4.3.12 Winter Storm

This section provides a profile and vulnerability assessment for the winter storm hazard. Winter storms occur, on average, approximately five times each year in Pennsylvania. From November through March, the State is exposed to winter storms that move up the Atlantic coast or those that sweep in from the west. Every county in the Commonwealth is subject to severe winter storms; however, the northern tier, western counties and mountainous regions tend to experience winter weather more frequently and with greater severity (LVPC, 2006).

Winter storms have the potential to produce more damage than any other severe weather event, including tornadoes. Winter storms have the potential to cause road closures, especially secondary and farm roads; business losses to commercial centers built in outlying areas due to supply interruption and loss of customers; property losses and roof damages from snow and ice loading and falling trees; utility interruptions; and loss of water supplies (LVPC, 2006). Flooding can result from winter storm events as well.

Most severe winter storm hazards include heavy snow (snowstorms), blizzards, sleet, freezing rain, Nor'Easters, and ice storms. Since most extra-tropical cyclones (mid-Atlantic cyclones locally known as Northeasters or Nor'Easters), generally take place during the winter weather months (with some events being an exception), these hazards have also been grouped as a type of severe winter weather storm. These types of winter events or conditions are further defined below.

- Heavy Snow: According to the National Weather Service (NWS), heavy snow is generally snowfall accumulating to 4 inches or more in depth in 12 hours or less; or snowfall accumulating to six inches or more in depth in 24 hours or less. A snow squall is an intense, but limited duration, period of moderate to heavy snowfall, also known as a snowstorm, accompanied by strong, gusty surface winds and possibly lightning (generally moderate to heavy snow showers) (NWS, 2005). Snowstorms are complex phenomena involving heavy snow and winds, whose impact can be affected by a great many factors, including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and occurrence during the course of the day, weekday versus weekend, and time of season (Kocin and Uccellini, 2011).

- Blizzard: Blizzards are characterized by low temperatures, wind gusts of 35 miles per hour (mph) or more and falling and/or blowing snow that reduces visibility to ¼-mile or less for an extended period of time (three or more hours) (NWS, 2005). A severe blizzard is defined as having a wind velocity of 45 mph, temperatures of 10°F or lower, a high density of blowing snow with visibility frequently measured in feet over an extended period of time

- Sleet or Freezing Rain Storm: Sleet is defined as pellets of ice composed of frozen or mostly frozen raindrops or refrozen partially melted snowflakes. These pellets of ice usually bounce after hitting the ground or other hard surfaces. Freezing rain is rain that falls as a liquid but freezes into glaze upon contact with the ground. Both types of precipitation, even in small accumulations, can cause significant hazards to a community (NWS, 2005).

- Ice storm: An ice storm is used to describe occasions when damaging accumulations of ice are expected during freezing rain situations. Significant accumulations of ice pull down trees and utility lines resulting in loss of power and communication. These accumulations of ice make walking and driving extremely dangerous, and can create extreme hazards to motorists and pedestrians (NWS, 2005).

- Nor'Easter (abbreviation for North Easter): Nor'Easters are named for the strong northeasterly winds that blow in from the ocean ahead of the storm and over coastal areas. They are also referred to as a type of extra-tropical cyclone (mid-latitude storms, or Great Lake storms). A Nor'Easter is a macro-scale extra-tropical storm whose winds come from the northeast, especially in the coastal areas of the northeastern U.S. and Atlantic Canada. Wind gusts associated with Nor'Easters can exceed hurricane forces in intensity. Unlike tropical cyclones that form in the tropics and have warm cores (including tropical depressions, tropical storms and hurricanes), Nor'Easters contain a cold core of low barometric pressure that forms in the mid-latitudes. Their strongest winds are close to the earth's surface and often measure several hundred miles across. Nor'Easters may occur at any time of the year but are more common during fall and winter months (September through April) (NYCOEM, 2008).

  Nor'Easters can cause heavy snow, rain, gale force winds and oversized waves (storm surge) that can cause beach erosion, coastal flooding, structural damage, power outages and unsafe human conditions. If a Nor'Easter cyclone stays just offshore, the results are much more devastating than if the cyclone travels up the coast on an inland track. Nor'Easters that stay inland are generally weaker and usually cause strong winds and rain. Those that stay offshore can bring heavy snow, blizzards, ice, strong winds, high waves, and severe beach erosion. In these storms, the warmer air is aloft. Precipitation falling from this warm air moves into the colder air at the surface, causing crippling sleet or freezing rain (McNoldy [Multi-Community Environmental Storm Observatory (MESO)], 1998-2007). While some of the most devastating effects of Nor'Easters are experienced in coastal areas (e.g. beach erosion, coastal flooding), the effects on inland areas, like the Lehigh Valley Planning Area, may include heavy snow, strong winds and blizzards.

4.3.12.1 Location and Extent

Winter storms are regional events, with most events impacting a large area or the entire Commonwealth. In many cases, surrounding states and even the northeast U.S. region are affected by a single winter storm event.

The magnitude, severity, or extent of a winter storm can be classified by meteorological measurements, such as snowfall amounts and rates, wind speeds, temperatures, visibility, storm duration, topography, time of occurrence during the day, and time of season, and by evaluating its societal impacts. The Northeast Snowfall Impact Scale (NESIS) categorizes snowstorms, including Nor'Easter events, in this manner. Unlike the Fujita Scale (tornado) and Saffir-Simpson Scale (hurricanes), there is no widely used scale to classify snowstorms. NESIS was developed by Paul Kocin of The Weather Channel and Louis Uccellini of the NWS to characterize and rank high-impact, northeast snowstorms. These storms have large areas of ten inch snowfall accumulations and greater. NESIS has five ranking categories: Notable (1), Significant (2), Major (3), Crippling (4), and Extreme (5) (Table 4.3.12-1). The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Thus, NESIS gives an indication of a storm's societal impacts. This scale was developed because of the impact northeast snowstorms can have on the rest of the country in terms of transportation and economic impact (Kocin and Uccellini, 2011).

Table 4.3.12-1. NESIS Ranking Categories 1 – 5

Category	Description	NESIS Range	Definition
1	Notable	1.0 – 2.49	These storms are notable for their large areas of 4-inch accumulations and small areas of 10-inch snowfall.
2	Significant	2.5 – 3.99	Includes storms that produce significant areas of greater than 10-inch snows while some include small areas of 20-inch snowfalls. A few cases may even include relatively small areas of very heavy snowfall accumulations (greater than 30 inches).
3	Major	4.0 – 5.99	This category encompasses the typical major Northeast snowstorm, with large areas of 10-inch snows (generally between 50 and 150 × 103 mi^2—roughly one to three times the size of New York State with significant areas of 20-inch accumulations.
4	Crippling	6.0 – 9.99	These storms consist of some of the most widespread, heavy snows of the sample and can be best described as crippling to the northeast U.S, with the impact to transportation and the economy felt throughout the United States. These storms encompass huge areas of 10-inch snowfalls, and each case is marked by large areas of 20-inch and greater snowfall accumulations.
5	Extreme	10 +	The storms represent those with the most extreme snowfall distributions, blanketing large areas and populations with snowfalls greater than 10, 20, and 30 inches. These are the only storms in which the 10-inch accumulations exceed 200 × 103 mi^2 and affect more than 60 million people.

Source: Kocin and Uccellini, 2004

As shown above, NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. These numbers are calculated into a raw data number ranking from "1" for an insignificant fall to over "10" for a massive snowstorm. Based on these raw numbers, the storm is placed into its decided category. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers (Enloe, 2007).

4.3.12.2 Range in Magnitude

A winter storm can adversely affect roadways, utilities, businesses, and can cause loss of life, frostbite, and freezing conditions. These storms typically fall into one of the following categories which have been previously defined:

- Heavy snowstorm
- Sleet storm
- Ice storm
- Blizzard
- Severe blizzard

4.3.12.3 Past Occurrence

Many sources provided historical information regarding previous occurrences and losses associated with winter storm events throughout the Commonwealth of Pennsylvania and the Lehigh Valley. With so many sources reviewed for the purpose of this Plan, loss and impact information for many events could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this Plan.

According to the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) storm events database, the Lehigh Valley experienced 219 winter storm events between 1950 and 2012. Total property damages resulting from these winter storm events were estimated at $43.1 million. This total also includes damages to other counties.

According to the Hazard Research Lab at the University of South Carolina's Spatial Hazard Events and Losses Database for the U.S. (SHELDUS), between 1960 and 2010, 270 winter storm events occurred within the Lehigh Valley. Losses totaled over $14.3 million in property damage and over $5 million in crop damage. However, these numbers may vary due to the database identifying the location of the hazard event in various forms or throughout multiple counties or regions.

Between 1954 and 2012, FEMA declared that the State of Pennsylvania experienced six winter storm-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types: severe winter storms, snowstorms, blizzard, winter storm, severe storm, and snowfall. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations. Of those events, PEMA and other sources indicate that the Lehigh Valley has been declared as a disaster area as a result of four winter storm events (FEMA, 2012; PEMA, 2012).

Based on all sources researched, known winter storm events that have affected the Lehigh Valley are identified in Table 4.3.12-1. With winter storm documentation for the State of Pennsylvania being so extensive, not all sources have been identified or researched. Therefore, Table 4.3.12-1 may not include all events that have occurred throughout the Lehigh Valley.

Table 4.3.12-2. Winter Storm Events between 1950 and 2012 in the Lehigh Valley

Dates of Event	Event Type	FEMA Declaration Number	Counties Designated?	Losses / Impacts	Source(s)
March 13-17, 1993	Severe Snowfall and Winter Storm	EM-3105	Yes	N/A	FEMA
January 4 – February 25, 1994	Winter Storm / Severe Storm	DR-1015	Yes	N/A	FEMA
January 7-8, 1996	Blizzard ("Blizzard of 1996")	DR-1085	Yes	Record breaking snow fell on most of southeastern Pennsylvania. The storm caused a total of 42 deaths and many injuries. One woman died in the City of Allentown. All-time single storm records were set at the Lehigh Valley International Airport (25.6 inches). Snowfall accumulations averaged around two feet in the Lehigh Valley. A state of emergency was declared on January 7th and was lifted on the 9th. The snow caused numerous building collapses, with one of the worst at the Penn Crest Gardens Apartments in South Whitehall Township. Residents had to be evacuated from one building after the roof buckled.	FEMA, LVPC
January 12, 1996				Heavy snow moved into southeastern Pennsylvania with accumulations of four to six inches. Two people in Northampton County died. In Whitehall Township, 60 hockey players were trapped as the roof of the Lehigh Valley ice arena collapsed. Another roof collapsed in the Borough of Coopersburg, causing $150,000 in damages.	
February 16-17, 2003	Snowstorm ("Presidents Day Storm")	EM-3180	Yes	This was the most powerful storm to affect eastern Pennsylvania since the Blizzard of 1996. A state of emergency was declared on February 17th. Snow accumulations ranged from 25.5 inches in Williams Township, 22 inches in the Cities of Easton and Allentown and 20 inches at the Lehigh Valley International Airport.	FEMA, LVPC
February 13-14, 2007	Nor'Easter / Winter Storm	N/A	N/A	Governor Ed Rendell declared a disaster emergency across the entire state on the 15th. PPL Electric Utilities Corporation reported 1,542 customers were without power for a time during the storm in the Lancaster, Harrisburg and Allentown areas. In Lehigh County, Allentown declared a snow emergency early on the 14th. The weight of snow and ice brought down the dome over the swimming pool at the West End Racquet and Fitness Club in South Whitehall Township. The Brookside Country Club in Wescosville also reported dome damage as a result of the snow and ice.	NOAA-NCDC, PEMA

Dates of Event	Event Type	FEMA Declaration Number	Counties Designated?	Losses / Impacts	Source(s)
				In Northampton County, an 83-year-old woman was found dead on the rear porch of her home from hypothermia. In the City of Bethlehem, a pedestrian was hospitalized after a private snowplow operator backed over him. County Emergency Dispatch officials reported about a dozen or so minor vehicle accidents due to the slippery conditions. The weight of snow and ice collapsed the dome covering a soccer field at the Iron Lakes Sports Club in North Catasauqua Borough. Some snow/sleet accumulations included 10.0 inches in Lehigh Township, 8.0 inches in Alburtis Township, 8.0 inches in New Tripoli (Lehigh County), and 7.6 inches at the Lehigh Valley International Airport near Allentown.	
March 16-17, 2007	Nor'Easter	N/A	N/A	A Nor'easter caused heavy snow and sleet to fall across the Lehigh Valley on the 16th into the early morning of the 17th. Accumulations averaged five to nine inches in the Lehigh Valley. In Lehigh County, a tractor-trailer jack-knifed near Pennsylvania State Route 100 at Fogelsville and closed the interstate. Both southbound lanes of the Pennsylvania Turnpike Northeast Extension were closed after two tractor-trailers and a car collided in Lower Milford Township. Many flights at the Lehigh Valley International Airport were delayed, and a few were cancelled. Commuter buses bringing workers home from New York City had long delays. A driver was injured on U.S. Route 22 in Whitehall Township when ice chunks from a tractor-trailer hit their vehicle. In Upper Macungie Township, ice chunks that flew off a Wal-Mart tractor-trailer cracked the windshield and dented the hood of a vehicle on Interstate 78 near the Pennsylvania State Route 100 exit. In Northampton County, a tractor-trailer jack-knifed on the eastbound lanes of Interstate 78 near the Pennsylvania State Route 33 junction. In Moore Township, a school bus collided head-on with a car, injuring both drivers. In Lower Mount Bethel Township, a Jeep Cherokee slid into a home on Pennsylvania State Route 611 and injured the driver. A Ford Explorer driver was injured after the vehicle struck a tree in Wind Gap Borough. Problems on the Lehigh Valley roadways continued long after the snow and sleet ended.	NOAA-NCDC

Dates of Event	Event Type	FEMA Declaration Number	Counties Designated?	Losses / Impacts	Source(s)
				Snow and sleet totals included 10 inches in Slatington Borough, 8.5 inches at the Lehigh Valley International Airport, 5.3 inches in Marshalls Creek (Northampton County), and 5.0 inches in the City of Bethlehem.	
December 13, 2007	Wintery Mix	N/A	N/A	This storm produced one to five inches of snow and sleet across eastern Pennsylvania. The combination of snow and ice caused slippery roadways, causing early school and business dismissals in the Lehigh Valley. Snow, sleet and ice accumulations in the Lehigh Valley included 1.2 inches at Trexlertown (Lehigh County); 1.0 inch at the Lehigh Valley International Airport, Tatamy Borough and New Tripoli (Lehigh County), and 0.8 of an inch in Weisenberg Township and Easton. Freezing rain amounts totaled 0.2 inches in the City of Easton.	NOAA-NCDC
February 12-13, 2008	Winter Storm	N/A	N/A	A winter storm brought snow, sleet and freezing rain to eastern Pennsylvania. More freezing rain and sleet fell in the Lehigh Valley than snow. Numerous accidents occurred in the area due to slippery roadways. The winter weather led to power outages due to fallen tree limbs and downed wires. About 50,000 homes and businesses were without power. In the Lehigh Valley, snow and sleet accumulations ranged from two to five inches. Ice accretions averaged between one-quarter and one-half inch with the highest amounts in the Lehigh Valley. Several people were injured due to an accident along Route 309 in Heidelberg Township. In Whitehall Township a large, ice-covered tree fell on Fifth Street, damaging a vehicle. The Lehigh Valley and the Poconos had approximately 7,500 PPL customers without power, with 5,000 in the Allentown area and 1,000 in the City of Bethlehem area. Met-Ed reported 2,068 customers without power in Northampton County. The Lehigh Valley had approximately $25,000 in property damage. Snow and sleet accumulations in the Lehigh Valley included 4.5 inches in Walnutport Borough and 2.3 inches at the Lehigh Valley International Airport.	NOAA-NCDC
December 19-20, 2009	Nor'Easter	N/A	N/A	A major winter storm affected central and southeast Pennsylvania. Snowfall totals averaged around six inches in the Lehigh Valley. Many municipalities declared state of	NOAA-NCDC

Dates of Event	Event Type	FEMA Declaration Number	Counties Designated?	Losses / Impacts	Source(s)
				emergencies.	
February 1-2, 2011	Snow / Ice	N/A	N/A	A winter storm brought several inches of sleet and snow to the area, with up to one-half inch of ice in the Lehigh Valley. The ice brought down tree limbs, trees and wires. Nearly 300,000 people were without power. In the Lehigh Valley, numerous car crashes were reported along Route 22, Route 33 and I-78 in Northampton County. In the City of Bethlehem, a 100-foot section of a porch roof collapsed due to the weight of snow and ice. Snow and sleet accumulations in the Lehigh Valley included 2.1 inches at the Lehigh Valley International Airport and 1.0 inch in Easton and Martins Creek (Northampton County). Ice accretions included 0.50 inches in Emmaus Borough, 0.38 inches in Allentown, and 0.25 inches in Bangor Borough. The Lehigh Valley had approximately $200,000 in property damage.	NOAA-NCDC
October 29, 2011	Heavy Snow	N/A	N/A	Heavy snow fell across most of eastern Pennsylvania in late October. This storm was considered an unprecedented event. It caused widespread power outages and road closures. Nearly one million utility customers were without power and most of it not restored until November 6th. There were eight fatalities due to this event. Snow accumulations averaged between six and 12 inches, with some larger amounts in higher terrains. The hardest hit areas include Lehigh Valley, Berks County and Bucks County. Shelters, warming stations, showers and ice distribution locations were opened in these areas. In Lehigh County, a 60-year-old man died of carbon monoxide poisoning after using a charcoal grill to heat their home in Emmaus. A 17-year-old boy died from an ATV accident in the snow in North Whitehall Township. The Lehigh Valley was one of the hardest hit locations. Some schools and universities were closed through November 2nd. Two-thirds of Emmaus Borough lost power. Boil water advisories and shelters for pets were opened. Leaf collections were suspended. About 6,100 customers still did not have power as of November 3rd. Snowfall totals for Lehigh Valley ranged from 6.5 inches in Nazareth to 9.5 inches in Bushkill Township. At the Lehigh	NOAA-NCDC

Dates of Event	Event Type	FEMA Declaration Number	Counties Designated?	Losses / Impacts	Source(s)
				Valley Airport, 6.8 inches of snow was reported which was the heaviest snow to ever fall during the month of October since 1925.	

Note (1): Monetary figures within this table were U.S. Dollar (USD) figures calculated during or within the approximate time of the event. If such an event would occur in the present day, monetary losses would be considerably higher in USDs as a result of increased U.S. Inflation Rates.

DR Federal Disaster Declaration
EM Federal Emergency Declaration
FEMA Federal Emergency Management Agency
HMP Hazard Mitigation Plan
LVPC Lehigh Valley Planning Commission
N/A Not applicable/available
NCDC National Climate Data Center
NOAA National Oceanic Atmospheric Administration
PEMA Pennsylvania Emergency Management Agency

4.3.12.4 Future Occurrence

Given the history of winter storms events that have impacted the Lehigh Valley, it is apparent that future winter storm events of varying degrees will occur. The facts that the elements required for winter storms exist and that major events have occurred throughout the Lehigh Valley in the past suggest that many people and properties are at risk from the winter storm hazard in the future.

Based on available historical data, the future occurrence of winter storm events can be considered *likely* as defined by the Risk Factor Methodology probability criteria (refer to Section 4.4).

4.3.12.5 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For winter storm events, the entire Lehigh Valley has been identified as the hazard area. Therefore, all assets (population, structures, critical facilities and lifelines), as described in the Regional Profile (Section 2), are vulnerable. The following section includes an evaluation and estimation of the potential impact winter storm events have on the Lehigh Valley including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, safety and health, (2) general building stock, (3) critical facilities (4) economy, (5) environment and (6) future growth and development
- Effect of climate change on vulnerability
- Further data collections that will assist understanding this hazard over time

4.3.12.5.1 Overview of Vulnerability

Winter storms are a concern to the Lehigh Valley because of its location and geographic propensity to experience winter weather more frequently and with greater severity than many other parts of the State. Additionally, winter storms are of significant concern due to the direct and indirect costs associated with these events; delays caused by the storms; and impacts on the people and facilities of the region.

4.3.12.5.2 Data and Methodology

National weather databases, the State HMP and local resources were used to collect and analyze severe winter storm impacts on the Lehigh Valley. The 2010 U.S. Census data and the custom building inventory for the Lehigh Valley was used to support an evaluation of assets exposed to this hazard and the potential impacts associated with this hazard.

4.3.12.5.3 Impact on Life, Health and Safety

According to the NOAA National Severe Storms Laboratory (NSSL), every year, winter weather indirectly and deceptively kills hundreds of people in the U.S., primarily from automobile accidents, overexertion and exposure. Winter storms are often accompanied by strong winds creating blizzard conditions with blinding wind-driven snow, drifting snow and extreme cold temperatures and dangerous wind chill. They are considered deceptive killers because most deaths and other impacts or losses are indirectly related to the storm. People can die in traffic accidents on icy roads, heart attacks while shoveling snow, or of hypothermia from prolonged exposure to cold.

Heavy snow can immobilize a region and paralyze a city, shutting down air and rail transportation, stopping the flow of supplies, and disrupting medical and emergency services. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. Storms near the coast can cause coastal flooding and beach erosion as well as sink ships at sea. In the mountains, heavy snow can lead to avalanches (NSSL, 2006).

Heavy accumulations of ice can bring down trees, electrical wires, telephone poles and lines, and communication towers. Communications and power can be disrupted for days while utility companies work to repair the extensive damage. Even small accumulations of ice may cause extreme hazards to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces (NSSL, 2006).

For the purposes of this Plan, the entire population of the Lehigh Valley is exposed to winter storm events (U.S. Census, 2010). The elderly are considered most susceptible to this hazard due to their increased risk of injuries and death from falls and overexertion and/or hypothermia from attempts to clear snow and ice. In addition, winter storm events can reduce the ability of these populations to access emergency services. Residents with low incomes may not have access to housing or their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply). Refer to the Regional Profile (Section 2) for population statistics for each participating municipality and a summary of the more vulnerable populations (over the age of 65 and individuals living below the Census poverty threshold).

4.3.12.5.4 Impact on General Building Stock

The entire general building stock inventory in the Lehigh Valley is exposed and vulnerable to the winter storm hazard. In general, structural impacts include damage to roofs and building frames, rather than building content. Current modeling tools are not available to estimate specific losses for this hazard. As an alternate approach, this plan considers percentage damages that could result from winter storm conditions. Table 4.3.12-2 below summarizes percent damages that could result from winter storm conditions on the Lehigh Valley's total general building stock (structure only). Given professional knowledge and the currently available information, the potential losses for this hazard are considered to be overestimated; hence, the following represent conservative estimates for losses associated with severe winter storm events.

Table 4.3.12-3. General Building Stock Exposure (Structure Only) and Estimated Losses from Winter Storm Events in the Lehigh Valley

Municipality	Total (All Occupancies) RV	1% Damage Loss Estimates	5% Damage Loss Estimates	10% Damage Loss Estimates
Lehigh County				
Alburtis Borough	$174,822,000	$1,748,220	$8,741,100	$17,482,200
Allentown, City of	$11,903,318,000	$119,033,180	$595,165,900	$1,190,331,800
Bethlehem, City of	$2,628,517,000	$26,285,170	$131,425,850	$262,851,700
Catasauqua Borough	$560,521,000	$5,605,210	$28,026,050	$56,052,100
Coopersburg Borough	$249,541,000	$2,495,410	$12,477,050	$24,954,100
Coplay Borough	$254,287,000	$2,542,870	$12,714,350	$25,428,700
Emmaus Borough	$1,218,443,000	$12,184,430	$60,922,150	$121,844,300
Fountain Hill Borough	$577,138,000	$5,771,380	$28,856,900	$57,713,800
Hanover Township	$1,121,295,000	$11,212,950	$56,064,750	$112,129,500
Heidelberg Township	$332,855,000	$3,328,550	$16,642,750	$33,285,500
Lower Macungie Township	$3,559,416,000	$35,594,160	$177,970,800	$355,941,600
Lower Milford Township	$345,853,000	$3,458,530	$17,292,650	$34,585,300
Lowhill Township	$235,030,000	$2,350,300	$11,751,500	$23,503,000
Lynn Township	$385,596,000	$3,855,960	$19,279,800	$38,559,600
Macungie Borough	$322,034,000	$3,220,340	$16,101,700	$32,203,400
North Whitehall Township	$1,689,865,000	$16,898,650	$84,493,250	$168,986,500
Salisbury Township	$1,959,935,000	$19,599,350	$97,996,750	$195,993,500
Slatington Borough	$426,505,000	$4,265,050	$21,325,250	$42,650,500
South Whitehall Township	$2,828,990,000	$28,289,900	$141,449,500	$282,899,000
Upper Macungie Township	$5,403,642,000	$54,036,420	$270,182,100	$540,364,200
Upper Milford Township	$743,671,000	$7,436,710	$37,183,550	$74,367,100
Upper Saucon Township	$1,886,155,000	$18,861,550	$94,307,750	$188,615,500
Washington Township	$556,271,000	$5,562,710	$27,813,550	$55,627,100
Weisenberg Township	$694,670,000	$6,946,700	$34,733,500	$69,467,000
Whitehall Township	$3,158,161,000	$31,581,610	$157,908,050	$315,816,100
Lehigh County (est. total)	***$43,216,531,000***	***$432,165,310***	***$2,160,826,550***	***$4,321,653,100***
Northampton County				
Allen Township	$449,063,000	$4,490,630	$22,453,150	$44,906,300
Bangor Borough	$527,429,000	$5,274,290	$26,371,450	$52,742,900
Bath Borough	$275,179,000	$2,751,790	$13,758,950	$27,517,900
Bethlehem Township	$3,173,542,000	$31,735,420	$158,677,100	$317,354,200
Bethlehem, City of	$5,550,240,000	$55,502,400	$277,512,000	$555,024,000
Bushkill Township	$805,813,000	$8,058,130	$40,290,650	$80,581,300
Chapman Borough	$19,081,000	$190,810	$954,050	$1,908,100

Municipality	Total (All Occupancies) RV	1% Damage Loss Estimates	5% Damage Loss Estimates	10% Damage Loss Estimates
East Allen Township	$596,473,000	$5,964,730	$29,823,650	$59,647,300
East Bangor Borough	$74,240,000	$742,400	$3,712,000	$7,424,000
Easton, City of	$2,739,624,000	$27,396,240	$136,981,200	$273,962,400
Forks Township	$1,804,634,000	$18,046,340	$90,231,700	$180,463,400
Freemansburg Borough	$213,832,000	$2,138,320	$10,691,600	$21,383,200
Glendon Borough	$48,844,000	$488,440	$2,442,200	$4,884,400
Hanover Township	$1,932,002,000	$19,320,020	$96,600,100	$193,200,200
Hellertown Borough	$531,959,000	$5,319,590	$26,597,950	$53,195,900
Lehigh Township	$928,266,000	$9,282,660	$46,413,300	$92,826,600
Lower Mt. Bethel Township	$306,640,000	$3,066,400	$15,332,000	$30,664,000
Lower Nazareth Township	$1,197,083,000	$11,970,830	$59,854,150	$119,708,300
Lower Saucon Township	$1,240,742,000	$12,407,420	$62,037,100	$124,074,200
Moore Township	$778,212,000	$7,782,120	$38,910,600	$77,821,200
Nazareth Borough	$729,045,000	$7,290,450	$36,452,250	$72,904,500
North Catasauqua Borough	$232,842,000	$2,328,420	$11,642,100	$23,284,200
Northampton Borough	$1,068,331,000	$10,683,310	$53,416,550	$106,833,100
Palmer Township	$2,408,388,000	$24,083,880	$120,419,400	$240,838,800
Pen Argyl Borough	$372,456,000	$3,724,560	$18,622,800	$37,245,600
Plainfield Township	$643,358,000	$6,433,580	$32,167,900	$64,335,800
Portland Borough	$84,500,000	$845,000	$4,225,000	$8,450,000
Roseto Borough	$161,114,000	$1,611,140	$8,055,700	$16,111,400
Stockertown Borough	$153,656,000	$1,536,560	$7,682,800	$15,365,600
Tatamy Borough	$118,758,000	$1,187,580	$5,937,900	$11,875,800
Upper Mt. Bethel Township	$759,478,000	$7,594,780	$37,973,900	$75,947,800
Upper Nazareth Township	$631,001,000	$6,310,010	$31,550,050	$63,100,100
Walnutport Borough	$264,219,000	$2,642,190	$13,210,950	$26,421,900
Washington Township	$524,741,000	$5,247,410	$26,237,050	$52,474,100
West Easton Borough	$144,947,000	$1,449,470	$7,247,350	$14,494,700
Williams Township	$729,593,000	$7,295,930	$36,479,650	$72,959,300
Wilson Borough	$935,258,000	$9,352,580	$46,762,900	$93,525,800
Wind Gap Borough	$298,194,000	$2,981,940	$14,909,700	$29,819,400
Northampton County (est. total)	***$33,452,777,000***	***$334,527,770***	***$1,672,638,850***	***$3,345,277,700***

Source: HAZUS-MH 2.1
Note (1): The valuation of general building stock and the loss estimates determined in the Lehigh Valley were based on the custom building stock database developed for this plan.
Note (2): Value reflects the replacement cost for building structure.
est. = Estimated; RV = Replacement Value.

A specific area that is vulnerable to the winter storm hazard is the floodplain. At risk general building stock and infrastructure in floodplains are presented in the flood hazard profile (Section 4.3.4). Generally, losses from flooding associated with winter storms should be less than that associated with a 1% or 0.2%-flood. In summary, snow and ice melt can cause both riverine and urban flooding. Estimated losses due to riverine flooding in the Lehigh Valley are discussed in Section 4.3.4.

4.3.12.5.5 Impact on Critical Facilities

Full functionality of critical facilities such as police, fire and medical facilities is essential for response during and after a winter storm event. These critical facility structures are largely constructed of concrete and masonry; therefore, they should only suffer minimal structural damage from severe winter storm events. Because power interruption can occur, backup power is recommended for critical facilities and infrastructure.

4.3.12.5.6 Impact on the Economy

Infrastructure at risk for this hazard includes roadways that could be damaged due to the application of salt and intermittent freezing and warming conditions that can damage roads over time. The cost of snow and ice removal and repair of roads from the freeze/thaw process can drain local financial resources. The potential secondary impacts from winter storms also impact the local economy including loss of utilities; interruption of transportation corridors; and loss of business function.

4.3.12.5.7 Impact on the Environment

Environmental impacts often include damage to trees and shrubs due to heavy snow loading, ice build-up and/or high winds which can break limbs and down large trees. An indirect effect of winter storms is the threat of roadway surfaces with salt, chemicals, and other de-icing materials which can impair adjacent surface and groundwater (PEMA, 2010).

Winter storms have a positive environmental impact; gradual melting of snow and ice provides groundwater recharge. However, abrupt high temperatures following a heavy snowfall can cause snowmelt, rapid surface water runoff and severe flooding (PEMA, 2010).

4.3.12.5.8 Future Growth and Development

Areas targeted for potential future growth and development in the next five (5) years have been identified across the Lehigh Valley at the municipal level. Refer to the jurisdictional annexes in Volume II of this Plan. Table B.1 in each jurisdictional annex lists the location of the potential new development and its exposure (if any) to known hazard zones. For the winter storm hazard, the Lehigh Valley in its entirety has been identified as the hazard area. Therefore, any new development will be exposed to such risks.

4.3.12.5.9 Effect of Climate Change on Vulnerability

Climate is defined not simply as average temperature and precipitation but also by the type, frequency and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extremes such winter storms. While predicting changes of winter storm 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).

The climate of Pennsylvania has changed in several ways. Over the past 100 years, annual average temperatures have been rising across the state. Warmer winters have led to a decrease in snow cover and an earlier arrival of spring. Recent analyses based on the Intergovernmental Panel on Climate Change models suggest a decrease in frequency and an increase in intensity of extra-tropical winter cyclones. However based on the methodology used, some models show no significant change in the storm track whereas others indicate a northward displacement of the storm track in the North Atlantic. For the mid-Atlantic region, there is little indication of a change in storm activity or track over Pennsylvania. An overall increase in winter precipitation is anticipated with a decrease in snow and increase in rain during the winter months. There is substantial uncertainty in projections of extra-tropical cyclones for Pennsylvania. With that said, it is anticipated winter storms will continue to pass over Pennsylvania in the future. Future improvements in modeling smaller scale climatic processes can be expected and will lead to improved understanding of how the changing climate will alter temperature, precipitation and storms events in Pennsylvania (Shortle et. al, 2009).

4.3.12.5.10 Additional Data and Next Steps

The assessment above identifies vulnerable populations and economic losses associated with this hazard of concern. Historic data on structural losses to general building stock are not adequate to predict specific losses to this inventory; therefore, the percent of damage assumption methodology was applied. This methodology is based on FEMA's How to Series (FEMA 386-2), Understanding Your Risks, Identifying and Estimating Losses (FEMA, 2001) and FEMA's Using HAZUS-MH for Risk Assessment (FEMA 433) (FEMA, 2004). The collection of additional/actual valuation data for general building stock and critical infrastructure losses would further support future estimates of potential exposure and damage for the general building stock inventory.