



## 4.3 Hazard Profiles

### 4.3.7 Flood

This section provides a profile and vulnerability assessment of the flood hazard in Pike County. Flooding is the temporary condition of partial or complete inundation of normally dry land, and it is the most frequent and costly of all natural hazards in Pennsylvania. Flash flooding is usually a result of heavy localized precipitation falling in a short time period over a given location, often along mountain streams and in urban areas where much of the ground is covered by impervious surfaces. Winter flooding can include ice jams which occur when warm temperatures and heavy rain cause snow to melt rapidly. Snow melt combined with heavy rains can cause frozen rivers to swell, which breaks the ice layer on top of a river. The ice layer often breaks into large chunks, which float downstream, piling up in narrow passages and near other obstructions such as bridges and dams (PEMA 2020).

For the purpose of this Plan and as deemed appropriate by the Planning Team, riverine, flash, ice-jam, dam failure, and stormwater flooding are the main flood types of concern for Pike County. These types of floods are further discussed below.

#### Riverine Floods

Riverine floods are the most common flood type and occur along a channel. Channels are defined features on the ground that carry water through and out of a watershed. They may be called rivers, creeks, streams, or ditches. When a channel receives too much water, the excess water flows over its banks and inundates low-lying areas. These floods usually occur after heavy rains, heavy thunderstorms, or snowmelt, and can be slow or fast-rising, and generally develop over a period of hours to days (FEMA 2015, Illinois Association for Floodplain and Stormwater Management 2006).

#### Streambank Erosion

Streambank erosion is a natural process that occurs when the forces exerted by flowing water exceed the resisting forces of bank materials and vegetation. Erosion occurs in many natural streams that have vegetated banks (USDA 2022). Higher-than-natural volumes of water (e.g., flood waters) flowing quickly downstream causes streambanks to erode and become unstable. Eroding streambanks contribute to sediment pollution. As streambanks erode, it increases the risk to nearby bridges and culverts as well as a loss of property (Kock 2020).

#### Flash Floods

According to the National Weather Service (NWS), flash floods are a rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within 6 hours of the causative event (e.g., intense rainfall, dam failure, or ice jam) (NWS 2011).

Flash floods can occur very quickly and with very little warning. This type of flood can be deadly because it produces rapid rises in water levels and has devastating flow velocities. Urban areas are more susceptible to flash floods because a high percentage of the surface area is impervious (Pennsylvania Emergency Management Agency [PEMA] 2013). Time elapsed before flash flooding occurs may vary in different parts of the country. Ongoing flooding can



intensify to flash flooding where intense rainfall results in a rapid surge of rising flood waters (NWS 2011). A flash flood can have a dangerous wall of roaring water that carries rocks, mud, and other debris, and can sweep away most things in its path. Flash floods usually result from intense storms dropping large amounts of rain within a brief period with little or no warning and can reach their peak within only a few minutes. They normally occur in the summer during the thunderstorm season. The most severe flooding conditions usually occur when direct rainfall is augmented by snowmelt. If the soil is saturated or frozen, stream flow may increase because of inability of the soil to absorb additional precipitation (FEMA 2008).

### Ice-Jam Floods

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An ice jam is an accumulation of ice that acts as a natural dam and restricts flow of a body of water. Ice jams occur when warm temperatures and heavy rains cause rapid snow melt. The melting snow, combined with the heavy rain, causes frozen rivers to swell. The rising water breaks the ice layers into large chunks, which float downstream and often pile up near narrow passages and obstructions (bridges and dams). Ice jams may build up to a thickness great enough to raise the water level and cause flooding (Northeast States Emergency Consortium [NESEC] Date Unknown, U.S. Army Corps of Engineers [USACE] 2002).

Ice jams are of two different types: freeze-up and breakup. Freeze-up jams occur in the early to mid-winter when floating ice may slow or stop due to a change in water slope as it reaches an obstruction to movement. Breakup jams occur during periods of thaw, generally in late winter and early spring. The ice cover breakup is usually associated with a rapid increase in runoff and corresponding river discharge caused by a heavy rainfall, snowmelt, or warmer temperatures (USACE 2002).

### Dam Failure Floods

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A dam is an artificial barrier that can impound water, wastewater, or any liquid-borne material for the purpose of storage or control of water (FEMA 2010). Dams are man-made structures built across a stream or river that impound water and reduce flow downstream (FEMA 2004). They are built for purposes of power production, agriculture, water supply, recreation, and flood protection. Dam failure is any malfunction or abnormality outside of the design that adversely affects a dam's primary function of impounding water (FERC 2011). Dams can fail for one or a combination of the following reasons:

- Overtopping caused by floods that exceed capacity of the dam (inadequate spillway capacity)
- Prolonged periods of rainfall and flooding
- Deliberate acts of sabotage (terrorism)
- Structural failure of materials used in dam construction
- Movement and/or failure of the foundation supporting the dam
- Settlement and cracking of concrete or embankment dams
- Piping and internal erosion of soil in embankment dams
- Inadequate or negligent operation, maintenance, and upkeep
- Failure of upstream dams on the same waterway
- Earthquake (liquefaction/landslides) (FEMA 2010).



Flooding can occur when a dam fails or breaks, producing effects similar to flash floods. Areas most susceptible to effects of floods are low-lying areas near water or downstream from a dam (FERC 2011).

### Stormwater Floods

Stormwater flooding described below is due to local drainage issues and high groundwater levels. Locally, heavy precipitation may produce flooding in areas other than delineated floodplains or along recognizable channels. If local conditions cannot accommodate intense precipitation through a combination of infiltration and surface runoff, water may accumulate and cause flooding problems. During winter and spring, frozen ground and snow accumulations may contribute to inadequate drainage and localized ponding. Flooding issues of this nature generally occur in areas with flat gradients and generally increase with urbanization which speeds the accumulation of floodwaters because of impervious areas. Shallow street flooding can occur unless channels have been improved to account for increased flows (FEMA 1997).

High groundwater levels can be a concern and cause problems even where there is no surface flooding. While stormwater flooding can cause damage to structures and foundations, basements in particular are susceptible to high groundwater levels. Seasonally high groundwater is common in many areas, while elsewhere high groundwater occurs only after a long period of above-average precipitation (FEMA 1997).

Heavy rainfall that overwhelms a developed area's stormwater infrastructure causing flooding is commonly referred to as urban flooding. Urban flooding can be worsened by aging and inadequate infrastructure and over development of land. The growing number of extreme rainfall events that produce intense precipitation are resulting in increased urban flooding (Center for Disaster Resilience 2016). While riverine and coastal flooding is mapped and studied by FEMA, urban flooding is not.

NOAA defines urban flooding as the flooding of streets, underpasses, low lying areas, or storm drains. (NOAA 2009). Urban drainage flooding is caused by increased water runoff due to urban development and inadequate drainage systems. Drainage systems are designed to remove surface water from developed areas as quickly as possible to prevent localized flooding on streets and other urban areas. The systems make use of a closed conveyance system that channels water away from an urban area to surrounding streams. This bypasses the natural processes of water filtration through the ground, containment, and evaporation of excess water. Because drainage systems reduce the amount of time the surface water takes to reach surrounding streams, flooding in those streams can occur more quickly and reach greater depths than prior to development in that area (Harris 2008).

#### **4.3.7.2 Location and Extent**

Flooding in Pennsylvania is typically associated with abnormally high and intense rainfall amounts. It can also be caused by sudden snowmelt, landslides, or dam failures. In Pennsylvania, flooding usually occurs in the summer; however, flooding has occurred during the winter months as well.

Floodplains are found in lowland areas adjacent to rivers, streams, creeks, lakes, or other bodies of water that become inundated during a flood. The size of a floodplain depends on the recurrence interval of a given flood. A 1-percent annual chance floodplain is smaller than the floodplain associated with a flood that has a 0.2-percent annual chance of occurring (PEMA 2013). Floodplain maps of each Pike County jurisdiction are available at the end of this profile.



These maps show locations of both the 1-percent chance annual floodplain and the 0.2-percent chance annual floodplain.

Pike County’s biggest flooding threat remains along the Delaware River corridor and portions of the Lackawaxen River. Other major creeks within the County include the East Branch Wallenpaupack, Shohola, Billings, and Blooming Grove Creek. Lake Wallenpaupack also comprises a portion of the County’s western border and is prone to flooding. It was also noted that Broadhead Road in Lehman Township is prone to flooding.

Most municipalities in Pike County have flood-prone areas because they are located along streams, creeks, or lakes. In addition, community development of the floodplain has resulted in frequent flooding. For inland areas, excess water from snowmelt or rainfall accumulates and overflows onto stream banks and adjacent floodplains.

Table 4.3.7-1 lists total land areas within the 1-percent and 0.2-percent annual chance flood zones calculated via a spatial analysis referencing the 2000 Digital Flood Insurance Rate Map (DFIRM).

*Table 4.3.7-1. Total Land Areas in the 1-Percent and 0.2-Percent Annual Chance Flood Zones (Acres)*

Municipality	NFIP-Participating Community	Total Area (acres)	1% Flood Event Hazard Area		0.2% Flood Event Hazard Area	
			Area (acres)	% of Total	Area (acres)	% of Total
Blooming Grove Township	Yes	49,458	1,986	4.02%	1,986	4.02%
Delaware Township	Yes	29,210	1,230	4.21%	1,230	4.21%
Dingman Township	Yes	38,493	2,892	7.51%	2,996	7.78%
Greene Township	Yes	39,581	2,305	5.82%	2,305	5.82%
Lackawaxen Township	Yes	51,955	1,641	3.16%	1,641	3.16%
Lehman Township	Yes	32,205	1,975	6.13%	1,975	6.13%
Matamoras Borough	Yes	509	125	24.56%	419	82.32%
Milford Borough	Yes	321	58	18.07%	61	19.00%
Milford Township	Yes	7,931	157	1.98%	163	2.06%
Palmyra Township	Yes	25,249	3,385	13.41%	3,385	13.41%
Porter Township	Yes	38,699	5,185	13.40%	5,185	13.40%
Shohola Township	Yes	30,101	928	3.08%	946	3.14%
Westfall Township	Yes	19,302	924	4.79%	1,237	6.41%
<b>Pike County (Total)</b>	-	<b>363,014</b>	<b>22,791</b>	<b>6.28%</b>	<b>23,529</b>	<b>6.48%</b>

Source: FEMA 2000

Note: Areas listed include areas of inland waterways

In accordance with the 1978 Pennsylvania Stormwater Management Act (Act 167), counties are required to prepare stormwater management plans on a watershed-by-watershed basis that provide for improved management of stormwater impacts associated with development of land. In 2010, Pike County developed and implemented Phase I of the Act 167 County Wide Plan Stormwater Management Plan. This phase of the Plan includes the Scope of Study—establishing procedures for use in preparing the Plan. These procedures are determined by an overall survey of:



- Specific watershed characteristics and hydrologic conditions
- Stormwater-related problems and significant obstructions
- Alternative measures for control
- Goals, objectives, solution strategies, and estimated costs for Phase 2 of the Plan.

Figure 4.3.7-1 shows PADEP-designated watersheds with critical facilities in Pike County.

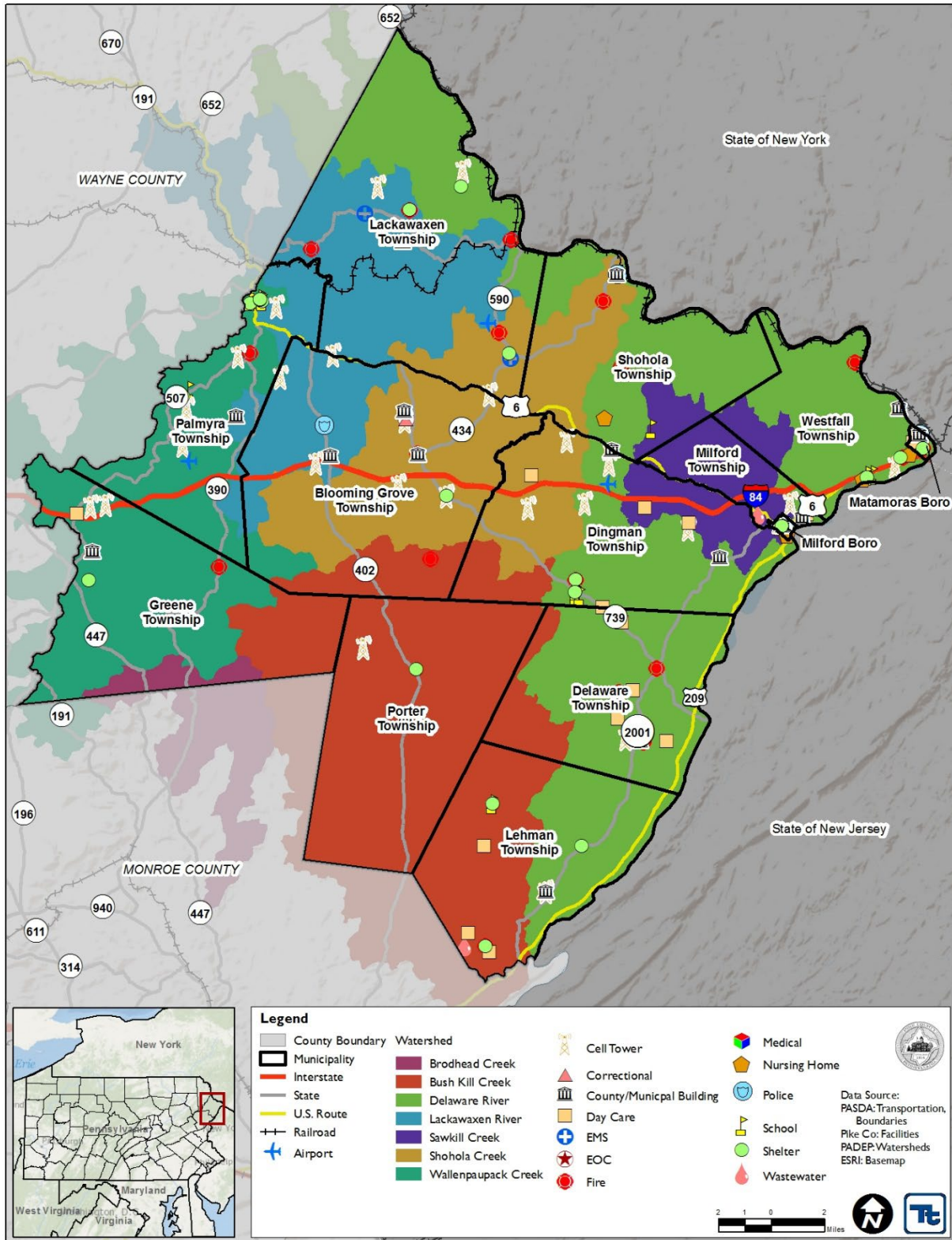
The 2000 FEMA Flood Insurance Study (FIS) for Pike County also documents the major flooding problems in the County, including areas along the Delaware River that flood at any point during the year (FEMA FIS 2000). Additionally, there are several floodprone areas in the Sawkill Creek Watershed area and Delaware Township. The Sawkill Creek Watershed is located in the eastern portion of Pike County and is contained within five municipalities: Dingman Township, Milford Borough, Milford Township, Shohola Township, and Westfall Township. The Sawkill Creek drains a watershed area of approximately 25 square miles and includes the following primary tributaries: Savantine Creek, Pinchot Brook, Dimmick Meadow Brook, Vantine Brook, and Sloat Brook. Areas of flooding were identified in the Sawkill Creek Watershed Act 167 Stormwater Management Plan. Township Road 428 (Schoccoppe Road) in Milford Township floods during heavy rains. Pinchot Brook floods onto the roadway. The roads serving this area were constructed on severe slopes which has led to erosion and flooding problems where the primary subdivision road intersects State Route 2011.

In the 1994 Act 167 Lackawaxen River Watershed Stormwater Management Plan for Wayne, Pike and Lackawana Counties, the following areas of Pike County were identified as locations of flooding problems and continue to flood as of the date of this HMP update:

- State Route 4004 in Blooming Grove Township
- Kimbles Road (T 367) along Decker Creek and adjacent wetland



Figure 4.3.7-1. PADEP-Designated Watersheds with Critical Facilities



Source: PADEP



## FEMA Regulatory Flood Zones

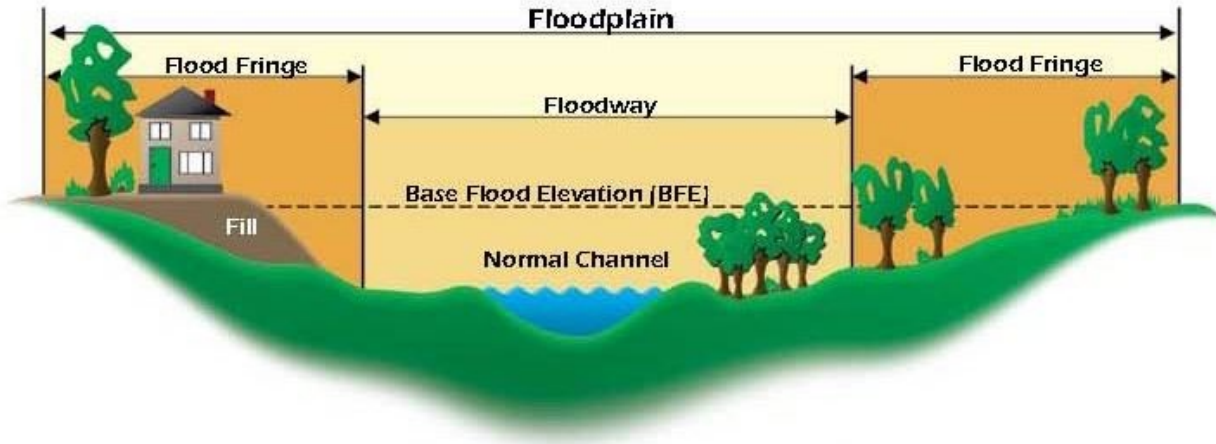
According to FEMA, flood hazard areas are defined as areas on a map shown to be inundated by a flood of a given magnitude. These areas are determined by use of statistical analyses of records of river flow, storm tides, and rainfall; information obtained through consultation with the community; floodplain topographic surveys; and hydrologic and hydraulic analyses. Flood hazard areas are delineated on FEMA's Flood Insurance Rate Maps (FIRM), which are official maps of a community on which the Federal Insurance and Mitigation Administration has delineated both Special Flood Hazard Areas (SFHA) and the risk premium zones applicable to the community. These maps identify SFHAs, location of a specific property in relation to the SFHA, the base flood elevation (BFE) (1-percent annual chance) at a specific site, the magnitude of a flood hazard within a specific area, undeveloped coastal barriers where flood insurance is not available, and regulatory floodways and floodplain boundaries (1-percent and 0.2-percent annual chance floodplain boundaries) (FEMA 2003, 2005, 2008). Pike County's FIRMs can be accessed online via the FEMA Flood Map Service Center (<https://msc.fema.gov/portal>).

The land area covered by floodwaters of the base flood is the SFHA on a FIRM. It is the area where the National Flood Insurance Program's (NFIP) floodplain management regulations must be enforced, and the area where mandatory purchase of flood insurance applies. This regulatory boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities because many communities have maps showing the extent of the base flood and likely depths that will occur.

The 1-percent annual chance flood is referred to as the base flood. As defined by NFIP, the BFE on a FIRM is the elevation of a base flood event, or a flood which has a 1-percent chance of occurring in any given year. The BFE describes the exact elevation of the water that will result from a given discharge level, which is one of the most important factors used in estimating potential damage within a given area. A structure within a 1-percent annual chance floodplain has a 26-percent chance of undergoing flood damage during the term of a 30-year mortgage. The 1-percent annual chance flood is a regulatory standard used by federal agencies and most states to administer floodplain management programs. The 1-percent annual chance flood is used by NFIP as the basis for insurance requirements nationwide. FIRMs also depict 0.2-percent annual chance flood designations (FEMA 2003). Figure 4.3.7-2 depicts the SFHA, the base flood elevation, the flood fringe, and the floodway areas of a floodplain for the 1-percent annual chance flood.

Figure 4.3.7-2. Floodplain Illustration

### Characteristics of a Floodplain



Source: Mille Lacs County 2022

Notes: *Base flood elevation - elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year.*

*Floodway - the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height*

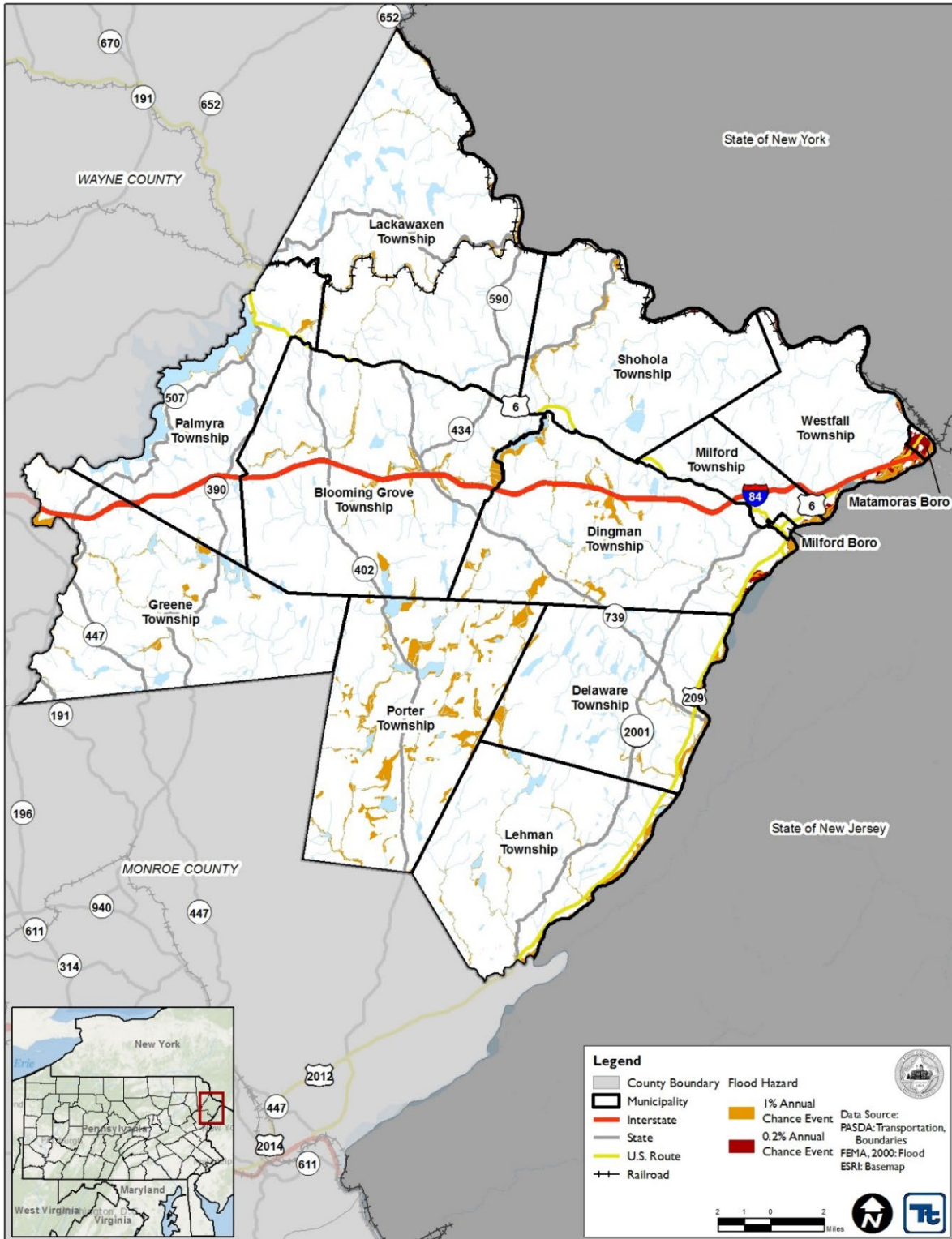
*Flood Fringe - the portion of the floodplain outside the floodway that is usually covered with water from the 100-year flood or storm event.*

The SFHA serves as the primary regulatory boundary used by FEMA and Pennsylvania. Digitized Flood Insurance Rate Maps (DFIRM), FIRMs, and other flood hazard information can be referenced to identify the expected spatial extent of flooding from a 1-percent annual chance event and 0.2-percent annual chance event.

At the time this Plan was written, the 2000 DFIRMs were considered the best available, and were used for the risk analysis. Figure 4.3.7-3 illustrates NFIP flood zones in Pike County. Maps of each municipality's flood zones are shown in Appendix D.



Figure 4.3.7-3. NFIP Floodplains in Pike County



Source: FEMA 2000



While the FIRMs provide a creditable source to document extent and location of the flood hazard, accuracy of data reflected on these maps has limitations. Notably, FIRMs are based on existing hydrological conditions at the time of map preparation. FIRMs are not set up to account for possible changes in hydrology over time.

### Flood Insurance Study

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In addition to FIRM and DFIRMs, FEMA also provides Flood Insurance Studies (FIS) of entire counties and individual jurisdictions. These studies aid in administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. They are narrative reports of countywide flood hazards, including descriptions of flood areas studied and engineered methods used, principal flood problems, flood protection measures, and graphic profiles of flood sources (FEMA 2008). The countywide FIS for Pike County was last completed in 2000, at the same time as the DFIRM revisions.

### Dam Failure

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Dam failures cause serious downstream flooding either because of partial or complete dam collapse. Failures are usually associated with intense rainfall and prolonged flood conditions, however, dam breaks may occur during dry periods as a result of progressive erosion of an embankment. The greatest threat from a dam break is to areas immediately downstream.

There are many sources that track the number and classification of dams in Pike County. According to the Pennsylvania Department of Environmental Protection (PA DEP), there are 147 dams in Pike County, 50 of which are classified as high hazard dams (category 1 and 2). The PA DEP defines a high hazard dam as “any dam so located as to endanger populated areas downstream by its failure” [Def. added May 16, 1985, P.L.32, No. 15]. A spatial dataset maintained by Pike County indicates there are 45 high hazard dams in the County. In addition to these dams, there are three flood control dams in Greene Township – Taylor Pond Dam, Sky View Dam, and Kintz Creek Dam. The Kintz Creek dam is scheduled for a major rehabilitation/replacement to alleviate flood concerns in the County (Pike County Conservation District 2022).

There are also dams located outside of Pike County which have the potential to inflict loss or hardship upon municipalities within the County. One is the dam at the Swinging Bridge Reservoir along the Mongaup River in Sullivan County, New York. A failure of this dam would release a large volume of water into the Mongaup River which drains to the Delaware River and would impact many Pike County communities that border the river. In addition, the New York City reservoirs along the Delaware River and the Neversink River in New York also pose a significant threat should a major failure occur (Pike County HMP 2012).

High hazard dams receive two inspections each year – once by a professional engineer on behalf of the owner and once by a DEP inspector (PA DEP 2016). High hazard dams are required to have an Emergency Action Plan (EAP) in place which should be reviewed at a minimum of every two years. While not available for all dams, downstream inundation maps can be obtained from the DEP for some of the high hazard dams.

### Ice-Jam Hazard Areas

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Ice jams are common in northeastern United States, and the Commonwealth of Pennsylvania is not an exception. The Ice Jam Database, maintained by the Ice Engineering Group at the USACE Cold Regions Research and



Engineering Laboratory (CRREL), currently consists of over 19,000 records from across the United States. According to the USACE-CRREL, Pike County underwent or may have been impacted by four historical ice jam incidents between 1784 and 2021 (USACE 2021). Ice Jams have formed along Delaware River and Shohola Creek. Historical events are further mentioned in the “Previous Occurrences” section of this hazard profile.

### Flood Problem Areas

For this plan update, the County and municipalities identified areas known to flood, particularly those associated with stormwater flooding which does not traditionally have mapping as flood issues can quickly arise and also be addressed and solved through mitigation to prevent future flooding issues. Potential flood related problems identified include erosion, excessive runoff, flooded roadways, and sedimentation. Figure 4.3.7-4 illustrates these areas throughout the County.

#### **4.3.7.3 Range of Magnitude**

Both localized and widespread floods are considered hazards when people and property are affected. Injuries and deaths can occur when people are swept away by flood currents, or bacteria and disease are spread by moving or stagnant floodwaters. Most property damage results from inundation by sediment-filled water. A large amount of rainfall over a short period of time can result in flash floods. Small amounts of rain can cause flooding in areas with frozen soil or saturated soils from a previous event, or if the rain is concentrated in areas with impervious surfaces (PEMA 2013).

Several factors determine severity of floods, including intensity and duration, topography, ground cover, and rate of snowmelt. Water runoff is greater in areas with steep slopes and little or no vegetative ground cover. Many areas in Pennsylvania have relatively steep slopes that promote quick surface water runoff. Most storms track from west to east; however, some originate in the Great Lakes or the Atlantic Ocean (PEMA 2013).

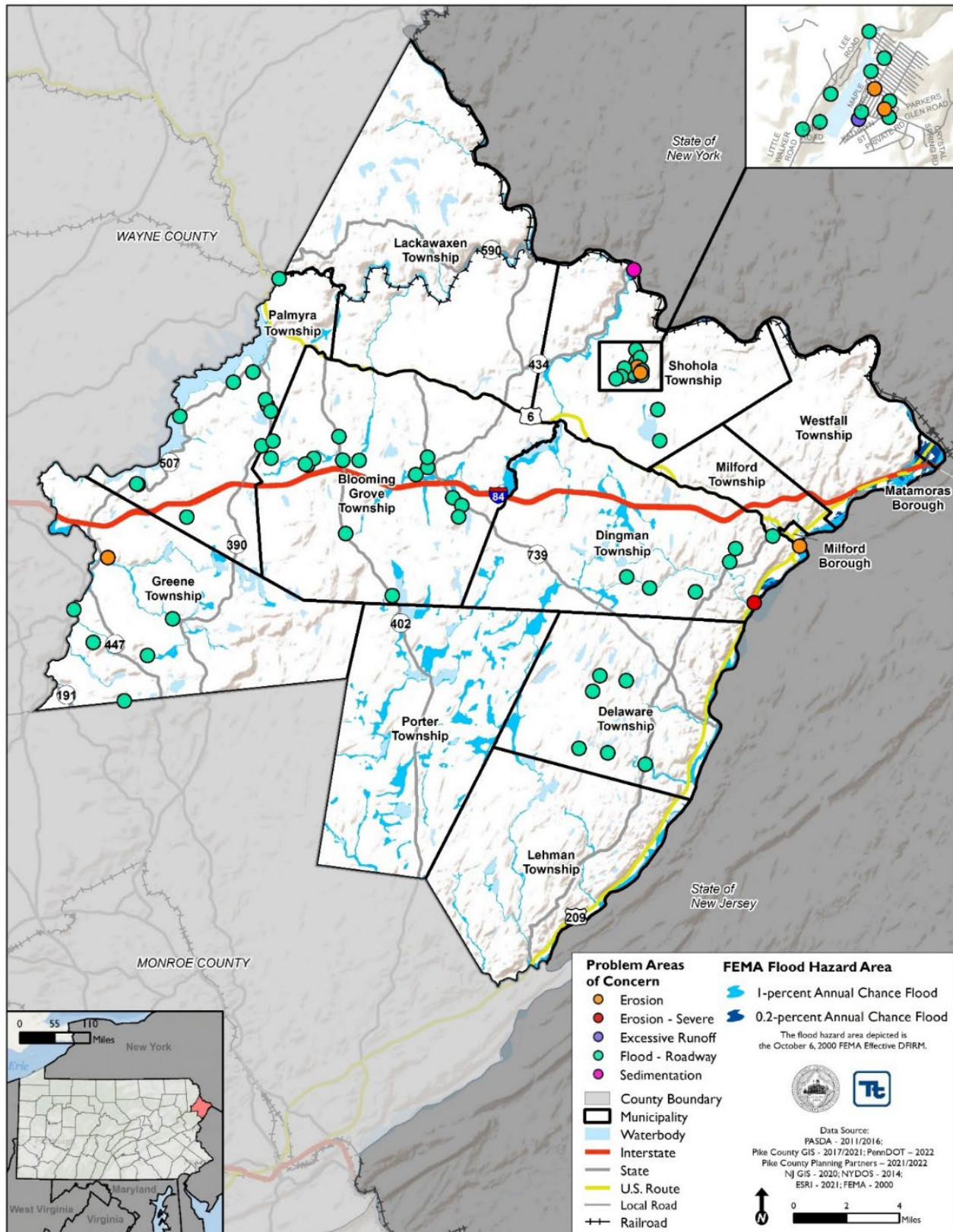
Rainfall in Pennsylvania is about average for the eastern United States. Amounts of precipitation can be divided into the following six categories:

- Very light rain – precipitation rate of <0.01 inch per hour
- Light rain – precipitation rate between 0.01 inch and 0.04 inch per hour
- Moderate rain – precipitation rate between 0.04 inch and 0.16 inch per hour
- Heavy rain – precipitation rate between 0.16 inch and 0.63 inch per hour
- Very heavy rain – precipitation rate between 0.63 inch and 2 inches per hour
- Extreme rain – precipitation rate greater than 2 inches per hour (PEMA 2013).

Severity of a flood depends not only on the amount of water that accumulates within a period of time, but also on the land's ability to manage this water. One element is the size of rivers and streams in an area; but an equally important factor is the land's absorbency. When it rains, soil acts as a sponge. When the land is saturated or frozen, infiltration into the ground slows, and any more water that accumulates must flow as runoff (Harris 2008).



Figure 4.3.7-4. Flood Problem Areas in Pike County





In the case of riverine or flash flooding, once a river reaches flood stage, the flood extent or severity categories used by NWS include minor flooding, moderate flooding, and major flooding. Each category has a definition based on property damage and public threat:

- Minor Flooding – minimal or no property damage, but possibly some public threat or inconvenience.
- Moderate Flooding – some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary.
- Major Flooding – extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary (NWS 2011).

The extent or magnitude of a dam failure event can be measured in terms of the classification of the dam. FEMA has three classification levels of dams: low, significant, and high. The classification levels build on each other. The hazard potential classification system should be used with the understanding that the failure of any dam or water-retaining structure could represent a danger to downstream life and property (FEMA 2004). Each of FEMA’s dam classification levels is described below:

- Low hazard potential dams are those where failure or misoperation would result in no probable loss of human life and low economic or environmental losses. Losses are principally limited to the owner’s property.
- Significant hazard potential dams are those where failure or misoperation would result in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas.
- High hazard potential dams are those where failure or misoperation will probably cause loss of human life.

USACE developed the classification system shown in Table 4.3.7-2 for the hazard potential of dam failures. The USACE hazard rating system is based only on the potential consequences of a dam failure; it does not take into account the probability of failures.

*Table 4.3.7-2. U.S. Army Corps of Engineers Hazard Potential Classification*

Hazard Category <sup>a</sup>	Direct Loss of Life <sup>b</sup>	Lifeline Losses <sup>c</sup>	Property Losses <sup>d</sup>	Environmental Losses <sup>e</sup>
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

Source: USACE 2011

Note:

- a. Categories are assigned to overall projects, not individual structures at a project.
- b. Loss-of-life potential is based on inundation mapping of the area downstream of the project. Analysis of loss-of-life potential should take into account the population at risk, time of flood wave travel, and warning time.
- c. Lifeline losses include indirect threats to life caused by the interruption of lifeline services from project failure or operational disruption; for example, loss of critical medical facilities or access to them.



- d. Property losses include damage to project facilities and downstream property and indirect impact from loss of project services, such as impact from loss of a dam and navigation pool, or impact from loss of water or power supply.
- e. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.

A worst case scenario for flooding occurred in September 2004, following a very wet August that included some rain from the remnants of Tropical Storm Bonnie and Tropical Depression Charley. Remnants of Hurricane Frances dumped an average of 3 inches in the county on September 8th. On September 18th, Tropical Depression Ivan dumped 4 to 5 inches of rain over an already saturated county causing widespread damage. Rainfall for August and September averaged over 20 inches across the county. In addition to the damage caused by runoff, many streams flooded. Rainfall in the headwaters of the Delaware River was such that both the Lackawaxen River and Delaware River rose above flood stage causing the evacuation of many low lying areas, including portions of Westfall Township, Matamoras Borough, and Lackawaxen Township. Pike County qualified for both Public Assistance and Individual Assistance as part of the Presidential Declaration of Major Disaster. Over 300 property owners applied for Individual Assistance. Many roads remained closed for weeks while repairs were made. Particularly hard hit were Shohola, Lackawaxen, Palmyra, Greene, Dingman, Delaware and Lehman Townships. Two county-owned bridges – one in Shohola Township and one in Lehman Township - sustained major damage. A portion of the Twin Lakes road was washed away.

#### 4.3.7.4 Past Occurrence

Pike County has a long history of flooding events. While flooding is often localized to streets and small neighborhoods, the County has historically experienced periodic storm events that affect multiple communities over a large area. Past building practices often resulted in homes being constructed in the FEMA designated floodplains, exacerbating flooding problems within certain communities.

There are gauges at Barryville (BRYN6) and Matamoras/Port Jervis (MTMP1) which are used to monitor hydrologic conditions on the Delaware River. The National Weather Service uses flood categories as forecast points which describe the severity of flood impacts in the river/stream reach. Table 4.3.7-3 summarizes the flood categories in feet at each of these gauges; and Table 4.3.7-4 summarizes the top historic crests at these locations.

Table 4.3.7-3. Flood Categories at the Barryville (BRYN6) and Matamoras/Port Jervis (MTMP1) Gages

Flood Category	Flood Category Definition	Barryville (in feet)	Matamoras/Port Jervis (in feet)
Major Flood Stage	Life-threatening and extensive inundation of structures and roads; significant evacuations are expected at this stage.	26	21.5
Moderate Flood Stage	Inundation of buildings usually begins at this stage; roads are likely to be closed and some areas cut off (evacuations may be necessary).	22	20
Flood Stage	Gage height above which a rise in water surface level begins to create a hazard to lives, property or commerce; issuance of flood warnings is linked to flood stage.	17	18
Action Stage	Level where the NWS needs to take some type of mitigation action in preparation for possible significant hydrologic activity	15	16

Source: NWS 2021; NWS 2021



Table 4.3.7-4. Historic Crests at the Barryville (BRYN6) and Matamoras/Port Jervis (MTMP1) Gages

Barryville		Matamoras/Port Jervis	
Feet	Date	Feet	Date
28.97	June 28, 2006	26.60	February 12, 1981
26.40	August 19, 1955	25.50	March 8, 1904
24.80	April 30, 2005	23.91	August 19, 1955
24.09	September 18, 2004	23.10	October 10, 1903
23.19	May 23, 1942	21.47	June 28, 2006
22.18	January 20, 1996	20.52	April 3, 2005
20.90	February 11, 1981	19.52	September 18, 2004
20.07	March 22, 1948	18.50	March 7, 1923
20.06	June 29, 1973	18.37	January 20, 1996
19.28	March 15, 1986		

Source: NWS 2017

According to the National Oceanic and Atmospheric Administration’s National Climatic Data Center (NOAA NCDC) storm event database, Pike County experienced 23 flood events between January 1, 1950, and August 30, 2021 (the date range of data availability). Total property damages as a result of these flood events were estimated at \$52,270,000. This total also includes damages to other counties.

Between 1954 and 2021, the Commonwealth of Pennsylvania underwent 33 FEMA-declared, flood-related disaster declarations (DR) or emergencies classified as one or a combination of the following disaster types: severe storms, mudslides, flash flooding, tropical storms, tropical depressions, high winds, and rains. Typically, these disasters covered a wide region of the State; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations (FEMA 2021). Pike County was included in nine of the declarations, as listed in Table 4.3.7-5

Based on all sources researched, known flooding events that have affected Pike County and its municipalities, resulting in property damages, are listed in Table 4.3.7-5. With flood documentation for the Commonwealth of Pennsylvania so extensive, not all sources have been identified or researched. Therefore, Table 4.3.7-5 may not include all events that have occurred throughout the County.



Table 4.3.7-5. Flooding Events between 1950 and 2020 in Pike County

Date of Event	Event Type	Location	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
August 1955	Remnants of Hurricanes Connie and Diane	Countywide	DR-40	No	The remnants of Hurricanes Connie and Diane caused flooding in Pike County as a result of heavy rains. Both storms moved through the area less than one week apart. After a relatively dry summer, the two storms dumped closed to 20 inches of rain over a wide area with some areas receiving more. The results were devastating, particularly along the Lackawaxen and Delaware Rivers and the many streams.
August 1969	Severe Storms and Flooding	Countywide	DR-273	Yes	N/A
June 1972	Remnants of Hurricane Agnes	Countywide	DR-355	No	The remnants of Hurricane Agnes produced very heavy rains across most of Pennsylvania including Pike County. There was some minor flooding within the county.
February 13, 1981	Ice Jams	Matamoras, Westfall	N/A	N/A	A series of ice jams along both the Lackawaxen and Delaware. Rivers caused significant flooding. On February 13, 1981, tons of ice and river water clogged behind massive ice jams in the Delaware River and flooded low-lying residential and commercial areas in Matamoras Borough. The flooding resulted from a storm the previous day that provided over two inches of rain in the area. Runoff from the storm was blocked by an ice jam in the river between Port Jervis and Matamoras. Before the ice jam broke, the water backed up and flooded a vast majority of the Matamoras area including Port Jervis, NY.
November 27, 1993	Flash/Flash Flood	Eastern Pennsylvania	N/A	N/A	General rainfall totals of 2.50 to 3.50 inches occurred throughout eastern Pennsylvania with numerous locations receiving 4.00 to 5.00 inches.
September 27, 1994	Flash/Flash Flood	Countywide	N/A	N/A	The worst damage was along the Sawkill Creek. Three households along the creek had to be evacuated in Milford.
January 19, 1996	Severe Storms and Flooding / Flash Flood	Countywide	DR-1093	Yes	According to the Pennsylvania State Climatologist, the county had \$23 million in damages from this event.
September 8, 1996	Flash Flood	Milford	N/A	N/A	Serious street flooding was reported in Milford. Also, local law enforcement officials had to rescue 500 to 700 people from the agricultural fairgrounds as flood waters rapidly reached a depth of one to two feet.
May 31-June 2, 1998	Severe Storms, Tornadoes and Flooding	Countywide	DR-1219	Yes	N/A
September 16, 1999	Flood	Countywide	N/A	N/A	Water was seen rushing down hillsides where numerous road washouts were reported.



Date of Event	Event Type	Location	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
July 16, 2000	Urban/Small Stream Flood	Countywide	N/A	N/A	Minor flooding was reported in the southern portion of the county due to heavy thunderstorm rains.
June 26, 2002	Flash Flood	Shohola	N/A	N/A	Localized heavy thunderstorm rains caused numerous road washouts in Shohola Township. A state of emergency was declared in the township due to the washouts and also to trees and wires blocking the roads. According to the Pennsylvania State Climatologist, the county had \$70,000 in damages from this event.
June 21, 2003	Flash Flood	Milford and Dingman Townships	N/A	N/A	State route 739 washed out in Dingman Township. Heavy rain fell during the afternoon into the evening of the 21st. Radar estimated 2 to 3 inches of rain fell. Rain also fell on the 20th making the ground saturated. According to the Pennsylvania State Climatologist, the county had \$20,000 in damages from this event.
May 12, 2004	Flash Flood	Pecks Pond	N/A	N/A	Pecks Pond, Pike County. Flash flood – 2 to 3 feet of water on Route 402.
August 12, 2004	Flash Flood	Shohola	N/A	N/A	Shohola, Pike County. Flash Flood – Numerous road washouts from flash flooding reported in the towns of Shohola, Lackawaxen, Porter, and Blooming Grove. This included the settlements of Lords Valley and Pecks Pond. According to the Pennsylvania State Climatologist, the county had \$1 million in damages from this event.
August 30, 2004	Flash Flood	Milford	N/A	N/A	Heavy rain caused numerous roads to flood just west of Milford. Rainfall amounts were 1.5 to 3 inches. According to the Pennsylvania State Climatologist, the county had \$5,000 in damages from this event.
September 8-9, 2004	Severe Storms and Flooding Associated with Tropical Depression Frances	Countywide	DR-1555	Yes	N/A
September 18, 2004	Flash Flood (Tropical Depression Ivan)	Countywide	DR-1557	Yes	Rainfall amounts were 4 to 7 inches which started on the 16th and continued into the 18th. This rain was from the remnants of hurricane Ivan. Most creeks and streams went out of their banks. In addition, the Delaware and Lackawaxen Rivers had major flooding. About a dozen rescues were performed. Over 100 roads were closed. The entire village of Newfoundland was evacuated. 6 bridges were closed. 2 businesses were closed. According to the Pennsylvania State Climatologist, the county had \$15 million in damages from this event.



Date of Event	Event Type	Location	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
April 2, 2005	Severe Storms and Flooding	Pike County and Southern Wayne County	DR-1587	Yes	Lackawaxen River at Hawley rose to its flood stage of 11 feet and crested, which was the fourth highest crest on record. The high crest was partially due to Lake Wallenpaupack making high releases. This was the second highest flood of record and the highest in almost 50 years.
April 3, 2005	Flash Flood	Countywide	DR-1555	Yes	Storm from the Ohio Valley brought 2 to 4 inches of rain. Rivers and streams already had high flows due to rainstorm and snowmelt. Numerous roads, bridges and buildings were damaged. All streams and creeks were out of their banks. A state of emergency was declared in Matamoras. 100 homes were damaged. 15 homes had damage to the foundations and were condemned.
October 8, 2005	Flash Flood	Southeastern Pike County	N/A	N/A	Streams and creeks went out of their banks. Many roads were closed. 6 to 10 inches of rain fell in this area.
June 28, 2006	Flood	Milford	DR-1649	Yes	Major flooding occurred along the Delaware River from Matamoras, PA and Port Jervis, NY south through the eastern border of Pike County.
March 11, 2011	Flash Flood	Dingmans Ferry	N/A	N/A	Rainfall amounts ranged from 1.5 to 2 inches, with isolated amounts over 3 inches in Pike County resulting in road flooding throughout the County.
August 26-30, 2011 September 3-October 5, 2011	Hurricane Irene Tropical Storm Lee	Countywide	DR-4025 DR-4030	Yes No	<p>Hurricane Irene and Tropical Storm Lee are two recent storm events that impacted Pike County resulting in rainfall and flooding. Hurricane Irene made landfall in the United States on August 27, 2011. It was downgraded to a tropical storm as it headed north and remnants of it affected Pike County with rainfall on August 28th. Tropical Storm Lee developed as a tropical disturbance in the Gulf of Mexico and was a particularly large and slow-moving storm. By the time it reached Pennsylvania, the storm had lost its tropical characteristics and merged with an upper level trough positioned over the eastern third of the US. The storm then stalled over Pennsylvania, bringing rainfall to the region.</p> <p>While both storm events brought rainfall and flooding to Pike County, neither Hurricane Irene nor Tropical Storm Lee resulted in flooding and damages that surpassed other major storm events that have impacted Pike County and resulted in worst case scenarios or record flood levels. According to the Pike County EMA, the results of the two storms were minor in comparison to other storms that have affected the County. Hurricane Irene resulted in more of an impact to Pike County than Tropical Storm Lee. Many homes had flooded basements as a result of sump pump failure from periods of utility interruption during Irene. There were approximately 120 structures which were classified as minor, affected, or inaccessible due to damages resulting from the storm. No homes or businesses</p>



Date of Event	Event Type	Location	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
					were destroyed or suffered major damage that would render the structures inhabitable for an extended period of time. In addition, while there was some damage to municipal roads and some municipal property, no public buildings or treatment facilities were damaged. There were however a few bridges or private culverts that were damaged by Irene. According to the Pike County EMA, there were few, if any reports of damage from Tropical Storm Lee. The rainfall was not as steady as it was with Hurricane Irene. Damages that did occur from Lee were only additional damage to roads that were already damaged by Hurricane Irene.
August 22, 2014	Flash Flood	Lackawaxen	N/A	N/A	Flash flood waters rushed into Woodloch Pines Resort near Hawley. Several parts of the resort were flooded after heavy rains.
August 4, 2020	Flash Flood	Greentown, Lackawaxen	N/A	N/A	Rain and embedded thunderstorms moved through Northeast Pennsylvania on the 4th associated with Tropical Storm Isaias. Widespread rainfall of 3 to 5 inches occurred across the region. Locally heavy rainfall produced areas of flash flooding.

Sources: NOAA-NCEI 2021; FEMA 2021; Pike County HMP 2012; Pennsylvania State Climatologist 2016

DR Federal Disaster Declaration  
 EM Emergency Management  
 EMA Emergency Management Agency  
 FEMA Federal Emergency Management Agency  
 NCEI National Centers for Environmental Information

NOAA National Oceanic Atmospheric Administration  
 N/A Not applicable / not available  
 SBA Small Business Administration  
 US United States



Ice jams are a frequent occurrence on the Delaware River near Pike County and on the Lackawaxen River. Based on review of the CRREL database and recording of several events in news articles, Table 4.3.7-6 lists the ice-jam events that have occurred in or near the County between 1780 and 2021. Events listed below that occurred outside of the County were included because they were close enough to the County borders to cause possible flooding impacts on Pike County. Information regarding losses associated with these reported ice jams was limited.

Table 4.3.7-6. Ice Jam Events in Pike County between 1780 and 2021

City (Additional Geographic Identifier)	River	Jam Date	Water Year	Gage Number	Impact
Shohola	Shohola Creek	February 26, 1926	1926	1432500	Discharge 800 cfs affected by ice
Bushkill	Delaware River	February 5, 1970	1970	Unknown	An ice jam was reported on the Delaware River two miles north of Bushkill. The water level rose 10 feet above normal, but no flooding had occurred.
Matamoras	Delaware River	January 1, 1981	1981	Unknown	A midwinter ice jam was reported at Port Jervis followed by the spring break-up, causing flooding in Matamoras
Matamoras	Delaware River, Lackawaxen River	February 15, 1981	1981	Unknown	An ice jam and heavy rain event led to the evacuation of 4,000 people. In Matamoras, 44 businesses and 400 homes were damaged. A woman's body was found outside her home after she drowned from this event. This event also impacted Port Jervis in New York State. The flooding caused \$3.5 million in damages.
Dingman's Ferry to Milford	Delaware River	February 1988	1988	-	In February of 1988, a 10-mile ice jam was reported on the Delaware River stretching from Dingmans Ferry to just north of Milford. Backwater flooding occurred just north of the ice jam.
Milford	Delaware River	January 1999	1999	-	In January of 1999, an ice jam that formed in New York moved down the Delaware River and lodged south of Milford. It resulted in minor flooding.

Source: CRREL 2021; New York Times 1981; The Morning Call 1988; The Morning Call 1999

Notes:

Although events were reported for Pike County, information pertaining to every event was not easily ascertainable; therefore, this table may not list all ice jams in the County.

cfs Cubic feet per second

CRREL Cold Regions Research and Engineering Laboratory

USGS U.S. Geological Survey

### 4.3.7.5 Future Occurrence

Floods are described in terms of their extent (including the horizontal area affected and the vertical depth of floodwaters) and the related probability of occurrence. The NFIP uses historical records to determine the probability of occurrence for different extents of flooding. The probability of occurrence is expressed in percentages as the chance of a flood of a specific extent occurring in any given year.

The NFIP recognizes the 1-percent annual chance flood, also known as the *base flood*, as the standard for identifying properties subject to federal flood insurance purchase requirements. A one-percent annual chance flood is a flood which has a one percent chance of occurring over a given year. The DFIRMs identify areas subject to the 1- and 0.2-percent-annual-chance flooding. Areas subject to 2- and 10-percent annual chance events are not shown on maps; however, water surface elevations associated with these events are included in the flood source profiles contained in the Flood Insurance Study Report. Table 4.3.7-7 shows a range of flood recurrence intervals and associated probabilities of occurrence.



Table 4.3.7-7. Recurrence intervals and associated probabilities of occurrence

Flood Recurrence Interval	Chance Of Occurrence In Any Given Year (%)	Flows
5 year	20	Extreme
10 year	10	Heavy to extreme
25 year	4	Moderate
50 year	2	Light to moderate
100 year	1	Light
500 year	0.2	Mild

Source: Pike County HMP 2012

Based on the historic and more recent flood events in Pike County, it is clear that the County has a high probability of flooding for the future. The fact that the elements required for flooding exist and that major flooding has occurred throughout the County in the past, whether major or minor, suggests that many people and properties are at risk from the flood hazard in the future.

For the 2022 HMP update, the most up-to-date data was collected to calculate the probability of future occurrence of flooding events for Pike County. Information from NOAA-NCEI storm events database, FEMA, Pennsylvania State Climatologist and the CRREL ice jam database were used to identify the number of flood events that occurred between 1950 and 2021. Using these sources ensures the most accurate probability estimates possible. The table below shows these statistics, as well as the annual average number of events and the estimate percent chance of an incident occurring in a given year. Based on these statistics, there is an estimated 33.33-percent chance of flood event occurring in any given year in Pike County.

Table 4.3.7-8. Probability of Future Flooding Events

Hazard Type	Number of Occurrences Between 1950 and 2021	Percent chance of occurrence in any given year
Flash Flood	13	18.06%
Flood	5	6.94%
Ice Jam	6	8.33%
<b>Total</b>	<b>24</b>	<b>33.33%</b>

Sources: NOAA-NCEI 2021; CRREL 2021; Pennsylvania State Climatologist 2016; The Morning Call, 1988; The Morning Call, 1999

It is estimated that Pike County will continue to experience direct and indirect impacts of flooding events annually that may induce secondary hazards such as coastal erosion, storm surge in coastal areas, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents and inconveniences. Therefore, the future occurrence of floods in Pike County has been adjusted and characterized as *highly likely*, when taking into consideration flash flooding, as defined by the Risk Factor Methodology probability criteria (see Table 4.4-1).



### 4.3.7.6 Vulnerability Assessment

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To understand risk, a community must evaluate the assets exposed or vulnerable within the identified hazard area. For the flood hazard, the 1-percent (100-year) and 0.2-percent (500-year) annual chance flood events are examined. The following sections evaluate and estimate potential impact of flooding in Pike County, presenting:

- Impacts on: (1) life, health, and safety of residents; (2) general building stock; (3) critical facilities; (4) economy; and (5) environment
- Future changes that may impact vulnerability
- Change of vulnerability since the 2017 HMP

#### Impact on Life, Health, and Safety

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Impacts of flooding on life, health, and safety depend on several factors including severity of the event and whether or not adequate warning time is provided to residents. Assumedly, the population living in or near floodplain areas that could be impacted by a flood would be exposed. However, exposure should not be limited only to those who reside within a defined hazard zone, but everyone who may be affected by a hazard event (e.g., people are at risk while traveling in flooded areas, or their access to emergency services is compromised during an event); the degree of that impact varies and is not strictly measurable.

Cascading impacts may also include exposure to pathogens such as mold. After flood events, excess moisture and standing water contribute to growth of mold in buildings. Mold may present a health risk to building occupants, especially those with already compromised immune systems such as infants, children, the elderly, and pregnant women. The degree of impact will vary and is not strictly measurable. Molds can grow in as short a period as 24-48 hours in wet and damaged areas of buildings that have not been properly cleaned. Very small mold spores can easily be inhaled, creating potential for allergic reactions, asthma episodes, and other respiratory problems. Buildings should be properly cleaned and dried out to safely prevent mold growth (Centers for Disease Control and Prevention [CDC] 2015).

Molds and mildews are not the only public health risk associated with flooding. Floodwaters can be contaminated by pollutants such as sewage, human and animal feces, pesticides, fertilizers, oil, asbestos, and rusting building materials. Common public health risks associated with flood events also include:

- Unsafe food
- Contaminated drinking and washing water and poor sanitation
- Mosquitos and animals
- Carbon monoxide poisoning
- Secondary hazards associated with re-entering/cleaning flooded structures
- Mental stress and fatigue.

Current loss estimation models such as HAZUS-MH are not equipped to measure public health impacts. The best level of mitigation for these impacts is to be aware that they can occur, educate the public on prevention, and be prepared to deal with these vulnerabilities in responding to flood events.



To estimate the population exposed to the 1-percent annual chance flood event, the FEMA DFIRM floodplain boundaries were overlaid upon the Census Block 2010 boundaries and 2019 ACS data in Geographic Information Systems (GIS). Please note that the 2020 Census was not available during the planning process; therefore, 2010 Census and 2019 ACS statistics were used for this plan update. Census blocks are not consistent with boundaries of the floodplain, and gross overestimate or underestimate of exposed population can occur via use of the centroid or intersect of the Census block with these zones. Limitations of these analyses are recognized, and thus results are used only to provide a general estimate.

The 2010 Census blocks with their centroids located in the flood boundaries were used to calculate the estimated population exposed to this hazard. Table 4.3.7-9 lists the estimated population located within the 1-percent annual chance flood zone by municipality. Use of this approach resulted in an estimate of 1,749 people within the 1-percent annual chance floodplain (3.2 percent), and 3,894 people within the 0.2-percent annual chance floodplain (7.0 percent)

Table 4.3.7-9. Estimated Pike County Population Exposed to the 1- and 0.2-Percent Flood Hazard (2019 ACS)

Municipality	Total Population	1-Percent Annual Chance Event		0.2-Percent Annual Chance Event	
		Population in Hazard Area	Percent Population in Boundary	Population in Hazard Area	Percent Population in Boundary
Blooming Grove Township	4,645	69	1.5%	69	1.5%
Delaware Township	7,063	43	0.6%	43	0.6%
Dingman Township	11,619	302	2.6%	303	2.6%
Greene Township	3,825	182	4.8%	182	4.8%
Lackawaxen Township	5,020	95	1.9%	95	1.9%
Lehman Township	10,183	292	2.9%	292	2.9%
Matamoras Borough	2,336	62	2.6%	1,798	77.0%
Milford Borough	1,172	81	6.9%	84	7.2%
Milford Township	1,329	41	3.1%	43	3.2%
Palmyra Township	3,215	73	2.3%	73	2.3%
Porter Township	400	41	10.2%	41	10.2%
Shohola Township	2,133	45	2.1%	46	2.1%
Westfall Township	2,513	425	16.9%	826	32.9%
<b>Pike County (Total)</b>	<b>55,453</b>	<b>1,749</b>	<b>3.2%</b>	<b>3,894</b>	<b>7.0%</b>

Sources: U.S. Census 2010, ACS 2019; FEMA 2000

Note: At the time of the vulnerability assessment, the 2020 U.S. Census data was not available. Therefore, the 2010 U.S. Census and the 2019 American Community Survey (ACS) population estimates were used for this plan update.

% Percent

The table above shows Westfall Township has the largest portion of its population within the 1-percent annual chance event floodplain—16.9 percent of the population, while Matamoras Borough has the largest population within 0.2-percent annual chance events; 77.0 percent of its population is exposed. For this project, potential population exposed is used as a guide for planning purposes.

Of the population exposed, the most vulnerable include the economically disadvantaged and the population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on net economic impact on their families. The population over the age of 65



is also more vulnerable because they are more likely to seek or need medical attention that may not be available because of isolation during a flood event, and they may have more difficulty evacuating.

Using 2010 U.S. Census data, HAZUS-MH 3.1 estimates potential sheltering needs based on a 1-percent annual chance flood event. During the 1-percent flood event, HAZUS-MH 3.1 estimates 1,865 households will be displaced, and 854 people will seek short-term sheltering, representing 1.5 percent of the Pike County population seeking short-term shelter. These statistics, by municipality, are listed in Table 4.3.7-10. The estimated displaced population and number of persons seeking short-term sheltering differ from the number of persons exposed to the 1-percent annual chance flood (Table 4.3.7-10), because the displaced population numbers take into consideration that not all residents will be significantly impacted enough to be displaced or to require short-term sheltering during a flood event.

*Table 4.3.7-10. Estimated Population Displaced or Seeking Short-Term Shelter from the 1-Percent Annual Chance Flood Event*

Municipality	Total Population (2010 U.S. Census)	1-Percent Annual Chance Event	
		Displaced Households	Persons Seeking Short-Term Sheltering
Blooming Grove Township	4,819	52	2
Delaware Township	7,396	52	14
Dingman Township	11,926	216	31
Greene Township	3,956	118	18
Lackawaxen Township	4,994	141	16
Lehman Township	10,663	278	184
Matamoras Borough	2,469	224	130
Milford Borough	1,021	127	62
Milford Township	1,530	53	25
Palmyra Township	3,312	36	5
Porter Township	485	16	0
Shohola Township	2,475	81	8
Westfall Township	2,323	471	359
<b>Pike County (Total)</b>	<b>57,369</b>	<b>1,865</b>	<b>854</b>

Source: HAZUS-MH 3.1

Note: The population displaced and seeking shelter was calculated using 2010 U.S. Census data. At the time of the vulnerability assessment, the 2020 U.S. Census data was not available. Therefore, the 2010 U.S. Census was used for this plan update.

Total number of injuries and casualties resulting from typical riverine flooding is generally limited because of advance weather forecasting, blockades, and warnings. Therefore, injuries and deaths generally are not anticipated if proper warning occurs and precautions are in place. Warning time for flash flooding is often limited. Flash flood events are frequently associated with other natural hazard events such as earthquakes, landslides, or severe weather, which limits their predictability and compounds the hazard. Populations without adequate warning of the event are highly vulnerable to this hazard. Ongoing mitigation efforts should help to avoid the most likely cause of injury—persons trying to cross flooded roadways or channels. Mitigation action items addressing this issue are included in Section 6 (Mitigation Strategies) of this Plan.



### Impact on General Building Stock

After consideration of the population exposed and vulnerable to the flood hazard, the built environment was evaluated. Exposure to the flood hazard includes those buildings within the flood zone. Potential damage is the modeled loss that could occur to the exposed inventory, including structural and content value.

To estimate replacement cost value exposure and number of structures in the hazard area, default dasymetric building stock data from HAZUS-MH 3.1 were used. Replacement cost values of the dasymetric Census blocks with their centroids in the floodplain were totaled. Table 4.3.7-11 lists building stock exposure per municipality, and Table 4.3.7-12 lists number of exposed structures per watershed.

In total, 519 structures, or 1.4-percent of the building stock, are within the 1-percent annual chance flood zone; and 1,727 structures, or 4.5-percent of the building stock, are within the 0.2-percent flood zone. Approximately \$189 million of building/contents are within the 1-percent annual chance flood zone in Pike County. This represents approximately 1.4-percent of the County's total general building stock replacement value inventory (\$13 billion). Also, an estimated \$658 million of building/contents is within the 0.2-percent annual chance flood zone (5.0-percent of the County's total).

As discussed in the Methodology section, Pike County's current spatial data did not support a countywide HAZUS-MH general building stock update. Therefore, the HAZUS-MH flood model estimated potential damages to buildings in Pike County using the dasymetric dataset. Development of the dasymetric dataset involved removing homogeneous undeveloped areas (such as areas covered by bodies of water, parks, or forests) from the Census blocks. Cumulative building exposure is distributed only in developed sub-Census Block areas. As a result, more accurate flood loss determinations were produced using this dataset. Potential damage estimated to the Pike County general building stock inventory associated with the 1-percent annual chance flood exceeds \$2.9 billion. Building stock potential loss estimates per municipality are listed in Table 4.3.7-13.



Table 4.3.7-11. Estimated General Building Stock Exposure to the 1-Percent Annual Chance Flood Event

Municipality	Total # Housing Units	Total RCV (Structure and Contents)	Total (All Occupancies)							
			1-Percent Annual Chance Event				0.2-Percent Annual Chance Event			
			# Units	% Total	Total RCV (Structure and Contents)	% Total	# Units	% Total	Total RCV (Structure and Contents)	% Total
Blooming Grove Township	3,998	\$1,160,095,000	22	<1%	\$4,649,000	<1%	22	<1%	\$4,649,000	<1%
Delaware Township	4,253	\$1,496,677,000	11	<1%	\$4,622,000	<1%	11	<1%	\$4,622,000	<1%
Dingman Township	5,480	\$1,984,820,000	223	4.1%	\$78,611,000	4.0%	223	4.1%	\$78,611,000	4.0%
Greene Township	3,275	\$956,640,000	72	2.2%	\$18,329,000	1.9%	72	2.2%	\$18,329,000	1.9%
Lackawaxen Township	4,562	\$1,231,170,000	5	<1%	\$1,590,000	<1%	5	<1%	\$1,590,000	<1%
Lehman Township	5,995	\$1,992,003,000	5	<1%	\$1,538,000	<1%	5	<1%	\$1,538,000	<1%
Matamoras Borough	972	\$377,318,000	6	<1%	\$1,882,000	<1%	781	80.3%	\$304,862,000	80.8%
Milford Borough	718	\$413,430,000	14	1.9%	\$6,256,000	1.5%	14	1.9%	\$6,256,000	1.5%
Milford Township	784	\$670,787,000	7	<1%	\$3,150,000	<1%	7	<1%	\$3,150,000	<1%
Palmyra Township	3,981	\$1,244,483,000	4	<1%	\$1,272,000	<1%	4	<1%	\$1,272,000	<1%
Porter Township	912	\$388,599,000	93	10.2%	\$38,300,000	9.9%	93	10.2%	\$38,300,000	9.9%
Shohola Township	2,311	\$759,299,000	46	2.0%	\$13,378,000	1.8%	46	2.0%	\$13,378,000	1.8%
Westfall Township	1,175	\$383,781,000	11	<1%	\$15,013,000	3.9%	444	37.8%	\$181,394,000	47.3%
<b>Pike County (Total)</b>	<b>38,416</b>	<b>\$13,059,102,000</b>	<b>519</b>	<b>1.4%</b>	<b>\$188,590,000</b>	<b>1.4%</b>	<b>1,727</b>	<b>4.5%</b>	<b>\$657,951,000</b>	<b>5.0%</b>

Source: HAZUS-MH 3.1; FEMA 2000

Notes:

% Percent

RCV Replacement cost value (structure and contents)



Table 4.3.7-12. Estimated General Building Stock Exposure by Watershed to the 1- and 0.2-Percent Annual Chance Flood Events

Watershed	Total Number of Housing Units	1% Annual Chance Flood Boundary		0.2% Annual Chance Flood Boundary	
		Number of Units	% of Total	Number of Units	% of Total
Brodhead Creek	192	0	0.0%	0	0.0%
Bushkill Creek	6,788	98	1.4%	98	1.4%
Delaware River	15,273	193	1.3%	1,401	9.2%
Lackawaxen River	2,781	27	1.0%	27	1.0%
Sawkill Creek	2,139	30	1.4%	30	1.4%
Shohola Creek	4,484	95	2.1%	95	2.1%
Wallenpaupack Creek	6,759	76	1.1%	76	1.1%
<b>Pike County (Total)</b>	<b>38,416</b>	<b>519</b>	<b>1.4%</b>	<b>1,727</b>	<b>4.5%</b>

Source: FEMA 2000, Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR) 2014; HAZUS-MH 3.1



Table 4.3.7-13. Estimated General Building Stock Potential Loss to the 1-Percent Annual Chance Flood Event

Municipality	Total Replacement Cost Value	1% Annual Chance Event							
		All Occupancies		Residential		Commercial		Industrial, Religious, Education and Government	
		Estimated Loss	% of Total	Estimated Loss	% of Total	Estimated Loss	% of Total	Estimated Loss	% of Total
Blooming Grove Township	\$1,160,095,000	\$114,611	<1%	\$105,249	<1%	\$5,528	<1%	\$3,834	<1%
Delaware Township	\$1,496,677,000	\$135,830	<1%	\$131,741	<1%	\$2,848	<1%	\$1,241	<1%
Dingman Township	\$1,984,820,000	\$538,317	<1%	\$510,619	<1%	\$22,209	<1%	\$5,489	<1%
Greene Township	\$956,640,000	\$388,458	<1%	\$374,412	<1%	\$8,882	<1%	\$5,164	<1%
Lackawaxen Township	\$1,231,170,000	\$340,619	<1%	\$330,303	<1%	\$6,884	<1%	\$3,432	<1%
Lehman Township	\$1,992,003,000	\$462,309	<1%	\$444,218	<1%	\$14,144	<1%	\$3,947	<1%
Matamoras Borough	\$377,318,000	\$73,740	<1%	\$56,103	<1%	\$15,989	<1%	\$1,648	<1%
Milford Borough	\$413,430,000	\$95,052	<1%	\$51,230	<1%	\$32,096	<1%	\$11,726	<1%
Milford Township	\$670,787,000	\$75,168	<1%	\$67,705	<1%	\$4,222	<1%	\$3,241	<1%
Palmyra Township	\$1,244,483,000	\$286,405	<1%	\$285,121	<1%	\$480	<1%	\$804	<1%
Porter Township	\$388,599,000	\$179,652	<1%	\$176,133	<1%	\$2,173	<1%	\$1,346	<1%
Shohola Township	\$759,299,000	\$262,190	<1%	\$198,864	<1%	\$29,110	<1%	\$34,216	<1%
Westfall Township	\$383,781,000	\$305,954	<1%	\$223,545	<1%	\$70,659	<1%	\$11,750	<1%
<b>Pike County (Total)</b>	<b>\$13,059,102,000</b>	<b>\$3,258,305</b>	<b>&lt;1%</b>	<b>\$2,955,243</b>	<b>&lt;1%</b>	<b>\$215,224</b>	<b>&lt;1%</b>	<b>\$87,838</b>	<b>&lt;1%</b>

Source: HAZUS-MH 3.1

Note: % Percent



To further enhance the risk assessment, FEMA Region III provided the total exposure in the floodplain (TEIF) for Pike County. This data utilizes best available data including the 2010 U.S. Census geography and 2012 RS Means valuations. This data is used in lieu of the average annualized loss study. This data indicates the total exposure in the floodplain for Pike County is \$397,925,522. Table 4.3.7-14 below lists the TEIF for each municipality.

Table 4.3.7-14. 2010 TEIF Results by Municipality for Pike County

Municipality	TEIF 2010
Blooming Grove Township	\$23,968,400
Delaware Township	\$26,087,021
Dingman Township	\$58,050,910
Greene Township	\$32,241,499
Lackawaxen Township	\$20,740,483
Lehman Township	\$87,273,241
Matamoras Borough	\$6,317,334
Milford Borough	\$12,391,436
Milford Township	\$9,699,122
Palmyra Township	\$29,460,299
Porter Township	\$27,608,216
Shohola Township	\$13,933,447
Westfall Township	\$50,154,115
<b>Pike County (Total)</b>	<b>\$397,925,522</b>

Source: FEMA Region III

### NFIP Statistics

In addition to total building stock modeling, individual data available regarding flood policies, claims, repetitive loss (RL) properties, and severe repetitive loss (SRL) properties were analyzed.

There are two definitions of repetitive loss:

- The NFIP defines repetitive loss as two or more claims of at least \$1,000 over a 10 year rolling period. Pike County has 30 RL and 2 SRL properties spread across 6 municipalities based on this definition.
- The Hazard Mitigation Assistance program defines Repetitive Loss as having incurred flood-related damage on 2 occasions, in which the cost of the repair, on the average, equaled or exceeded 25 percent of the market value of the structure at the time of each such flood event; and, at the time of the second incidence of flood-related damage, the contract for flood insurance contains increased cost of compliance coverage.

According to section 1361A of the National Flood Insurance Act (NFIA), as amended, 42 *United States Code* (U.S.C.) 4102a, the definition of an SRL property is a residential property covered by an NFIP flood insurance policy, and for which at least one of the following sets of claim payments have occurred:

- At least four NFIP claim payments (including building and contents) over \$5,000 each, with the cumulative amount of these claims payments exceeding \$20,000.
- At least two separate claims payments (building payments only), with the cumulative amount of the building



portion of these claims payments exceeding the market value of the building.

Moreover, for both of the above, at least two of the referenced claims must have occurred within any 10-year period, and must have been submitted separately on dates more than 10 days apart.

Table 4.3.7-15 categorizes numbers of RL properties (using the NFIP definition) by municipality and by occupancy class (non-residential or residential)

*Table 4.3.7-15. Summary of Repetitive Loss Properties by Municipality*

Municipality	Repetitive Loss Properties				
	2-4 Family	Assumed Condo	Non Residential	Other Residential	Single Family
Blooming Grove Township	0	0	0	0	0
Delaware Township	0	0	0	0	0
Dingman Township	0	0	0	0	1
Greene Township	0	0	0	0	0
Lackawaxen Township	0	0	0	0	2
Lehman Township	0	0	0	0	2
Matamoras Borough	0	0	0	0	5
Milford Borough	0	0	0	0	0
Milford Township	0	0	0	0	0
Palmyra Township	0	0	0	0	0
Porter Township	0	0	1	0	1
Shohola Township	0	0	0	0	0
Westfall Township	0	0	2	0	17
<b>Pike County (Total)</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>0</b>	<b>28</b>

Source: FEMA 2021

Note: There is a discrepancy between the FEMA provided RL data broken down by municipality and the summary data. Summary data results in a RL count of 30 for Pike County. The above dataset results in an RL count of 31 for Pike County.

Table 4.3.7-16 summarizes NFIP policies and claims for Pike County as of July 31, 2021.

*Table 4.3.7-16. NFIP Policies, Claims, and Repetitive Loss Statistics*

Municipality	# Policies	# Claims (Losses)	# Repetitive Loss Properties	Total Loss Payments
Blooming Grove Township	7	2	0	\$40,387
Delaware Township	6	4	0	\$10,611
Dingman Township	19	12	1 RL	\$71,415
Greene Township	16	0	0	\$0
Lackawaxen Township	30	20	2 RL	\$558,100
Lehman Township	19	12	2 RL	\$47,562
Matamoras Borough	48	51	4 RL	\$13,717,300
Milford Borough	5	5	0	\$-*
Milford Township	9	6	0	\$43,149
Palmyra Township	7	1	0	\$3,785



Municipality	# Policies	# Claims (Losses)	# Repetitive Loss Properties	Total Loss Payments
Porter Township	1	7	2 RL	\$22,280
Shohola Township	9	4	0	\$5,777
Westfall Township	101	76	18 RL / 1 SRL	\$1,389,714
<b>Pike County (Total)</b>	<b>277</b>	<b>200</b>	<b>29 RL / 1 SRL</b>	<b>\$15,910,080</b>

Source: FEMA 2021a; FEMA 2021b

Notes: \*data unavailable from FEMA

(1) Policies, claims, RL, and SRL statistics provided by FEMA, and are current as of July 31, 2021. Communities with SRL properties are noted in the column. The number of claims represents claims closed by July 31, 2021.

(2) Total building and content loss information was collected from the claims file provided by FEMA

FEMA Federal Emergency Management Agency

RL Repetitive loss

SRL Severe repetitive loss

### Impact on Critical Facilities and Community Lifelines

In addition to consideration of general building stock at risk, risk of flood to critical facilities and utilities was evaluated. HAZUS-MH was used to estimate potential for flood loss to critical facilities exposed to the flood risk. Using depth/damage function curves, HAZUS estimates percent of damage to building and contents of critical facilities. HAZUS-MH estimates that few emergency and utility facilities within the County would be nonfunctional for more than 1 day, and most would undergo relatively minimal damages.

To address impacts on short-term functionality of critical facilities and utilities by a hazard during a disaster event, other facilities of neighboring municipalities may have to increase support response functions. Mitigation planning should consider means to reduce impacts on critical facilities and utilities and ensure that sufficient emergency and school services remain functional when a significant event occurs. Actions addressing shared services agreements are included in Section 6 (Mitigation Strategy) of this Plan.

Table 4.3.7-17 lists critical facilities and utilities within the 1-percent annual change flood boundary. Table 4.3.7-18 lists critical facilities and utilities within the 0.2 percent annual change flood boundary.

*Table 4.3.7-17. Critical Facilities and Utilities Within the 1-Percent Annual Chance Flood Boundary*

Municipality	Facility Types		
	Fire Station	Nursing Home	Shelter
Blooming Grove Township	0	0	0
Delaware Township	0	0	0
Dingman Township	0	0	1
Greene Township	0	0	0
Lackawaxen Township	0	0	0
Lehman Township	0	0	1
Matamoras Borough	0	0	0
Milford Borough	0	0	0
Milford Township	0	0	0
Palmyra Township	0	0	0
Porter Township	0	0	0
Shohola Township	0	0	0



Municipality	Facility Types		
	Fire Station	Nursing Home	Shelter
Westfall Township	1	1	1
<b>Pike County (Total)</b>	1	1	3

Source: Pike County 2021, FEMA 2000

Table 4.3.7-18. Critical Facilities and Utilities Within the 0.2-Percent Annual Chance Flood Boundary

Municipality	Number of Critical Facilities Located in the 0.2-Percent Annual Chance Flood Event								
	Central Water Facility	Day Care	Fire	Municipal Building	Nursing Home	Police	School	Shelter	Wastewater
Blooming Grove Township	0	0	0	0	0	0	0	0	0
Delaware Township	0	0	0	0	0	0	0	0	0
Dingman Township	0	0	0	0	0	0	0	1	0
Greene Township	0	0	0	0	0	0	0	0	0
Lackawaxen Township	0	0	0	0	0	0	0	0	0
Lehman Township	0	0	0	0	0	0	0	1	0
Matamoras Borough	1	1	0	1	0	1	1	0	0
Milford Borough	0	0	0	0	0	0	0	0	0
Milford Township	0	0	0	0	0	0	0	0	0
Palmyra Township	0	0	0	0	0	0	0	0	0
Porter Township	0	0	0	0	0	0	0	0	0
Shohola Township	0	0	0	0	0	0	0	0	0
Westfall Township	0	0	1	1	3	0	0	1	1
<b>Pike County (Total)</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>1</b>

Source: Pike County 2021, FEMA 2000

### Impact on the Economy

For impact on the economy, estimated losses from a flood event are considered. Losses include but are not limited to general building stock damages, agricultural losses, business interruption, and impacts on tourism and tax base within Pike County. Damages to general building stock can be quantified by use of HAZUS-MH as discussed above. Other economic components such as loss of facility use, functional downtime, and social economic factors are less susceptible to measurement with a high degree of certainty. For the purposes of this analysis, general building stock damages are discussed further.

Flooding can cause extensive damage to public utilities and disruptions in delivery of services. Loss of power and communications may occur, and drinking water and wastewater treatment facilities may be temporarily out of operation. Flooded streets and road blocks make it difficult for emergency vehicles to respond to calls for service. Floodwaters can wash out sections of roadway and bridges.

Direct building losses are estimated costs to repair or replace damage caused to buildings. Estimated potential damage to general building stock inventory associated with the 1-percent flood is approximately \$190 million, which represents 1.4 percent of the County’s overall total general building stock inventory. These dollar value losses from



the County’s total building inventory replacement value, in addition to damages to roadways and infrastructure, would impact the local economy.

HAZUS-MH estimates the amount of debris generated from a 1-percent annual chance flood event. The model breaks down debris into three categories because of the different types of equipment needed to handle debris: (1) finishes (dry wall, insulation, etc.), (2) structural (wood, brick, etc.), and (3) foundations (concrete slab and block, rebar, etc.). Table 4.3.7-19 summarizes the debris HAZUS-MH 3.1 estimates to result from a 1-percent annual chance flood event—32,000+ tons of debris. Notably, this table lists estimated debris generated only by riverine flooding and does not include additional potential damage and debris possibly generated by force of wind.

*Table 4.3.7-19. Estimated Debris Generated from the 1-Percent Annual Chance Flood Event*

Municipality	1% Flood Event			
	Total (tons)	Finish (tons)	Structure (tons)	Foundation (tons)
Blooming Grove Township	520	103	229	188
Delaware Township	23	12	6	5
Dingman Township	518	85	258	174
Greene Township	1,309	308	529	472
Lackawaxen Township	1,839	358	818	664
Lehman Township	536	288	138	111
Matamoras Borough	6,407	1,068	2,945	2,393
Milford Borough	5,241	959	2,546	1,736
Milford Township	392	74	172	146
Palmyra Township	86	18	38	30
Porter Township	99	95	1	3
Shohola Township	2,160	386	962	812
Westfall Township	13,046	2,221	6,412	4,413
<b>Pike County (Total)</b>	<b>32,175</b>	<b>5,975</b>	<b>15,053</b>	<b>11,147</b>

Source: HAZUS-MH 3.1

### Impact on the Environment

As discussed, floodplains serve beneficial and natural functions on ecological/environmental, social, and economic levels. Areas in the floodplain that typically provide these natural functions and benefits are wetlands, riparian areas, sensitive areas, and habitats for rare and endangered species. Floods, however, can also lead to negative impacts on the environment. Loss of riparian buffers, land use change within a watershed, and introduction of non-natural contaminants may be environmental issues when floods occur (Montz and Tobin 1997, Rubin 2013).

To determine exposure of natural and beneficial land in Pike County to the flood hazard, acreages of wetlands and forested land were calculated. Table 4.3.7-20 lists results of these calculations.

*Table 4.3.7-20. Acreage of Natural and Beneficial Land Within the Floodplain*

	Area in the 1-Percent Annual Chance Floodplain (acres)	Area in the 0.2-Percent Annual Chance Floodplain (acres)
Wetlands	15,649	15,664
Forest	10,020	10,274



Sources: USGS National Land Cover Data (NLCD) 2014, FEMA 2000

The basic environmental impact of major flooding is morphological, and shape of a river valley is often determined more by a catastrophic event than a long, gradual, methodical process. This is a primary factor in formation of natural habitat for flora and fauna and may influence habitats beyond the river corridor (Hickey and Salas 1995).

Flooding can cause a wide range of environmental impacts including but not limited to erosion and loss of vegetation and habitats. These in turn may lead to decreased protection of the waterbody from adjacent land uses, and to degraded water quality. Moreover, floods may generate large amounts of tree and construction debris, disperse household hazardous waste into the fluvial system, and contaminate water supplies and wildlife habitats with extremely toxic substances. Floods of greater depth are likely to result in greater environmental damage than floods of lesser depth. Long-duration floods could exacerbate environmental problems because cleanup likely would be delayed and contaminants could remain in the environment for a longer period of time. Cleanup after a flood raises additional environmental concerns. The volume of debris to be collected, the extent to which public utilities (water supply systems and sewer operations) have been damaged, and the quantity of agricultural and industrial pollutants entering water bodies might present additional issues (Montz and Tobin 1997, Rubin 2013).

#### Future Changes That May Impact Vulnerability

Understanding future changes that impact vulnerability in the County can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The County considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development.
- Projected changes in population.
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

#### Projected Development and Changes in Population

As discussed in Section 2, areas targeted for future growth and development have been identified across the County. Any areas of growth could be impacted by the flood hazard if within identified hazard areas. The County intends to discourage development within vulnerable areas and encourage higher regulatory standards on the local level. To do so, county and local ordinances will be reviewed to determine if higher standards are needed.

#### Effect of Climate Change on Vulnerability

Climate is defined not simply as average temperature and precipitation but also by type, frequency, and intensity of weather events. Both globally and at the local scale, climate change can alter prevalence and severity of extremes such as flood events. While predicting changes of flood events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society, and the environment (U.S. Environmental Protection Agency [EPA] 2006).

PADEP was directed by the Climate Change Act (Act 70 of 2008) to initiate a study of potential impacts of global climate change on the Commonwealth. The June 2009 Pennsylvania Climate Impact Assessment's main findings indicate that Pennsylvania is very likely to undergo increased temperatures in the 21st century. An increase in variability of temperature and precipitation may lead to increased frequency and/or severity of storm events. Summer floods and general stream flow variability are projected to increase due to increased variability in precipitation. Even



with the anticipated increase in winter precipitation as rain rather than snow, increased winter temperatures and a reduced snowpack may decrease rain-on-snow events and thus major flooding events in Pennsylvania. This conclusion, however, remains speculative until further studies can validate it. Future improvements in modeling smaller-scale climatic processes are expected and will lead to improved understanding of how the changing climate will alter temperature, precipitation, storms, and flood events in Pennsylvania (Shortle et al. 2009).