Sector Resilience Report: Dams

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SCOPE

The Department of Homeland Security's Office of Cyber and Infrastructure Analysis (DHS/OCIA)[1] produces Sector Resilience Reports to improve partner understanding of the interdependencies and resilience of certain sectors. This report provides a brief overview of Dams Sector facilities that have received Infrastructure Survey Tool (IST) assessments and provides an analysis of key dependencies and interdependencies from those results. The DHS Protective Security Advisors (PSAs) use the IST to assess the resilience measures of critical infrastructure assets to provide a relative measure of a facility's ability to resist, respond, and recover from disruptive events. There are over 87,000 dams in the National Inventory of Dams (NID) of which only 100 have had ISTs conducted. This report was produced to complement other sector-specific guidance, analyses, and scholarly papers on infrastructure resilience by applying data obtained from 100 DHS site visits and assessments analyzing resilience of critical infrastructure assets and systems.

The resilience issues and best practices identified in this report may be considered by dam owners, operators, and facilities; community risk management organizations (e.g., State or local emergency operations centers, emergency managers, public works, utility managers, and disaster relief organizations); and any critical infrastructure asset or system that depends on dams, levees, or industrial waste impoundments for their operations and safety to improve resilience. This product was coordinated with the DHS Office of Infrastructure Protection. A pre-production draft of this report was submitted to the Dams Sector for their review.

KEY FINDINGS

- **Of the 100 assessed Dams Sector facilities, more than half are dependent upon electric power (82 percent), communications (59 percent), and information technology (IT) (59 percent) for core operations.**
- **However, most of these facilities have backup or alternate sources for these external utilities: 90 percent have backup for electric power, 95 percent for communications, and 97 percent for IT, highlighting the ability of most of the assessed dams facilities to operate autonomously when a critical utility is lost. (*Note: The IST does not capture data on manual backups.*)**

[1] In February 2014, the National Protection and Programs Directorate (NPPD) created the Office of Cyber and Infrastructure Analysis by integrating analytic resources from across NPPD including the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC) and the National Infrastructure Simulation and Analysis Center (NISAC).

- **Without considering any backup or alternate sources of electric power for the assessed facilities, dam facility operability would be degraded 100 percent after 15 minutes from loss of electric power. For the 90 percent of the assessed facilities that do have backups or alternate power sources in place, the backup systems will, on average, provide enough power to fully support core operations for up to 5 days without the need to refuel.**

DAMS SECTOR OVERVIEW[2]

The National Inventory of Dams (NID) lists over 87,000 dams in the United States.[3] Almost 65 percent of the dams inventoried in the NID are privately owned, with the rest owned and operated by Federal, State, and local governments, and public utilities.[4] Critical assets in the Dams Sector are quite diverse, and include dam projects, hydroelectric plants, levees, navigational locks, dikes, hurricane barriers, industrial waste impoundments, and other similar water control operations. Definitions for some of these assets are provided below:[5]

- **Dams** are artificial barriers that have the ability to impound water, wastewater, or any liquid-borne material, for the purpose of storage or water control.[6] The resulting reservoir may be used for irrigation, fire protection, hydropower, navigation, recreation, water storage, and flood protection. The most common types of dams in use today are embankment dams followed by concrete dams.[7]
- **Hydroelectric dams** account for 6 to 8 percent of the Nation's energy production.[8] Turbines and generators in the dam powerhouse convert the energy captured from flowing water into electricity.[9] About 2,200 or 3 percent of the Nation's dams produce hydroelectric power, with more than 40 percent of the total U.S. hydroelectric production coming from the Columbia River Basin in the Pacific Northwest.[10] There is a vast, potential capacity to generate hydroelectric energy at existing non-powered dams, which if fully developed could increase existing U.S. conventional hydrocapacity by 15 percent.[11,12]
- **Navigation locks** allow for the transport of materials through sections of a river that would otherwise be unnavigable due to a dam or due to elevation and riverbed changes. Raising and lowering of water levels within chambers or locks allows vessels to navigate through these structures. The United States Army Corps of Engineers (USACE) owns and operates

[2] For more in-depth information about the Dams Sector, including function and management, please contact OCIA@hq.dhs.gov to request a copy of the *Infrastructure System Overview: Dams*, (forthcoming).
[3] The data and analyses contained in this SRR are specific to the 100 Dams Sector facilities assessed by PSAs using the IST and does not encompass findings from all 87,000 dams within the United States.
[4] USACE, "National Inventory of Dams," 2014, http://geo.usace.army.mil/pgis/f?p=397:5:0::NO, accessed June 9, 2014.
[5] DHS, *Dams Sector-Specific Plan: An Annex to the National Infrastructure Protection Plan*, 2010, www.dhs.gov/xlibrary/assets/nipp-ssp-dams-2010.pdf, accessed June 9, 2014.
[6] DHS FEMA, *Federal Guidelines for Dam Safety: Glossary of Terms*, April 1, 2004, www.fema.gov/media-library/assets/documents/3904, accessed March 23, 2015.
[7] Association of State Dam Safety Officials, "Introduction to Dams," 2014, www.damsafety.org/news/?p=e4cda171-b510-4a91-aa30-067140346bb2, accessed July 31, 2014.
[8] Department of Energy (DOE), *"Hydropower Resource Assessment and Characterization," 2014*, http://energy.gov/eere/water/hydropower-resource-assessment-and-characterization, accessed July 31, 2014.
[9] U.S. Geological Survey, "Hydroelectric Power: How It Works," 2014, http://water.usgs.gov/edu/hyhowworks.html, accessed June 14, 2014.
[10] Energy Information Administration, "The Columbia River Basin Provides More Than 40% of Total U.S. Hydroelectric Generation," June 27, 2014, www.eia.gov/todayinenergy/detail.cfm?id=16891, accessed July 31, 2014.
[11] DOE, "Powering Up America's Waterways," April 17, 2014, accessed July 31, 2014, http://energy.gov/articles/powering-america-s-waterways.
[12] DOE, *An Assessment of Energy Potential at Non-Powered Dams in the United States*, April 2012, http://energy.gov/sites/prod/files/2013/12/f5/npd_report_0.pdf, accessed July 31, 2014.

229 lock chambers at 187 sites across the U.S.; 204 locks are associated with a dam structure.[13,14]

- **Levees** are built to protect against flooding caused by seasonal floods, storm surges, and large precipitation events, and are built in strategic areas to withstand water loading for short periods of time (days or weeks). They allow land to be utilized that otherwise would not be useable due to water features and frequent flooding. Levees can be geographically extensive, because they normally run parallel to a watercourse. Of the levees within the U.S., 85 percent are locally owned and maintained, and 15 percent are overseen by USACE or other Federal or State agencies.[15]
- **Flood, surge, or hurricane barriers** are typical components of flood protection systems or networks. Hurricane barriers are usually large steel gates that can be adjusted to protect against storm surges that occur in bays, estuaries, rivers, and low lying areas. Several sets of gates may be used to protect an area through various open and closed arrangements. Pumping stations and dikes may also be associated with these facilities.
- **Mine tailings and other industrial waste impoundments** are used in the mining, power generation, and manufacturing industries to store and dewater waste products. The products in these impoundments are usually hazardous, and as such the environments of the impoundments are built to be contained and strategies are put in place to prevent the accidental release of waste products.

The Dams Sector is critical to the Nation's infrastructure because it provides both water retention and control. Dams Sector water management projects provide economic, environmental, and social benefits through hydroelectric power generation, river navigation, community water supplies, wildlife habitat, waste management, flood control, and recreation.

Figure 1 provides a visual representation of the 87,359 dams' primary purpose as listed in the NID. The inner circle depicts primary purpose of the sample of 100 dams facilities assessed through the IST. Similarly, Figure 2 provides a visual representation of the 87,359 dams by primary type as listed in the NID. The inner circle depicts primary type of the sample of 100 facilities assessed through the IST. Based on the comparisons in both Figures 1 and 2, the 100 dams facilities that have been assessed do not provide a representative sample of the Dams Sector in its entirety; however, the data does provide an overview of the dams facilities that have received assessments to provide additional insight into sector resilience.

[13] USACE, *Strongpoint: Facts and Figures,* April 11, 2014, www.usace.army.mil/Portals/2/docs/civilworks/budget/strongpt/fy15sp_mbi.pdf, , accessed July 31, 2014.
[14] USACE, "National Inventory of Dams," 2014, http://geo.usace.army.mil/pgis/f?p=397:5:0::NO, accessed June 9, 2014.
[15] Federal Emergency Management Agency (FEMA), "The Facts about Levees," 2012, www.fema.gov/media-library-data/20130726-1807-25045-3896/the_facts_about_levees.pdf, accessed June 11, 2014.

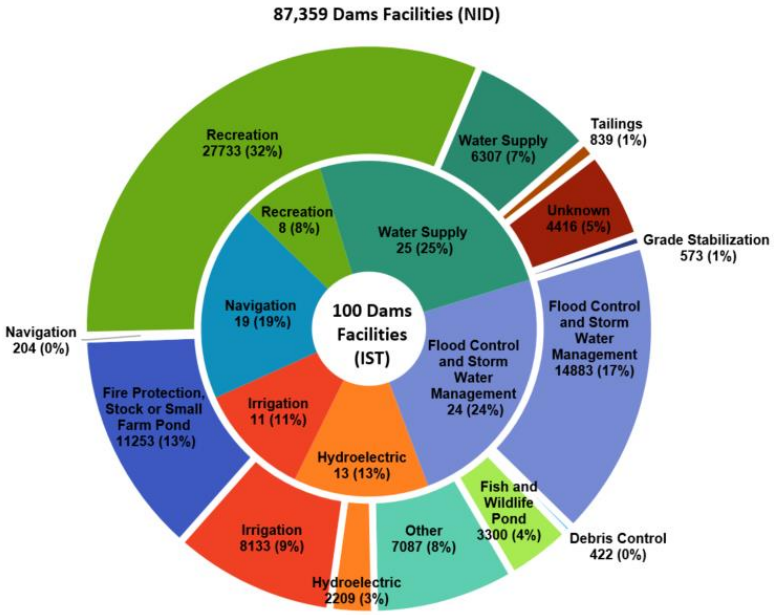


FIGURE 1—Numbers and Percentage of U.S. Dams by Primary Purpose[16]

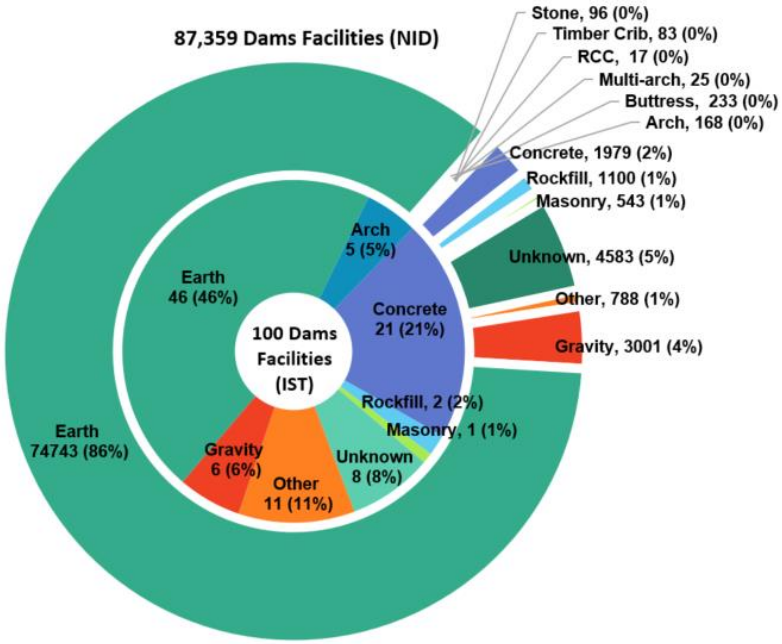


FIGURE 2—Numbers and Percentage of U.S. Dams by Primary Type[17]

[16] USACE, "National Inventory of Dams," 2014, http://geo.usace.army.mil/pgis/f?p=397:5:0::NO, accessed July 31, 2014.
[17] *Ibid.*

RESILIENCE

The common themes shared in this report are drawn from data collected through the Enhanced Critical Infrastructure Protection (ECIP) program, supplemented with information gleaned from industry reports and academic research.[18] This paper summarizes results from 100 Dams Sector infrastructure assessments that examine vulnerabilities, threats, and potential consequences from an all-hazards perspective, leading to the identification of dependencies, interdependencies, cascading effects, and resilience characteristics.[19]

PPD—8, National Preparedness, defines resilience as "the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies."

PPD—21, Critical Infrastructure Security and Resilience, directed the Federal Government to work with critical infrastructure owners and operators and State, local, tribal, and territorial partners to strengthen the security and resilience of its critical infrastructure.

Since 1996, the critical infrastructure community's primary focus has evolved from protective security to a greater emphasis on resilience to disruptive events.[20] National policies, such as Presidential Policy Directives (PPDs) 8 and 21, highlight the importance of collaborative engagement and information sharing with Federal agencies, private sector facility owners and operators, law enforcement, emergency response organizations, academic institutions, and other stakeholders in building a more resilient Nation.

THREATS AND HAZARDS – SECTOR OVERVIEW

The Dams Sector faces a broad range of potential threats and hazards including:

- Structural, mechanical, and hydraulic failures;
- Natural hazards such as drought, flooding, and earthquakes; and
- Intentional threats to both the physical structures and cyber-control systems.

The consequences of any threat or hazard are dependent on:

- The facility type and function,
- Its operational status at the time of occurrence,
- The population the facility serves,
- The facility's geographic location, and
- Elements such as nearby infrastructure.

[18] The ECIP Initiative is a voluntary program in which DHS PSAs conduct outreach with critical infrastructure facility owners and operators and provide security surveys, training and education, and recommended protective measures. ECIP metrics provide DHS with information on the protective and resilience measures in place at facilities and enable detailed analyses of site and sector vulnerabilities. For more information, please contact PDCDOperations@hq.dhs.gov.

[19] DHS, *Regional Resilience Assessment Program Fact Sheet*, December 2013.

[20] The Federal Government began to examine potential threats to critical infrastructure in the 1990s as a result of incidents of domestic and international terrorism. President Clinton issued Executive Order 13010 in 1996, which identified the Nation's critical infrastructure sectors and established a Presidential Commission on Critical Infrastructure Protection (PCCIP) whose objective was to recommend a comprehensive national infrastructure protection policy and implementation strategy.

Dams are designed to withstand a variety of unusual and extreme conditions, which makes them inherently robust structures.[21]

Inadequate upkeep, structural deficiencies, and aging infrastructure can pose a threat to dams. The average designed lifetime of a dam is 50 years.[22] As Figure 3 shows, many dams were built over 50 years ago and many others are nearing that age.[23]

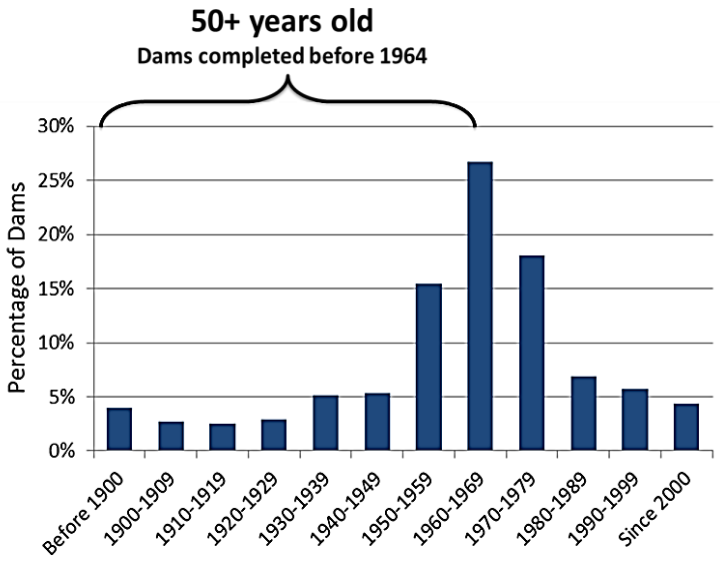


FIGURE 3—Dam Completion Dates (Courtesy of USACE)

Historically, over 1,000 dam failures or near-failures have occurred throughout the U.S., though the exact number of incidents is unknown.[24,25] The Association of State Dam Safety Officials reports that from January 2005 to June 2013 States "reported 173 dam failures and 587 'incidents'—episodes that, without intervention, would likely have resulted in dam failure."[26]

Inadequate spillway design, debris blockage of spillways, or settlement of the dam crest can cause overtopping, which accounts for approximately 34 percent of all U.S. dam failures.[27] Twenty percent of dam failures have been caused by piping, which is internal erosion due to seepage. Seepage often occurs around hydraulic structures, such as pipes and spillways; through animal burrows; around roots; and through cracks in the dam foundation. Thirty percent of dam failures are caused by foundation defects, including settlement and slope instability. Industrial waste impoundments are also at risk of failure, as illustrated by a stormwater pipe that failed

[21] DHS, *Worldwide Attacks Against Dams: A Historical Threat Resource for Owners and Operators*, 2012, www.cowarn.org/uploads/news/Worldwide%20Attacks%20against%20Dams%20-%202012.pdf, accessed July 31, 2014.
[22] Congressional Research Service, *Aging Infrastructure: Dam* Safety, 2008, RL33108, www.fas.org/sgp/crs/homesec/RL33108.pdf, accessed August 14, 2014.
[23] USACE, "National Inventory of Dams," 2014, http://geo.usace.army.mil/pgis/f?p=397:5:0::NO, accessed July 31, 2014.
[24] ASDSO, "Dam Failures and Incidents," 2014, www.damsafety.org/news/?p=412f29c8-3fd8-4529-b5c9-8d47364c1f3e, accessed March 23, 2015.
[25] National Performance of Dams Program, *Dam Incidents*, 2015, http://npdp.stanford.edu/, accessed March 23, 2015.
[26] ASDSO, "Dam Failures and Incidents," 2014, www.damsafety.org/news/?p=412f29c8-3fd8-4529-b5c9-8d47364c1f3e, accessed March 23, 2015.
[27] *Ibid*.

beneath a coal ash impoundment in North Carolina, releasing 74,400 tons of toxic coal ash and 27 million gallons of contaminated water into the Dan River in February 2014.[28]

Dams may also be at risk of disruption or failure from natural hazards such as earthquakes, extreme precipitation, flooding, storm surges, and drought. Due to the significant reliance on water to maintain power production at hydropower plants, both low water conditions (i.e., drought) and high water conditions (i.e., flooding) resulting from weather variability can impact operability of dams and increase competition for water resources.[29,30,31] For example, in January 2014 the Northwest River Forecast Center of the Department of Commerce indicated that below-normal run-off, as compared to the 30-year average would affect hydropower generation in the Pacific Northwest, which has the largest concentration of hydroelectric capacity in the country. Reduced hydropower generation not only affects the immediate area, but can also affect neighboring regions that import hydropower, and can greatly influence regional wholesale power prices.

Certain characteristics of dams can cause challenges to the physical protection of these structures. While assets in many other critical infrastructure sectors have a relatively small footprint, dams are normally large structures, often composed of multiple, non-adjacent, critical components, and are often located in remote locations. Dams Sector facilities can have personnel onsite, personnel operating the facility from offsite, or sites that are unstaffed for several days at a time. In addition, Dams Sector assets and facilities may be recreational facilities open to the public, and are accessible by land, water, and air.[32]

Cyber threats are becoming more of an issue as sector operating systems become increasingly networked and less reliant on proprietary software and hardware. Operational monitoring and control are based on information from sensors that monitor equipment and environments, and reactions to these readings can be controlled manually or automatically. Incidents may occur as a result of hacked networks or purchasing publically available hardware and software that may be vulnerable or become compromised. Harm from cyber threats may include:

- Disruption of control systems and the flow of information,
- Interference with protocol and safety limits,
- Disruption of electrical services, and/or
- Interference with nearby projects by using the attacked project's system as cover.[33]

[28] World Information Service on Energy, "Chronology of Major Tailings Dam Failures – Global," February 4, 2015, www.wise-uranium.org/mdaf.html, accessed March 25, 2015.
[29] DHS and DOE, *Dams and Energy Sector Interdependency Study*, September 2011, http://energy.gov/sites/prod/files/Dams-Energy%20Interdependency%20Study.pdf, accessed July 14, 2014.
[30] Energy Information Administration , "Reduced Water Supply Forecast Affects Hydropower Outlook in Pacific Northwest," February 7, 2014, www.eia.gov/todayinenergy/detail.cfm?id=14931, accessed August 14, 2014.
[31] U.S. Global Change Research Program, *Global Climate Change Impacts in the United States*, 2014, http://nca2014.globalchange.gov/report, accessed May 21, 2014.
[32] DHS, *Worldwide Attacks Against Dams: A Historical Threat Resource for Owners and Operators*, 2012, www.cowarn.org/uploads/news/Worldwide%20Attacks%20against%20Dams%20-%202012.pdf, accessed July 31, 2014.
[33] DHS, *Dams Sector Roadmap to Secure Control Systems*, 2010, http://damsafety.org/media/Documents2/security/files/DamsSectorRoadmapToSecureControlSystems.pdf, accessed May 23, 2014.

DEPENDENCIES, INTERDEPENDENCIES, AND POTENTIAL IMPACTS

The resilience of a community or region is a function of the resilience of its subsystems, including its critical infrastructure, economy, civil society, and governance (including emergency services). Resilience can be highly complex due to the dependencies and interdependencies that exist within infrastructure systems, the regions they serve, and the potential for cascading consequences.

To further highlight these dependencies and interdependencies, the following sections will discuss the dependencies of dams on other utilities based on data collected through the ECIP program. The term "dependency," as defined when collecting information as part of an ECIP assessment, is reliance of a facility on an outside or external utility or service to carry out its core operations (e.g., produce key services or goods). Core operations are specific to an asset or facility; some examples include domestic uses (e.g., potable water), security operations (e.g., electric power for closed circuit television (CCTV), scanners, sensors), or providing onsite heat/hot water (e.g., natural gas). ECIP dependency data captures the degradation in service (i.e., to one or more of those core operations), information which includes how soon and to what extent a facility will be affected if the source is lost. DHS partners work with State and local agencies and the private sector to conduct voluntary assessments of a large number of critical infrastructure facilities for the ECIP Initiative. DHS assessment data from the ECIP Initiative was analyzed to determine potential dependencies and resilience of 100 dam facilities.[34]

Infrastructure Survey Tool

The ECIP initiative collects data through the IST, a secure Web-based tool that provides the ability to collect, process, and analyze survey data in near–real time. Data collected during site visits are consolidated in the IST and compared against established values, weights, and data on similar facilities, which enables DHS to develop metrics; conduct sector-by-sector and cross-sector vulnerability comparisons, identify security gaps and trends across critical infrastructure sectors and subsectors; and establish sector baselines for security and resilience scores.

The term "dependency," as used in the IST and reported here, is defined as the reliance of a facility on an outside or external utility or service to carry out its core operations.

Degradation addresses how soon a facility will be affected if the source is lost, and to what extent it will be affected. Data on degradation are gathered in the IST exclusively from other related conditions: 0 percent degradation, 1–33 percent degradation, 34–66 percent degradation, 67–99 percent degradation, or 100 percent degradation.

Data are also collected on backup generation, duration of backup generation without refueling, and recovery time after external infrastructure service is restored.

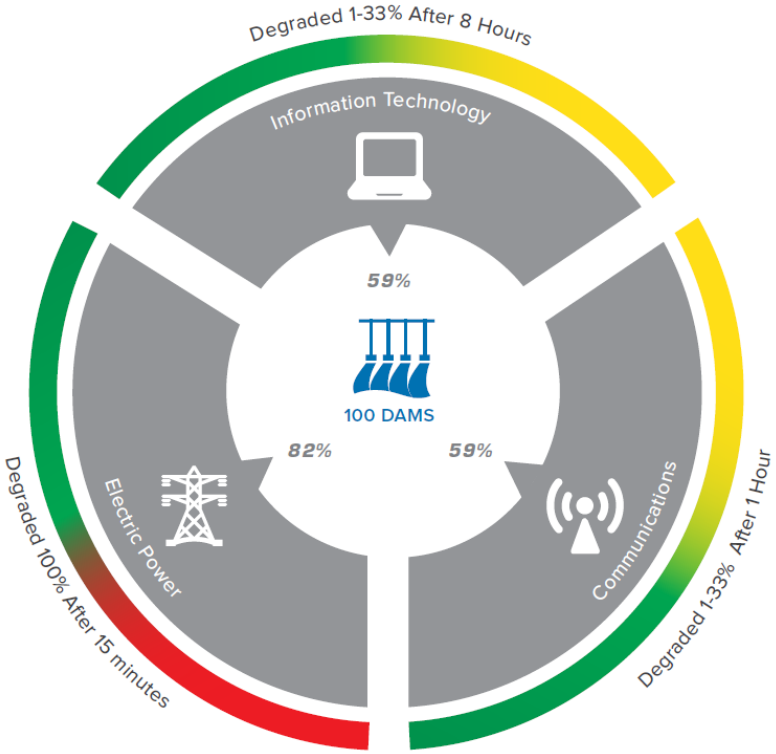
[34] Site assessments under the ECIP are voluntary; they may not be representative of the entire sector. The information and data from the Infrastructure Survey Tool (IST), on which the ECIP security survey resides) are often protected as For Official Use Only or as Protected Critical Infrastructure Information; the information provided below has been sanitized to remove any facility, system, or regional references.

DAMS SECTOR DEPENDENCIES

Since January 2011, 100 facilities have been assessed by PSAs in the Dams Sector as part of the ECIP initiative; these facilities include dams, locks, and water control structures.[35] Based on the collected data, these facilities generally require electricity to operate, and many also require communications and IT. Most of the other external utilities such as external water, wastewater treatment, transportation or critical products, are not required for core operations.

The inner circle of Figure 4 depicts the percentage of surveyed dams facilities that are dependent upon external products and services. The outer ring depicts the percentages by which assessed dams facilities core capabilities are degraded after loss of an external service provider and the time to impact without considering backup or alternate measures. In addition, Table 1 on page 11 provides statistics on common recovery mechanisms for the assessed dams.

[35] The 100 assessed dams facilities are identified within the following IST Assignments: (1) Dam Project, (2) Flood Damage Reduction Systems, and (3) Navigation Locks.



Information Technology	Communications	Electric Power
Of the 100 assessed dams facilities, 59 percent are dependent upon external IT to maintain core operations. Without considering backups or alternative measures, core operations would be degraded 1-33 percent after 8 hours if there is a loss of external IT.	Of the 100 assessed dams facilities, 59 percent are dependent upon external communications to maintain core operations. Without considering backups or alternative measures, core operations would be degraded 1-33 percent after 1 hour if there is a loss of external communications.	Of the 100 assessed dams facilities, 82 percent are dependent upon external electric power to maintain core operations. Without considering backups or alternative measures, core operations would be degraded 100 percent after 15 minutes if there is a loss of external electric power. (*Note: The IST does not capture data on manual backups*.)

FIGURE 4—Percent of DHS Assessed Dams Dependent upon External Products or Services, and the Percent Degradation Following the Loss of those Products or Services without considering Backup or Alternative Measures. Note: This data represents a majority (59 percent or more) of the 100 dams facilities assessed by PSAs that are dependent on the external product or service. (Courtesy of DHS and Argonne National Laboratory)

ELECTRICITY

Eighteen of the 100 facilities surveyed responded that although they rely on external electric power for operations (e.g., monitoring and controlling equipment and security), they also have an internal power plant. All but one of these facilities stated that this plant can generate enough electricity to handle the full facility load. According to the information captured during the assessments, generators are used as a backup or alternate source of electricity for the majority of these facilities. These generators generally operate on diesel fuel, and can maintain at least core

operations, if not the full facility load, for up to 5 days without the need to refuel. The reliance of these generators on an outside fuel source identifies a potential cascading impact if these generators cannot be refueled after 5 days. About half of the facilities also utilize uninterruptable power supply (UPS) devices to accommodate the switch from the external supply to backup generator(s).

COMMUNICATIONS AND IT

Radio or data links are the primary communication mode required by the facilities for their core operations. These links are primarily required for command and control integration and monitoring of equipment and processes (i.e., supervisory control and data acquisition). While more than 90 percent of the surveyed facilities stated they utilized an internal IT network, only half stated that they utilized the internet. IT is primarily used for control network purposes, although some facilities also utilize IT for business purposes. A little over 70 percent of the surveyed facilities have a control and business network; all of those facilities have network segmentation which can improve both performance and security.

TABLE 1—Dam Dependencies and Recovery Mechanisms of Surveyed Facilities

Utility Provider Type	Dependent upon External Utility Provider (%)	Backup or Alternate Utility Source (%)	Contingency Plan with Provider (%)	Priority Restoration Plan with Provider (%)
Electric Power	82	90[36]	34	37
Communications	59	95	47	33
IT	59	97	86	21

IMPACTS ON CRITICAL INFRASTRUCTURE FROM LOSS OF DAMS

Numerous critical infrastructure sectors are dependent on dams, levees, or impoundments for a wide range of operations:[37,38]

- **Food and Agriculture Sector** utilizes dams and levees as a source of water for irrigation and as a mechanism for water management and flood protection.
- **Transportation Systems Sector** uses dams and locks to facilitate and manage navigation throughout inland waterways.
- **Water Sector** utilizes the reservoirs behind dams as source water for community drinking water systems in the United States.

[36] In the electric power dependency section, the IST captures alternates and backups (backup generator and uninterrupted power system (UPS)) in place at the facility that can provide electric power in case of loss of the external source of electric power. This data does not account for manual backups.

[37] Folga, S., Allison, T., Peerenboom, J.P., Carr, J.P., Matheu, E.E., Seda-Sanabria, Y., "Incorporating Critical Infrastructure Interdependencies into Dam Failure Consequence Assessments," in *Collaborative Management of Integrated Watersheds*. Presented at the 30th Annual United States Society on Dams, United States Society of Dams (USSD), 2010, Sacramento, California.

[38] DHS, *National Infrastructure Protection Plan: Dams Sector*, 2008, www.dhs.gov/xlibrary/assets/nipp_snapshot_dams.pdf, accessed June 10, 2014.

- **Critical Manufacturing Sector** utilizes water provided by the Dams Sector that is necessary for production processes.
- **Nuclear Reactors Sector** utilizes water provided by the Dams Sector for cooling purposes.
- **Energy Sector** utilizes water provided by the Dams Sector for cooling equipment and processes, and currently uses hydropower dams to provide approximately 6 to 8 percent of the Nation's power needs.[39]
- **Emergency Services Sector** utilizes water provided by the Dams Sector for firefighting, emergencies, and waterborne access in the event of a significant disaster.

Dam failure can result in an uncontrolled release of water leading to downstream property damage and loss of life. Table 2 discusses the impacts that may accompany failure of a critical asset in the Dams Sector.

TABLE 2—Dams Sector Impacts from Failure

ASSET FAILURE	POTENTIAL IMPACTS
Dam	▪ Loss of water for drinking, wastewater treatment, emergency supplies, nearby manufacturing processes, nearby nuclear facilities, irrigation, or recreation. ▪ Possible loss of other infrastructure; railways, bridges, roads, communication lines, cables, pipelines, and any other infrastructure built alongside the dam or downstream may also be damaged or destroyed.
Hydropower Dam	▪ Same failure impacts as dams but also may include the loss of power generation and power generating equipment.
Levee	▪ Loss of protection to a number of infrastructures and facilities including roads, highways, railways, bridges, water treatment plants, utility systems, and port, industry, and manufacturing facilities.[40]
Lock	▪ Locks are crucial for transportation of agricultural, coal, and petroleum products; lock failure may halt or severely disable waterway traffic.
Hurricane Barrier	▪ Failure of a hurricane barrier in the gates-open position would allow for inland damage during storms. ▪ Failure in the gates-closed position would halt waterway traffic on both sides of the barrier.
Industrial Waste Impoundment	▪ Pollutants released into the environment could create a public health hazard and contaminate public water supplies. ▪ Impoundment failure may result in flooding and possible loss of other infrastructure alongside or downstream of the impoundment.

[39] DOE, *"Hydropower Resource Assessment and Characterization,"* http://energy.gov/eere/water/hydropower-resource-assessment-and-characterization, accessed July 31, 2014.
[40] Miller, K., Costa, K., Cooper, D., "Ensuring Public Safety by Investing in Our Nation's Critical Dams and Levees," *Center for American Progress*, 2012, www.americanprogress.org/issues/economy/report/2012/09/20/38299/ensuring-public-safety-by-investing-in-our-nations-critical-dams-and-levees/, accessed June 10, 2014.

RESILIENCE ISSUES AND BEST PRACTICES

Table 3 presents commonly observed resilience issues and best practices summarized for three categories of users: dams systems or facilities, community risk management organizations (e.g., State or local emergency operation centers, emergency managers, public works, utility managers, and disaster relief organizations), and any critical infrastructure asset or system that depends on dams. The issues and best practices listed in Table 3 were identified in DHS site assessments (100 assessed facilities), as well as general literature reviews.[41] The information is meant for general application within the dam engineering and risk management communities and other affected sectors and customers; the issues and best practices identified may apply to other facilities or types of facilities. See the appendix for supporting resources and references.

TABLE 3—Resilience Issues and Best Practices

FOR DAMS SYSTEMS OR FACILITIES
Some critical utility lines may be co-located or unprotected from manmade and natural disasters
▪ Relocate the co-located utilities that are feasible to separate (i.e., electric, communications, etc.) to reduce the single point of failure. ▪ Install bollards or enclose the utility connection points to help mitigate potential vehicular damage. ▪ Conduct daily and random security checks on critical utility areas. ▪ Install CCTV cameras to monitor critical utility lines and mitigate accidental or intentional damage.
Some Emergency Action Plans lack comprehensiveness, and limited training exists on these plans at some of the assessed facilities
▪ Regularly review existing Emergency Action Plans to ensure the plan addresses all-hazards. ▪ Train staff and exercise the Emergency Action Plan annually; include not only facility site personnel but also local emergency responders, and any others who may be affected. ▪ Regularly review all-hazards communications protocols between facility site personnel and adjacent dam owners (e.g., between multiple dam owners on adjacent facilities upstream and downstream on the same river). Annually train operators in all-hazard communication protocols with adjacent dam owners.
FOR COMMUNITY RISK-MANAGEMENT ENTITIES
Urbanization downstream of existing dams is altering the risk landscape and increasing the number of high hazard dams[42]
▪ Update Emergency Action Plans for those dams that have experienced downstream urbanization. ▪ Train local responders and increase public awareness regarding evacuation strategies for flooding events.
Lack of public awareness regarding the existence and potential danger of dams[43]
▪ Increase public awareness through educational tools and training regarding the hazards surrounding the geographical locations of dams, (i.e., flooding). ▪ Educate dam owners and operators on their responsibility and liability toward the downstream public and environment to ensure appropriate dam facility upkeep and maintenance.

[41] The degradation and recovery information and data from the IST are often protected as For Official Use Only or as Protected Critical Infrastructure Information; the information in Table 5 has been sanitized to remove any facility, system, or regional references.

[42] Association of State Dam Safety Officials, "Top Issues Facing the Dam Community," 2014, www.damsafety.org/news/?p=c0fdade4-ab98-4679-be22-e3d7f14e124f, accessed July 13, 2014.

[43] Association of State Dam Safety Officials, "Top Issues Facing the Dam Community," 2014, www.damsafety.org/news/?p=c0fdade4-ab98-4679-be22-e3d7f14e124f, accessed July 30, 2014.

- Change zoning ordinances or building codes to limit development in floodplains and flood inundation zones.

Lack of regular lock maintenance and upkeep along commercially navigable waterways[44,45]

- Schedule and perform regular maintenance on locks and their key components to prevent them from breaking down and causing unscheduled delays.
- Prioritize upgrades to those locks with an increased likelihood of failure and/or those with an increased consequence of failure.
- Replace or repair functionally obsolete locks.

FOR THE GENERAL PUBLIC

Lack of public awareness regarding the existence and potential danger of dams[46]

- Learn where the dam failure flood inundation zone is located relative to your home or business if in an area that could be impacted by a dam, levee, or impoundment breach.
    - Contact your local emergency management agency or the State dam safety program for information on flood inundation areas (www.damsafety.org).
    - Consider buying flood insurance if your home or business lies in a dam failure flood inundation area. Information about the National Flood Insurance Program can be found at www.FloodSmart.gov.
- Ask questions about the dam's condition and hazard potential.

Lack of public preparedness in the event of a dam emergency[47]

- Know if there is a warning system in place to warn residents of a dam failure.
- Find out if there is a current Emergency Action Plan for the dams, levees, or impoundments in your area.
- Know your evacuation routes.

[44] American Society of Civil Engineers, "Navigable Waterways: 2010 Report Card for Pennsylvania's Infrastructure," www.pareportcard.org/PARC2010/PDFs/nav%20waterways%20Final%20w%20NATL.pdf, accessed January 9, 2015.

[45] Minnesota Department of Transportation, "Statewide Ports and Waterways Plan," 2013, www.dot.state.mn.us/ofrw/PDF/draftpwp.pdf, accessed January 9, 2015.

[46] FEMA, "Living With Dams: Know Your Risks," 2013, www.fema.gov/media-library-data/20130726-1845-25045-7939/fema_p_956_living_with_dams.pdf, accessed July 30, 2014.

[47] *Ibid.*

APPENDIX

RESILIENCE ISSUES AND BEST PRACTICES: REFERENCES AND RESOURCES

The following references provide the reader with more in-depth information on the Dams Sector, including vulnerabilities, gaps, resilience technology, and other sector-specific guidance.

American Society of Civil Engineers

- *So You Live Behind a Levee!*, 2010, available at http://content.asce.org/files/pdf/SoYouLiveBehindLevee.pdf.

Army Corps of Engineers (USACE)

- *Levee Owner's Manual for Non-Federal Flood Control Works*, 2006, available at www.nws.usace.army.mil/Portals/27/docs/emergency/LeveeOwnersManual(final).pdf.
- *National Inventory of Dams*, 2013, available at http://geo.usace.army.mil/pgis/f?p=397:12.
- *National Levee Database*, 2013, available at http://nld.usace.army.mil/egis/f?p=471:1:0::NO.

Argonne National Laboratory

- *Resilience: Theory and Applications*, www.dis.anl.gov/pubs/72218.pdf.

Association of State Dam Safety Officials (ASDSO)

- *EAP Resource Center*, 2014, available at www.damsafety.org/community/owners/?p=3a95437d-1876-46d6-843b-d65d45beb46a.
- *Living With Dams: Know Your Risks*, 2012, www.livingneardams.org/.
- *Living With Dams: Extreme Rainfall Events*, 2015, www.livingneardams.org/.
- *Responsible Dam Ownership: Information Guidelines, and Tools*, 2014, www.damsafety.org/media/documents/owner%20documents/start.htm?2014.

Department of Energy (DOE)

- *Dams and Energy Sectors Interdependency Study*, 2011, available at http://energy.gov/sites/prod/files/Dams-Energy%20Interdependency%20Study.pdf.

Department of Homeland Security (DHS)

- *Dams Sector Crisis Management Handbook: A Guide for Owners and Operators*, 2015, available on the Homeland Security Information Network (HSIN). For distribution information contact dams@hq.dhs.gov.
- *Dams Sector Protective Measures Handbook: A Guide for Owners and Operators*, 2014, available on the Homeland Security Information Network Critical Infrastructure (HSIN-CI). For distribution information contact dams@hq.dhs.gov.

- *Dams Sector Security Awareness Handbook: A Guide for Owners and Operators*, 2014, available on the Homeland Security Information Network (HSIN). For distribution information contact dams@hq.dhs.gov.
- *Dams Sector Roadmap to Secure Control Systems*, 2010, available at http://damsafety.org/media/Documents2/security/files/DamsSectorRoadmapToSecureControlSystems.pdf (updated version will be available January 2015) .
- *Dams Sector Security Awareness Guide*, 2007, available at www.dhs.gov/sites/default/files/publications/ip_dams_sector_securit_awareness_guide_508_0.pdf.
- *Dams Sector Security Awareness Guide: Levees*, 2008, available at www.damsafety.org/media/Documents2/security/files/SecurityAwareness_LeveeGuide.pdf.
- *Dams Sector-Specific Plan: An Annex to the National Infrastructure Protection Plan*, 2010, www.dhs.gov/xlibrary/assets/nipp-ssp-dams-2010.pdf.
- *Emergency Preparedness Guidelines for Levees: A Guide for Owners and Operators*, 2012, available at www.usace.army.mil/Portals/2/docs/civilworks/levee/EP_guidforlevees.pdf.
- *National Infrastructure Protection Plan 2013, Partnering for Critical Infrastructure Security and Resilience*, www.dhs.gov/national-infrastructure-protection-plan.
- *Presidential Policy Directive 8: National Preparedness* (PPD-8), www.dhs.gov/presidential-policy-directive-8-national-preparedness.
- *Critical Infrastructure Cyber Community (C^3) Voluntary Program* helps critical infrastructure sectors and organizations reduce and manage their cyber risk by connecting them to existing cyber risk management capabilities provided by DHS, other U.S. Government organizations, and the private sector. At the time of launch in February 2014, available resources primarily consisted of DHS programs, which will grow to include cross-sector, industry, and State and local resources. Available at www.us-cert.gov/ccubedvp.

Environmental Protection Agency (EPA)

- *Industrial Surface Impoundments in the United States*, 2001, available at www.epa.gov/osw/hazard/tsd/ldr/icr/impdfs/sisreprt.pdf.

Federal Emergency Management Agency (FEMA)

- *CRS (Community Rating System) Credit for Dam Safety*, 2006, available at www.fema.gov/media-library-data/20130726-1755-25045-2620/crs_credit_dam_safety.pdf.
- *Federal Guidelines for Dam Safety: Emergency Action Planning for Dams*, 2013, www.fema.gov/media-library-data/5b20db599c212f77fd5e85d256f471a3/EAP+Federal+Guidelines_FEMA+P-64.pdf.

- *Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures*, 2013, www.fema.gov/media-library-data/96171edb98e3f51ff9684a8d1f034d97/Dam_Guidance_508.pdf.

Federal Energy Regulatory Commission (FERC)

- Current listing of FERC-licensed hydro facilities, 2010, available at www.ferc.gov/industries/hydropower/gen-info/licensing/licenses.xls.
- Current listing of FERC-exempt hydro facilities, 2010, available at www.ferc.gov/industries/hydropower/gen-info/licensing/exemptions.xls.
- *Dam Safety Performance Monitoring Program: Monitoring the Performance of Dams*, 2005, www.ferc.gov/industries/hydropower/safety/guidelines/eng-guide/chap14.pdf.
- FERC hydropower web portal, www.ferc.gov/industries/hydropower.asp.

Other Resources

- *Aging Infrastructure: Dam Safety*, 2008, www.fas.org/sgp/crs/homesec/RL33108.pdf.
- *Ensuring Public Safety by Investing in Our Nation's Critical Dams and Levees*, 2012, www.americanprogress.org/wp-content/uploads/2012/09/MillerLeveesDamsREPORT-2.pdf.
- *Dam and Levee Safety and Community Resilience: A Vision for Future Practice*, 2012, www.nap.edu/catalog.php?record_id=13393.
- National Committee on Levee Safety, www.leveesafety.org/.
- National Performance of Dams Program (NPDP) Stanford University, http://npdp.stanford.edu/node/83.
- United States Society on Dams (USSD), www.ussdams.org/.

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Homeland Security

National Protection and Programs Directorate

NPPD Customer Feedback Survey

Product Title:

1. Please select the partner type that best describes your organization. Select One

2. Overall, how satisfied are you with the usefulness of this product?

○ **Very Satisfied** ○ **Somewhat Satisfied** ○ **Neither Satisfied Nor Dissatisfied** ○ **Somewhat Dissatisfied** ○ **Very Dissatisfied**

3. How did you use this product in support of your mission?

☐ Integrated into one of my own organization's information or analytic products

☐ Used contents to improve my own organization's security or resiliency efforts or plans
If so, which efforts?

☐ Shared contents with government partners
If so, which partners?

☐ Shared contents with private sector partners
If so, which partners?

☐ Other (please specify)

4. Please rank this product's relevance to your mission. ***(Please portion mark comments.)***

○ Critical
○ Very important
○ Somewhat important
○ Not important
○ N/A

5. Please rate your satisfaction with each of the following:

	Very Satisfied	Somewhat Satisfied	Somewhat Dissatisfied	Very Dissatisfied	N/A
Timeliness of product or support	○	○	○	○	○
Relevance to your information needs	○	○	○	○	○

6. How could this product or service be improved to increase its value to your mission? ***(Please portion mark comments.)***

To help us understand more about your organization so we can better tailor future products, please provide (OPTIONAL):

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Organization: *State:*
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