LEVEES

C-

Floods are one of the most common and destructive hazards in the United States and Pennsylvania has historically been one of the most flood-prone states in the nation, having experienced billions of dollars in flood damages since the 1930s. The most commonly available protection against flooding in Pennsylvania is a levee. Over the last 100 years, 4,523 deaths have been attributed to levee failures nationwide. Flooding from Hurricane Agnes alone resulted in 48 fatalities in Pennsylvania and 122 deaths nationwide. During Hurricane Agnes, the Susquehanna River at Wilkes Barre crested at 40.9 feet, more than 18 feet above flood level. However, levees in the Wyoming Valley were built to provide protection to a maximum flood crest of only 37.0 feet above flood level. During Hurricane Agnes, the Susquehanna River was rising at more than one foot per hour, the rain continued to fall and flooding was inevitable. However, one day before the river crested, the levee in Forty Fort catastrophically failed sending 35 feet of water rushing through Kingston, where only 20 out of 6,600 houses remained above the flood waters. Large portions of both Kingston and Wilkes Barre were flooded. In Wilkes Barre and Kingston alone, 100,000 residents evacuated and 60 percent of Wilkes Barre was under water. In total, 250,000 Pennsylvania residents were forced to evacuate their homes during flooding from Hurricane Agnes, and many returned to find their homes gone or badly damaged. Damages were estimated at $2.119 billion including 68,000 homes and 126 bridges destroyed. The entire State of Pennsylvania was declared a disaster area due to flooding.

Pennsylvania's mountainous topography, more than 45,000 miles of rivers and streams and average annual rainfall of 42 inches, creates the potential for flooding to occur anywhere in the state at any time of the year. Levees were first constructed in Pennsylvania in 1939 to help prevent against flooding, and today, there are 64 recognized levee systems. Within these systems, there are 318 separate levee segments which provide a local protection length of about 151 miles and a total protected area of about 14,300 acres (22.3 square miles).

Flood protection projects are found along 115 separate creeks or rivers and are located in 51 of the 67 Pennsylvania counties. The average age of the flood protection systems is 48 years and more than one-third are older than 50 years. Levee systems are aging and deteriorating over time, with many of the systems approaching and/or exceeding their anticipated lifespan. The advanced age of the state's levee systems casts doubt on their ability to perform without incident or failure in an extreme flood event. The potential for the increasing frequency of flooding due to climate change results in an overall increase in the risk of flooding due to levee overtopping or failure.

The design level of flood protection for levees, as authorized by Congress, is based on the 100-year storm event. A 100-year storm refers to rainfall totals that have a one percent probability of occurring at that location in that year. Unfortunately, only a fraction of all earthen levees built with the level of flood protection at the established 100-year

storm event can be expected to provide protection for that event because of the uncertainties involved in establishing flood elevations; changing hydrologic conditions, and the possibility of levee failure before overtopping. A design level of flood protection at the 100-year storm event represents a 26 percent chance (1 in 4 chances) of flooding over the life of a 30-year home mortgage and represents a dangerously high level of flood risk, even in the presence of a properly designed and functioning levee system.

A grade of C- was assigned to the levee systems throughout the State of Pennsylvania. This grade reflects the benefit of the state effectively operating one of the few state-level comprehensive flood protection programs in the nation which requires a high level of standards for which levees are monitored and maintained. This grade also reflects the consequences resulting from the advanced age of the levee systems, the numerous flood-prone watersheds existing in Pennsylvania, the residual flood risk inherent in flood protection projects designed to the current flood protection standard, and the population at risk. Also considered is the ongoing struggle to obtain funds for the repair and maintenance of levee systems and the often under-appreciated threat to public safety resulting from flooding from catastrophic levee failure or overtopping.

BACKGROUND

Rivers and streams in Pennsylvania have been of great importance throughout its history. People have long elected to build in flood-prone river valleys because they sought access to waterways for easy access to water for drinking, transportation, farming, industry, etc. Many of these flood-prone sites continued to grow and became today's cities and towns. As these communities grew, engineering solutions to flood protection began to develop including the construction of flood control dams and levees.

A levee is defined as a man made embankment, usually an earthen structure built to provide flood protection from temporary high water (flooding). Flood levees are typically linear structures constructed adjacent to a river for the purpose of preventing water from overflowing the river channel and spreading into the flood plain and beyond. The construction of flood levees is the oldest, most widespread, and likely the most important method of flood protection provided to flood-prone communities in Pennsylvania.

Pennsylvania's climate and its steep and mountainous topography, which covers large areas of the state, have produced a long history of flooding. Portions of five major U.S. rivers flow through Pennsylvania, including the Delaware, Susquehanna, Potomac, Ohio, and St Lawrence rivers. Overall, there are approximately 45,000 miles of minor and major streams in Pennsylvania, and it is estimated that 10,000 to 15,000 miles of these streams are considered flood-prone. The Susquehanna River, which flows southward through the east-central part of the state, drains 20,888 square miles in Pennsylvania. The Susquehanna River Basin is the largest drainage system in the state and one of the most flood-prone watersheds in the nation, with more than 80 percent of the Basin's 1,400-plus communities having areas that are considered flood-prone. Roughly 30 percent of the Basin's population lives along its major rivers and streams.

There are currently 64 major levee systems located in Pennsylvania, according to the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) Database. Each levee system may contain one or more separate levee segments. Within the 64 levee systems, there are 318 separate levee segments which provide a local flood protection length of about 151 miles. It is important to note that levees do not provide full protection from the risk of flooding. Levees are designed to provide a specific level of flood protection and larger flood events can cause overtopping and possible failure of an entire levee system.

The National Flood Insurance Program was established by the Flood Insurance Act in 1968 to provide coverage to flood-prone properties, which private insurers would not cover. For the purposes of the insurance program, in 1973, the Senate Committee on Banking, Housing, and Urban Affairs adopted the ‘‘100-year floodplain’’ as the regulatory threshold. The 100-year flood (i.e., a return interval of 100 years as the annual maximum) has a one percent probability of occurring in any given year, so this is often termed the ‘‘one-percent’’ approach. The term “100-year flood” is misleading because it leads people to believe that it happens only once every 100 years. The truth is that an uncommonly large flood event can happen in any given year, particularly in Pennsylvania. The term “100-year flood” is really a statistical designation, which means that there is a 1-in-100 chance that a flood this size will happen during any year. A levee that is designed to withstand a 1-percent-annual-chance, or a 100-year flood, statistically has a roughly one-in-four likelihood of being overtopped by a flood during a 30-year period. And assuming the levee functions as designed and protects against the 100-year flood, there is still a residual risk of being flooded by overtopping of the levee by rainfall events that are larger than the design “100-year flood”. In addition to overtopping, residual risk is also present due to the potential of seepage and saturation, erosion and piping (internal erosion) occurring in the levee which may result in a catastrophic failure of the levee, even in rainfall events that are less than a “100-year flood”.

Floods produce damage through the immense power of moving water and through the deposition of dirt and debris when floodwaters finally recede. People who have not experienced a flood may have little or no appreciation for the dangers of moving water. Floodwaters typically contain suspended silt and potentially toxic microorganisms and dissolved chemicals. This means that floods usually compromise drinking water supplies, resulting in short-term shortages of potable water, with the additional long-term costs in restoring drinking water service to the residents of a flooded area. The debris left behind when floodwaters recede can be costly to clean up and also represent a human health hazard.

From a historical perspective, levees have long been constructed to protect property rather than people, a purpose expressed by the economic criteria controlling the engineering design of levees even today. Evacuation has been seen as the primary means for prevention of loss of life and the structural soundness of levees has traditionally been viewed in this context. However, over the past 100 years, there have

been 4,523 deaths recorded nationally caused by the failure of levees, compared to 816 fatalities recorded for dam failures over the same period. More than five times more fatalities have been caused by the failures of levees than dams over that time.

CONDITION AND CAPACITY

Levees and levee features deteriorate over time. Levees are constructed of materials subject to erosion, corrosion, weathering, scour, settlement, deformation and degradation. Depending on many factors, a levee may either deteriorate slowly or quickly, but every levee will always deteriorate over time. Regular maintenance and periodic upgrades are needed to ensure that they retain their design level of protection and function. Maintenance and upgrades can be a serious and expensive challenge as a levee system ages.

Levee systems in Pennsylvania includes various combinations of rolled earthen embankments; concrete L-walls, T-walls, and I-walls; plus 50 pump stations, 105 separate closure structures and approximately 200 separate relief wells. The average age of the federally authorized levee systems in Pennsylvania is approaching 50 years, which is the typical design life of a levee system. The average age of the non-federally authorized levee systems in Pennsylvania is 48 years, with the oldest system constructed in 1939 and the most recent system constructed in 2009. Approximately one-third of the non-federally authorized levee systems built in Pennsylvania are at least 50 years old and several were constructed almost 75 years ago.

The national levee Rehabilitation and Inspection Program is authorized by Public Law (PL) 84-99 and administered through 33 Code of Federal Regulations (CFR) Part 203. Public Law 84-99 provides discretionary authority given to the U.S. Army Corps of Engineers (USACE) to act and react to emergencies caused by floods, contaminated water sources, drought, or dam failures.

The USACE has authority under PL 84-99 to supplement local efforts in the repair of qualified levees which are damaged by a flood. This authority allows the Corps to repair and/or rehabilitate any qualified levee whether it is federally constructed or privately owned. To be eligible for rehabilitation assistance under PL 84-99, the levee must certain criteria and standards set forth by the U.S. Army Corps of Engineers and must be inspected and evaluated on a regular basis (approximately every two years).

In Pennsylvania, 109 levees are included in the Rehabilitation and Inspection Program, levee system types include:

Levee System Type	No. of Levees	Percentage of Total
Locally Constructed, Locally Operated and Maintained	77	71
Federally Constructed, Federally Operated and Maintained	7	6
Federally Constructed, Locally Operated and Maintained	25	23

The status of the levee systems included in the Rehabilitation and Inspection Program (RIP) are as follows:

RIP Levee Status	No. of Levees	Percentage of Total
Active	76	70
Inactive	22	20
Data Not Available	11	10

The term *Active Status* designates an Acceptable or Minimally Acceptable condition following an inspection, which means that the levee meets and maintains engineering and maintenance standards. The term *Inactive Status* designates an Unacceptable condition that would prevent the levee segment or system from performing as intended, likely due to poor maintenance or even from inadequate elevation or cross section in relation to the anticipated flood levels.

Within the 64 levee systems, there are 318 separate segments which provide a local protection length of about 151 miles and a total protected area of about 14,300 acres (22.3 square miles), including:

Flood Protected Areas		Percentage of Total
In Acres	In Square Miles	
<160	<0.25	75.0
>160 and <320	>0.25 and <0.5	12.5
>320	>0.5	12.5

Eight levee systems provide a protected area greater than 640 acres (one square mile). The largest protected area is the Kingston to Wyoming System located in the Wyoming Valley, which provides a protected area of more than 2,640 acres (4.6 square miles).

Levees have been constructed on 115 separate rivers or creeks and in all of the major river basins in Pennsylvania, including:

Major River Basin	No. of Levee Segments	Percentage of Total
Susquehanna River	181	57
Ohio River	85	27
Delaware River	47	15
Potomac River	4	1
St. Lawrence River	1	<1

Fifty-one (73 percent) of the 67 counties in Pennsylvania have levees. The Pennsylvania counties with the most levees are Luzerne with 32, Lackawanna with 25, and Lycoming with 23. These three counties account for approximately 25 percent of all Pennsylvania levee segments.

Despite the successful implementation of the Rehabilitation and Inspection Program and the fact that an effective levee inspection program is rigorously executed by both the Pennsylvania Department of Environmental Protection (PADEP) and the U.S. Army Corps of Engineers (USACE), a grade of “C-“ was assigned. This is attributed to the number of levees currently in an “*Inactive status*” in the Rehabilitation and Inspection Program (PL 84-99), the intrinsic uncertainty involved in establishing flood elevations, the changing hydrologic conditions, the advanced age of the levees, the numerous flood-prone watersheds existing in Pennsylvania, the residual flood risk inherent in flood

damage reduction projects designed to the current flood protection standard, the potential for the increasing frequency of flooding due to climate change, and the current low level of funding remaining for flood control projects in PA Act H2O. The possibility of catastrophic levee failure before overtopping is a constant and serious concern for every levee system. The consequences of a catastrophic levee failure or overtopping during a flood event are always devastating and include the potential for loss of life, property and commerce. The environmental and human health consequences of a levee failure are often an under-appreciated threat to public health and safety.

POLICY OPTIONS

Historically, PADEP has funded flood protection projects through the Flood Protection Grant Program, which has been superseded by the Pennsylvania H20 Act. The Pennsylvania H20 Act of 2008 currently provides single-year or multi-year grants to the Commonwealth, independent agencies, municipalities, or municipal authorities for flood control projects with $800 million designated to assist municipalities and authorities in paying for repairs to their water, sewer, and flood control projects. Flood control projects include construction, improvement, repair, or rehabilitation. Applicants must provide easements and rights of way, relocation of buildings and utilities, alterations or rebuilding of inadequate bridges, and operation and maintenance of the completed project. A minimum of $75 million was set aside for flood control projects, although current remaining funds available for flood control projects is low, with less than $1 million available. New flood control projects greater than $300,000 must be funded through the Capital Budget process. Act 13 of 2012 establishes the Marcellus Legacy Fund that allocates funds to the Commonwealth Financing Authority (CFA) for statewide initiatives to assist with flood mitigation projects. Limitations include 15 percent matching costs, maximum project cost of $1 million, and grants cannot exceed $500,000 per project. To date, 19 Act 13 projects have been reviewed by the CFA. In addition, the state funds its PADEP flood protection program through an annual line item in the budget. The line item was approximately $2.5 million for the FY11 budget year and $2.46 million for the FY12 budget year.

RECOMMENDATIONS

The four Pennsylvania sections of ASCE recommend that the following measures be taken to enhance and promote levee safety within Pennsylvania:

- Passage of state legislation to establish a statewide levee safety program, including legislation to allow for non-structural alternatives for flood damage reduction projects within the Commonwealth;
- Passage of state legislation to provide funding for levee certification for the 45 non-federal levee systems designed and constructed by PADEP;
- Continuation of state legislation to provide capital funding for new flood protection projects and legislative approval of flood protection funding through the annual PADEP flood control projects line item in the budget;

- Continuation of H20 Act program funding for levee improvements, upgrades, non-routine maintenance, or specialized equipment needs for the federal and non-federal (state) levee systems constructed in Pennsylvania;
- Establish a National Levee Safety Program that authorizes an entity to oversee a program for nonfederal levees, requires safety inspections, and maps flood-prone areas;
- Complete the National Levee Inventory for both federal and nonfederal levees;
- Adopt a levee hazard potential classification system;
- Complete levee mapping as outlined in the National Flood Insurance Program reform bill and implement FEMA's new levee mapping and analysis program;
- Increase funding at all levels of government and leverage private funds to address structural and nonstructural solutions that reduce flood risk to people and property;
- Require insurance where appropriate, and create emergency action plans for levee-protected areas; and
- Ensure that operation and maintenance plans cover all aspects of a complex levee system.

SOURCES

- American Society for Civil Engineers (ASCE) Central PA, Lehigh Valley, Philadelphia, Pittsburgh, *2010 Report Card for Pennsylvania's Infrastructure*: May 2010. Available at: http://www.pareportcard.org/
- American Society of Civil Engineers (ASCE), *2013 Report Card for American's Infrastructure*: March 2013. Available at: http://www.infrastructurereportcard.org/
- Pennsylvania Department of Environmental Protection (PADEP), *Flood Plain Management Act*, (1978).
- The *National Flood Insurance Program (NFIP)* regulations, 44 CFR 59 through 44 CFR 80.
- The *National Flood Insurance Act of 1968*, as amended, and the *Flood Disaster Protection Act of 1973*, as amended, 42 U.S.C. 4001 *et.seq.*
- The *National Flood Insurance Reform Act (NFIA)* of 1994.
- The *Flood Insurance Reform Act (FIRA)* of 2004.
- The Biggert-Waters *Flood Insurance Reform Act* (BW-12) of 2012.
- U.S. Army Corps of Engineers (USACE) Disaster Operations, Public Law 84-99, *Flood Control and Coastal Emergency Act (PL 84-99).*
- U.S. Army Corps of Engineers, (USACE) Department of the Army, *ER 500-1-1, Emergency Employment of Army and Other Resources* (September 2001). Available at: http://www.iwr.usace.army.mil/nfrmp/docs/USACE_Inspection%20Program_ER500-1-1.pdf
- Title 33, Code of Federal Regulations, Part 203 (33 CFR 203), *Navigation and Navigable Waters.* Available at: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl

- Title 44, Code of Federal Regulations, Section 65.10 (44 CFR 65.10), *Emergency Management and Assistance.* Available at: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl
- FEMA, NFIP database, http://www.fema.gov/national-flood-insurance-program.
- U.S. Army Corps of Engineers, National Levee Database, Available at: http://nld.usace.army.mil/egis/f?p=471:1:
- Schultz, C.H. ed. (2002) The Geology of Pennsylvania. Special Publication No. 1. Pennsylvania Geologic Survey and Pittsburgh Geological Society.
- Shank, W.H. (1972) Great Floods of Pennsylvania, A Two-Century History. American Canal and Transportation Center, York, PA.

ASCE POLICY STATEMENTS

- ASCE Policy Statement 529: *Levee Certification (PS 529)*
- ASCE Policy Statement 511: *National Levee Safety Program (PS 511)*