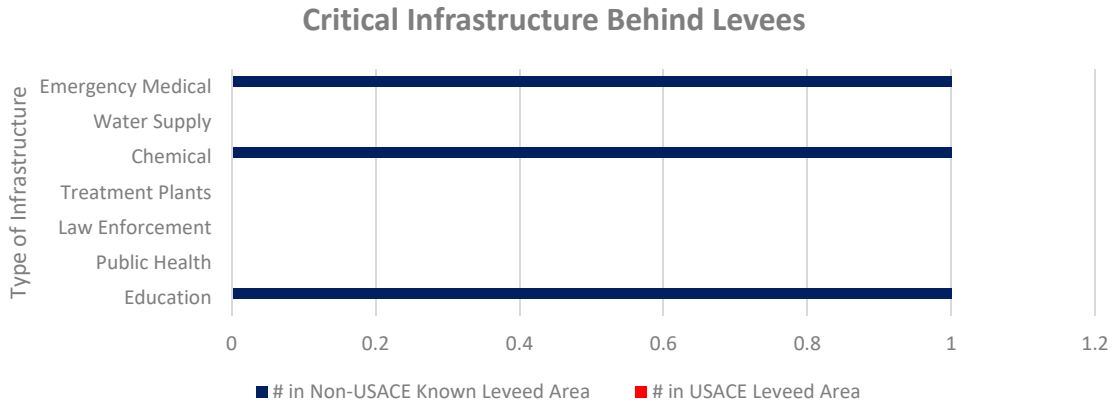
Number of non-USACE known levee systems:	11
Total miles of non-USACE known levees:	18
Population:	0

(*Estimated number of people who live behind non-USACE known levees*)

Image: Typical Earthen Levee in USACE Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of South Carolina. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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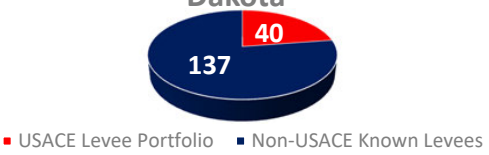
SOUTH DAKOTA
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in South Dakota*

Number of USACE levee systems:	16
Total miles of USACE levees:	40
Population:	26,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in South Dakota



Estimated Population and Property Value for three USACE levee systems near key cities in South Dakota:

Levee System	City	Population	Property Value ($, Billion)
Sioux Falls Big Sioux LB North and Div Channel	Havre	7,000	$0.8
Sioux Falls Big Sioux RB and Skunk Creek RB	Forsyth	5,000	$0.5
Aberdeen Moccasin Creek RB	Great Falls	4,000	$0.5

Source: National Levee Database

Known levees not within USACE authority in South Dakota*

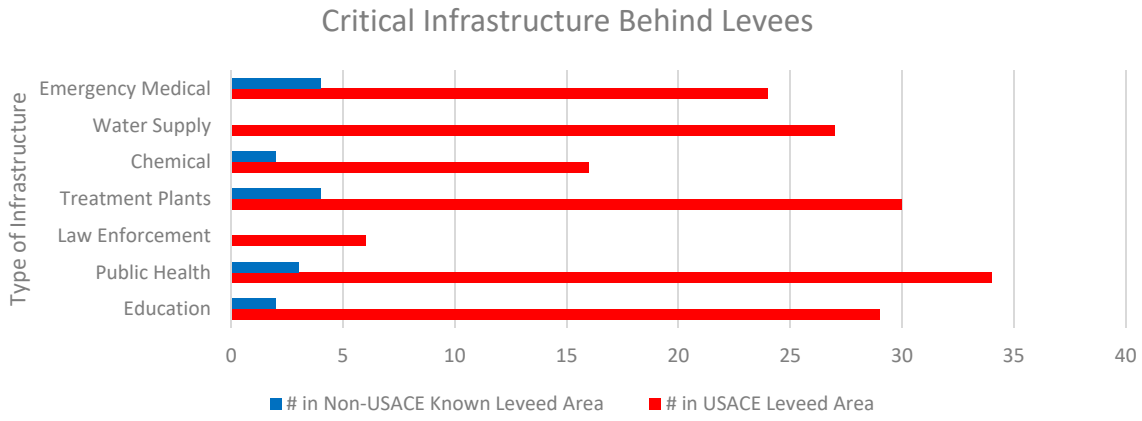
Number of non-USACE known levee systems:	91
Total miles of non-USACE known levees:	137
Population:	1,400

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of South Dakota. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 5, 2017**

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TENNESSEE
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

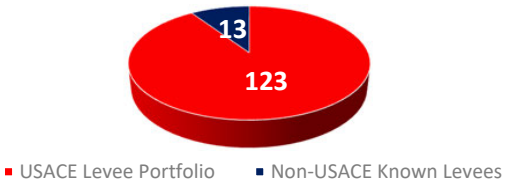
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Tennessee*

Number of USACE levee systems:	11
Total miles of USACE levees:	123
Population:	46,400

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Tennessee



Estimated Population and Property Value for three USACE levee systems near key cities in Tennessee:

Levee System	City	Population	Property Value ($, Billion)
Memphis Wolf River Backwater Levee System	Memphis	27,900	$1.7
Hickman KY Obion River System	Lenox	13,400	$1.4
NFFDR Levee System (Finley Street)	Dyersburg	1,400	$0.2

Source: National Levee Database

Known levees not within USACE authority in Tennessee*

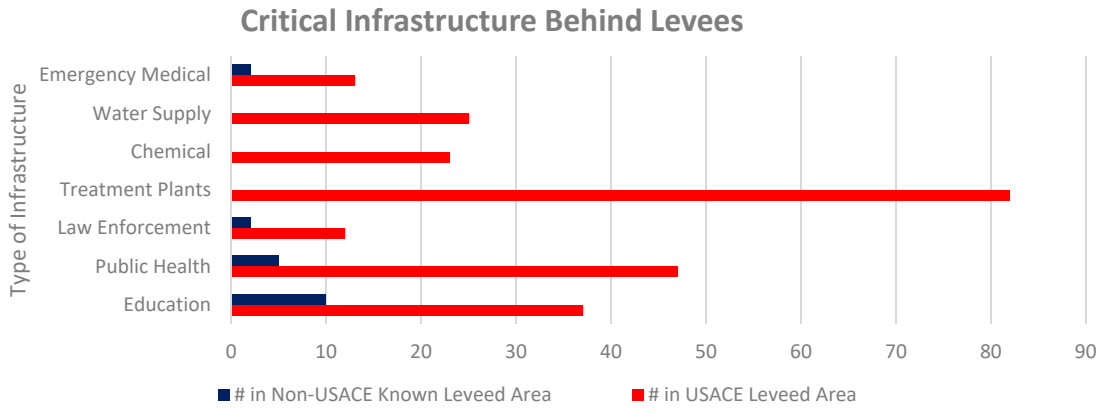
Number of non-USACE known levee systems:	6
Total miles of non-USACE known levees:	13
Population:	74

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Tennessee. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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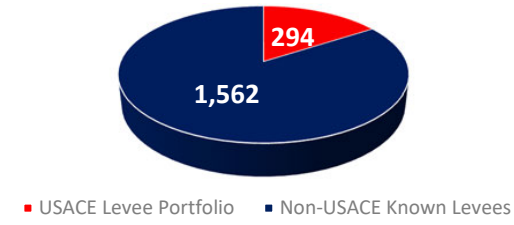
Levees within U.S. Army Corps of Engineers (USACE) authority in Texas*

Number of USACE levee systems:	51
Total miles of USACE levees:	294
Population:	291,900

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Texas



Estimated Population and Property Value for three USACE levee systems near key cities in Texas:

Levee System	City	Population	Property Value ($, Billion)
Port Arthur Hurricane Flood Protection	Port Arthur	78,000	$9.5
East Dallas Levee Trinity LB	Dallas	60,700	$10.2
Freeport Hurricane Flood Protection	Freeport	40,000	$5.3

Source: National Levee Database

Known levees not within USACE authority in Texas*

Number of non-USACE known levee systems:	276
Total miles of non-USACE known levees:	1,562
Population:	707,700

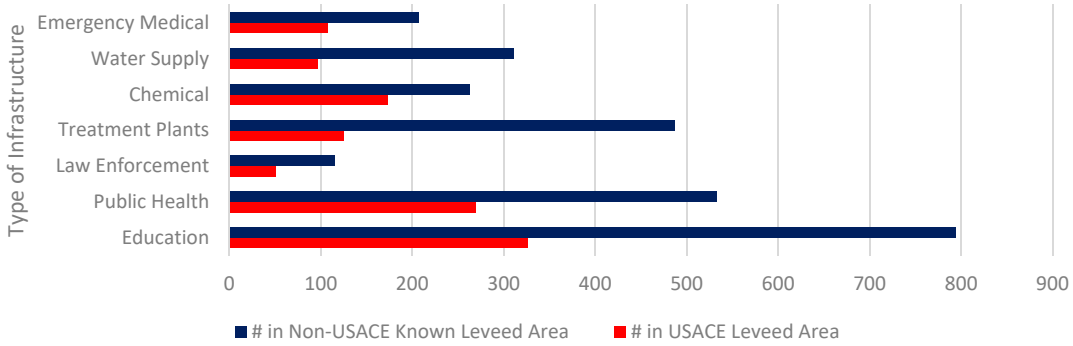
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in USACE Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Texas. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: July 5, 2017**

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U.S. VIRGIN ISLANDS

SUMMARY OF LEVEE INFORMATION

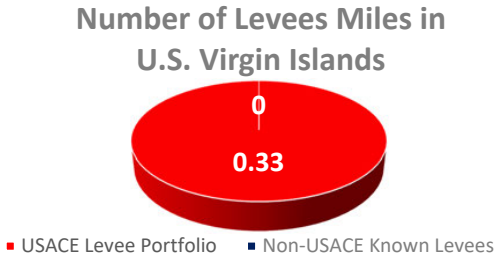
U.S. ARMY CORPS OF ENGINEERS

BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in U.S. Virgin Islands*

Number of USACE levee systems:	1
Total miles of USACE levees:	0.33
Population:	260

(*Estimated number of people who live behind USACE known levees*)



Estimated Population and Property Value for three USACE levee systems near key cities in U.S. Virgin Islands:

Levee System	City	Population	Property Value ($, Million)
Mon Bijou	Kingshill	260	$12

Source: National Levee Database

Known levees not within USACE authority in U.S. Virgin Islands*

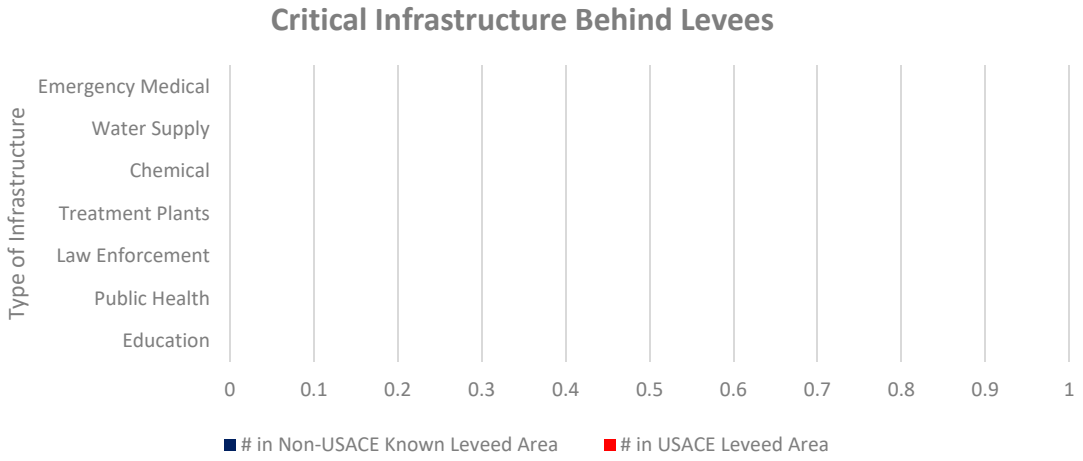
Number of non-USACE known levee systems:	0
Total miles of non-USACE known levees:	0
Population:	0

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the U.S. Virgin Islands. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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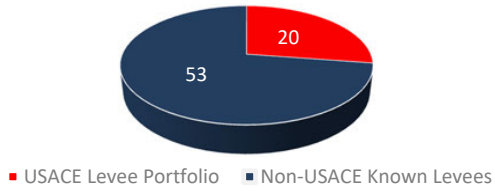
Levees within U.S. Army Corps of Engineers (USACE) authority in Utah*

Number of USACE levee systems:	4
Total miles of USACE levees:	20
Population:	51,010

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Utah



Estimated Population and Property Value for three USACE levee systems near key cities in Utah:

Levee System	City	Population	Property Value ($, Billion)
Surplus Canal East Bank – Salt Lake City	Salt Lake City	41,600	$3.1
Surplus Canal West Bank – Salt Lake City	Salt Lake City	8,200	$1.3
Big Wash Levee – Beaver County, UT	Milford	1,100	$0.1

Source: National Levee Database

Known levees not within USACE authority in Utah*

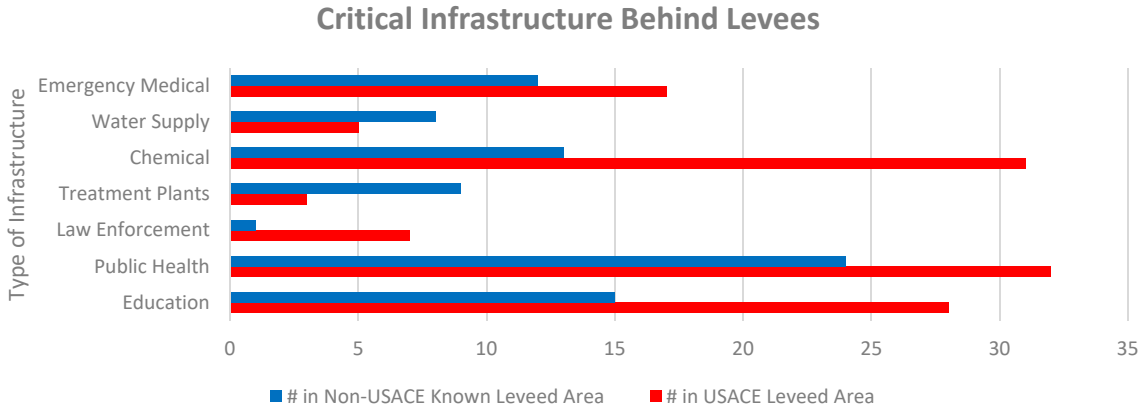
Number of non-USACE known levee systems:	42
Total miles of non-USACE known levees:	53
Population:	27,900

(*Estimated number of people who live behind non-USACE known levees*)

Image: Surplus Canal Levee, Salt Lake City, Utah

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Utah. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: May 24, 2017**

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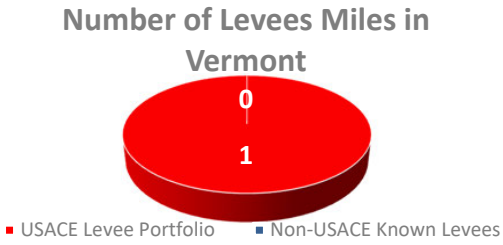
VERMONT

SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Vermont*

Number of USACE levee systems:	1
Total miles of USACE levees:	1
Population:	2,000

(*Estimated number of people who live behind USACE known levees*)



Estimated Population and Property Value for three USACE levee systems near key cities in Vermont:

Levee System	City	Population	Property Value ($, Billion)
Bennington Flood Control Project	Bennington	2,000	$0.2

Source: National Levee Database

Known levees not within USACE authority in Vermont*

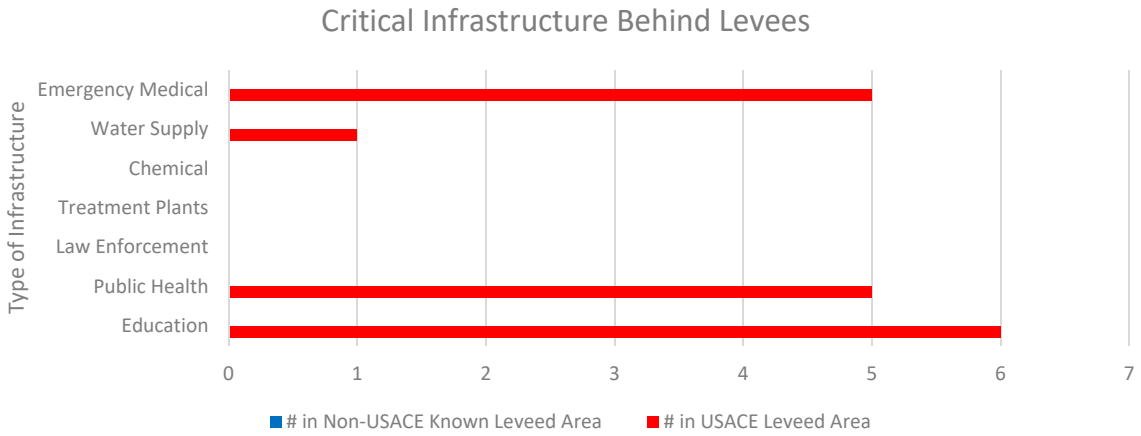
Number of non-USACE known levee systems:	0
Total miles of non-USACE known levees:	0
Population:	0

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Vermont. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 5, 2017**

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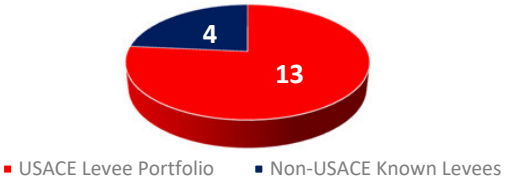
Levees within U.S. Army Corps of Engineers (USACE) authority in Virginia*

Number of USACE levee systems:	14
Total miles of USACE levees:	13
Population:	13,000

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Virginia



Estimated Population and Property Value for three USACE levee systems near key cities in Virginia:

Levee System	City	Population	Property Value ($, Billion)
Norfolk, Virginia Central Business District	Norfolk	2,500	$0.5
Bridgewater	Bridgewater	2,700	$0.3
Alexandria	Alexandria	2,200	$0.1

Source: National Levee Database

Known levees not within USACE authority in Virginia*

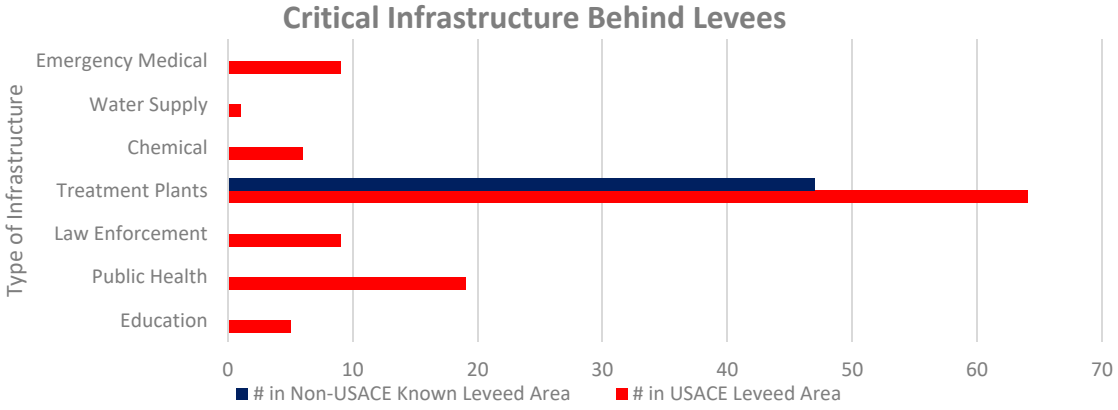
Number of non-USACE known levee systems:	7
Total miles of non-USACE known levees:	4
Population:	74

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Virginia. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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WASHINGTON
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

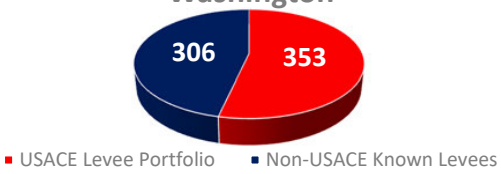
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Washington*

Number of USACE levee systems:	159
Total miles of USACE levees:	353
Population:	187,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Washington



Estimated Population and Property Value for three USACE levee systems near key cities in Washington:

Levee System	City	Population	Property Value ($, Billion)
Cowlitz CDID 1	Longview	38,500	$4.6
Lower Green (RB)	Kent	23,500	$3.8
Mill Creek 1 (Left Bank)	College Place	17,200	$2.6

Source: National Levee Database

Known levees not within USACE authority in Washington*

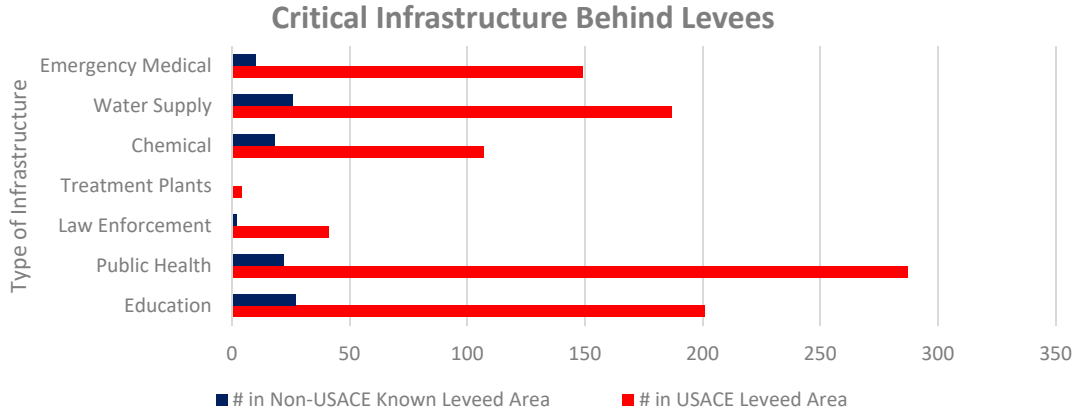
Number of non-USACE known levee systems:	204
Total miles of non-USACE known levees:	306
Population:	22,800

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Washington. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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WEST VIRGINIA

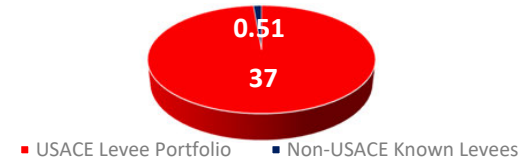
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in West Virginia*

Number of USACE levee systems:	19
Total miles of USACE levees:	37
Population:	41,500

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in West Virginia



Estimated Population and Property Value for three USACE levee systems near key cities in West Virginia:

Levee System	City	Population	Property Value ($, Billion)
Huntington, WV, LPP	Huntington	23,000	$4.5
Elkins, WV	Elkins	4,400	$0.8
CEREDO-KENOVA, WV, LPP	Kenova	3,500	$0.6

Source: National Levee Database

Known levees not within USACE authority in West Virginia*

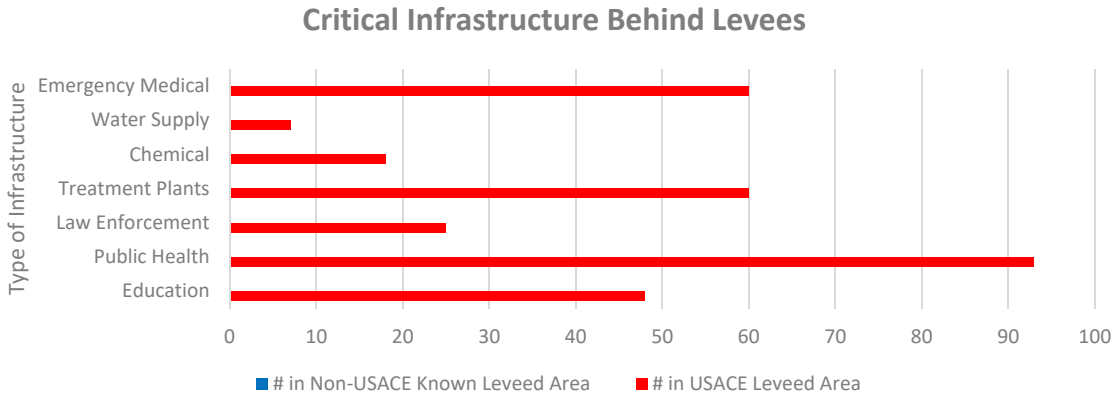
Number of non-USACE known levee systems:	2
Total miles of non-USACE known levees:	0.51
Population:	11

(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of West Virginia. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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WISCONSIN
SUMMARY OF LEVEE INFORMATION

U.S. ARMY CORPS OF ENGINEERS

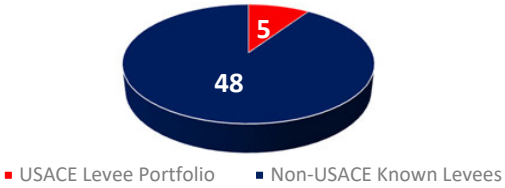
BUILDING STRONG

Levees within U.S. Army Corps of Engineers (USACE) authority in Wisconsin*

Number of USACE levee systems:	4
Total miles of USACE levees:	5
Population:	1,400

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Wisconsin



Estimated Population and Property Value for three USACE levee systems near key cities in Wisconsin:

Levee System	City	Population	Property Value ($, Billion)
Wisconsin River – Portage	Portage	1,000	$0.2
Mines Creek – Spring Valley	Spring Valley	197	$0.03
Black River Falls	Black River Falls	189	$0.09

Source: National Levee Database

Known levees not within USACE authority in Wisconsin*

Number of non-USACE known levee systems:	31
Total miles of non-USACE known levees:	48
Population:	3,100

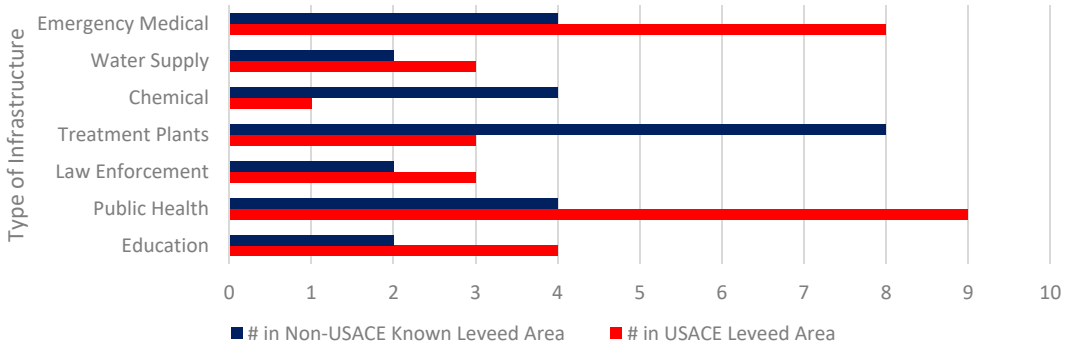
(*Estimated number of people who live behind non-USACE known levees*)

Image: Earthen Levee in Inventory

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Wisconsin. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.

Critical Infrastructure Behind Levees



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 21, 2017**

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WYOMING

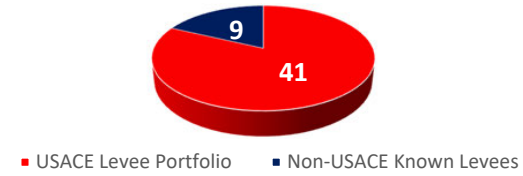
SUMMARY OF LEVEE INFORMATION

Levees within U.S. Army Corps of Engineers (USACE) authority in Wyoming*

Number of USACE levee systems:	14
Total miles of USACE levees:	41
Population:	8,900

(*Estimated number of people who live behind USACE known levees*)

Number of Levees Miles in Wyoming



Estimated Population and Property Value for three USACE levee systems near key cities in Wyoming:

Levee System	City	Population	Property Value ($, Billion)
Sheridan – Little Goose Cr LB & Big Goose Cr RB	Sheridan	2,500	$0.4
Jackson hole Upper Right Bank	Wilson	2,400	$0.3
Sheridan – Goose Creek RB	Sheridan	1,900	$0.2

Source: National Levee Database

Known levees not within USACE authority in Wyoming*

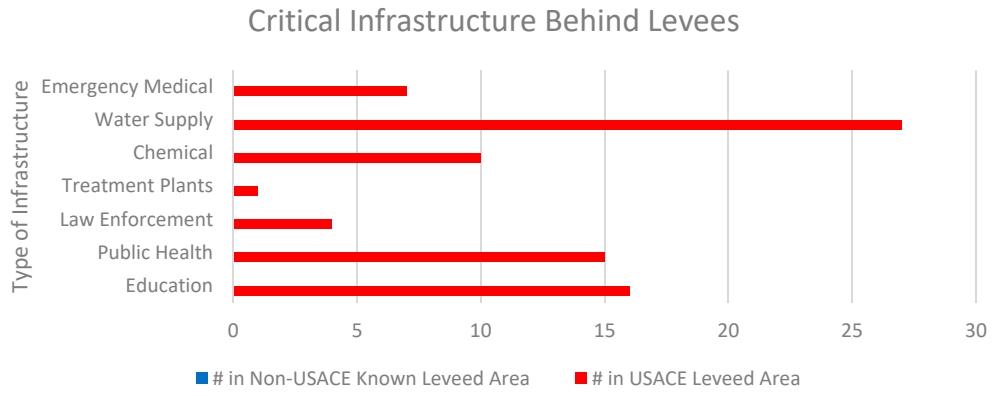
Number of non-USACE known levee systems:	17
Total miles of non-USACE known levees:	9
Population:	2,000

(*Estimated number of people who live behind non-USACE known levees*)

Image: Sheridan Little Goose Levee Sheridan, Wyoming

Infrastructure located behind known levees

The chart below depicts the number and type of structures that are behind known levees in the State of Wyoming. Levees help to reduce the risk of flooding to people, property, and infrastructure; however, levees cannot eliminate all risk.



Source: Homeland Security Infrastructure Program data, 2015

*** Data retrieved from the USACE National Levee Database (NLD), Levee information current as of: June 2, 2017**

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U.S. ARMY CORPS OF ENGINEERS
LEVEE PORTFOLIO REPORT

FOR MORE INFORMATION

For more information on the activities of the USACE Levee Safety Program, please visit http://www.usace.army.mil/Missions/Civil-Works/Levee-Safety-Program/.

The National Levee Database, http://nld.usace.army.mil, is a publicly-available inventory of the Nation's levees, including the location, condition, risks and benefits of levees in the USACE Levee Portfolio.