4.3.3 Extreme Temperature

This section provides a profile and vulnerability assessment for the extreme temperature hazard, including extreme heat and extreme cold. Extreme heat can be described as temperatures that hover 10°F or more above the average high temperature for a region during the summer months. What constitutes an extreme cold temperature event varies across different regions of the United States, but in the Lehigh Valley and other areas accustomed to winter weather, below zero temperatures may be considered as extreme cold (NOAA, 1998). Mainly, cold temperatures may be classified as extreme when they drop well below what is considered normal for an area during the winter months, and often when they are accompanied by winter storm events. Combined with increases in wind speed, such cold temperatures in Pennsylvania (including the Lehigh Valley) can be life threatening to those exposed for extended periods of time.

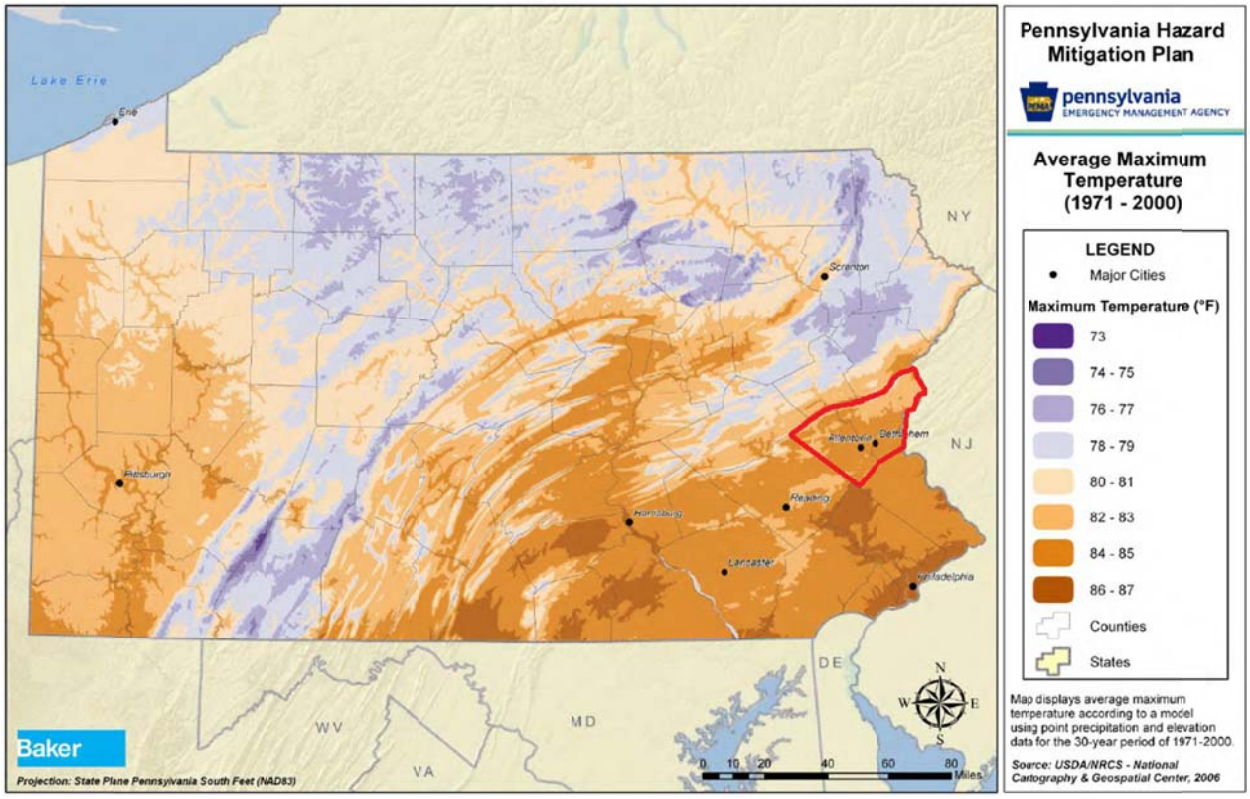
4.3.3.1 Location and Extent

The Lehigh Valley can experience many different temperature extremes in the summer and winter seasons. Areas most susceptible to extreme heat include urban environments, which tend to retain the heat well into the night, leaving little opportunity for dwellings to cool.

The Lehigh Valley falls within the Piedmont Plateau geographic area, which experiences long and at times uncomfortably hot summers. Records from across the Piedmont Plateau are generally representative of conditions in the Lehigh Valley, and show daily temperatures reaching 90°F or above on the average of 25 days during the summer season; however, readings of 100°F or above are comparatively rare. From about July 1 to the middle of September this geographic area occasionally experiences uncomfortably warm periods, four to five days per week in length, during which light wind movement and high relative humidity make conditions oppressive. In general, the winters are comparatively mild, with an average of less than 100 days with minimum temperatures below the freezing point. The freeze-free season averages 170 to 200 days (NCDC, Date Unknown).

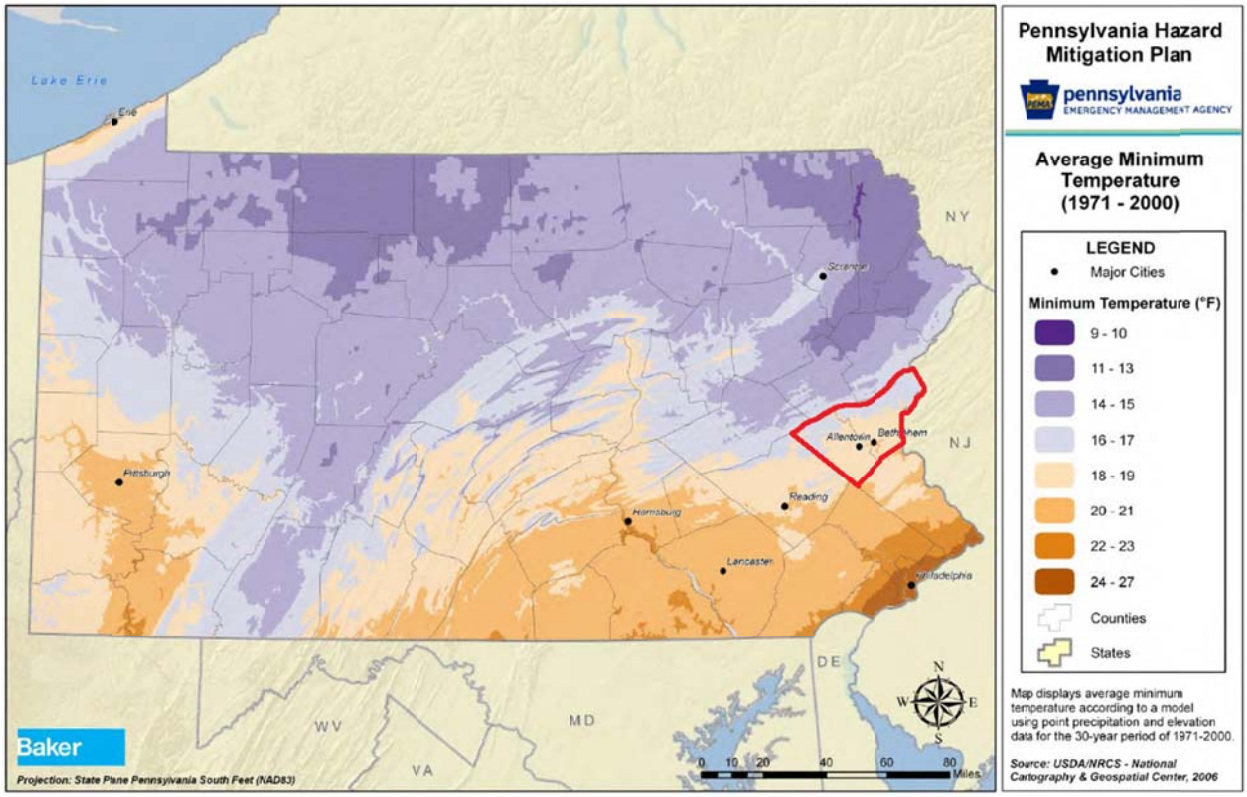
Figure 4.3.3-1 and Figure 4.3.3-2 show mean maximum and minimum temperatures throughout Pennsylvania by county. During July, the warmest month, high temperatures in the Lehigh Valley normally range from the low-80s in the northern areas to the mid-80s / upper-70s in the central and southern areas. Minimum temperatures in the Lehigh Valley range from the upper-60s in the southeast to the lower-50s in the north-central mountains. During the colder months, most of the Lehigh Valley experiences low temperature averages ranging from 16°F to 17°F in the north to as high as 21°F in urban areas.

Figure 4.3.3-1. Average Maximum Temperature throughout Pennsylvania (1971 and 2000)



Source: PEMA, 2010
Note: Highlight added.

Figure 4.3.3-2. Average Minimum Temperature throughout Pennsylvania (1971 to 2000)



Source: PEMA, 2010
Note: Highlight added.

4.3.3.2 Range of Magnitude

Exposure to heat can cause health problems indirectly, such as through the increased workload on the heart. This can be especially dangerous to individuals with preexisting medical conditions, typically the elderly. Extremely high temperatures cause heat stress which can be divided into four categories (see Table 4.3.3-1). Each category is defined by apparent temperature which is associated with a heat index value that captures the combined effects of dry air temperature and relative humidity on humans and animals. Major human risks for these temperatures include heat cramps, heat syncope, heat exhaustion, heatstroke, and death. Note that while the temperatures in Table 4.3.3-1 serve as a guide for various danger categories, the impacts of high temperatures will vary from person to person based on individual age, health, and other factors.

Table 4.3.3-1. Four Categories of Heat Stress

Danger Category	Heat Disorders	Apparent Temperature (°F)
I (Caution)	Fatigue possible with prolonged exposure and physical activity.	80 to 90
II (Extreme Caution)	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and physical activity.	90 to 105
III (Danger)	Sunstroke, heat cramps, or heat exhaustion likely; heat stroke possible with prolonged exposure and physical activity.	105 to 130
IV (Extreme Danger)	Heatstroke or sunstroke imminent.	>130

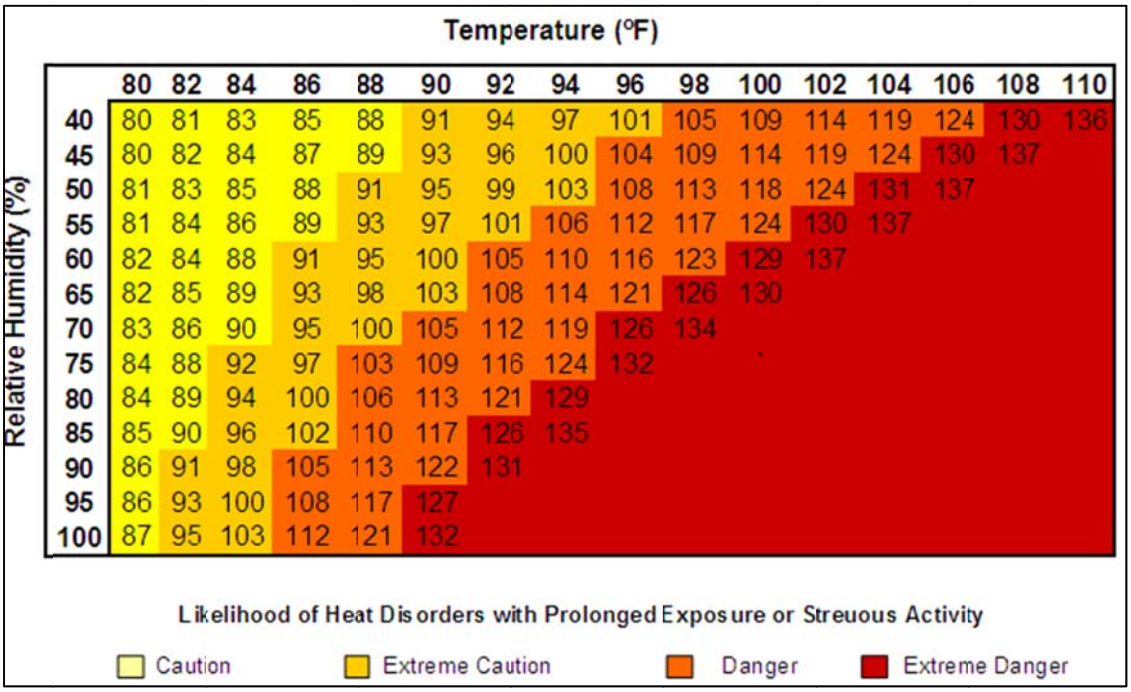
Source: PEMA, 2010

Temperature advisories, watches and warnings are issued by the National Weather Service (NWS) relating the above impacts to the range of temperatures typically experienced in Pennsylvania. Exact thresholds vary across the Commonwealth, but in the Lehigh Valley Heat Advisories are issued when the heat index will be equal to or greater than 100°F, but less than 105°F. Excessive Heat Warnings are issued when heat indices will attain or exceed 105°F. Excessive Heat Watches are issued when there is a possibility that excessive heat warning criteria may be experienced within 12 to 48 hours (NOAA NWS, 2010).

Cold weather has a number of effects, most dramatically on the general population's mortality rate. The average mortality on a winter's day is about 15 percent higher than on a summer's day. Cold weather is directly responsible for deaths through such things as hypothermia, influenza, and pneumonia. It is also an indirect factor in a number of ways, such as death and injury from falls, accidents, carbon monoxide poisoning, and house fires, all of which are partially attributable to cold temperatures. Wind chill temperatures are often used in place of raw temperature values due to the effect that wind can have in drawing heat from the body under cold temperatures. These values represent what temperatures actually feel like to humans and animals under cold, windy conditions. Similarly to high temperatures, the effect of cold temperatures will vary by individual. In Pennsylvania (including in the Lehigh Valley), Wind Chill Warnings are issued when wind chills drop to -25°F or lower. Wind Chill Advisories are issued in the Lehigh Valley when wind chill values drop to -15°F to -24°F (NOAA NWS, 2010).

Figure 4.3.3-3 shows the effects of humidity on extreme heat events and wind speed on extreme cold events. These compounding factors can increase the risk experienced by vulnerable populations and the general public.

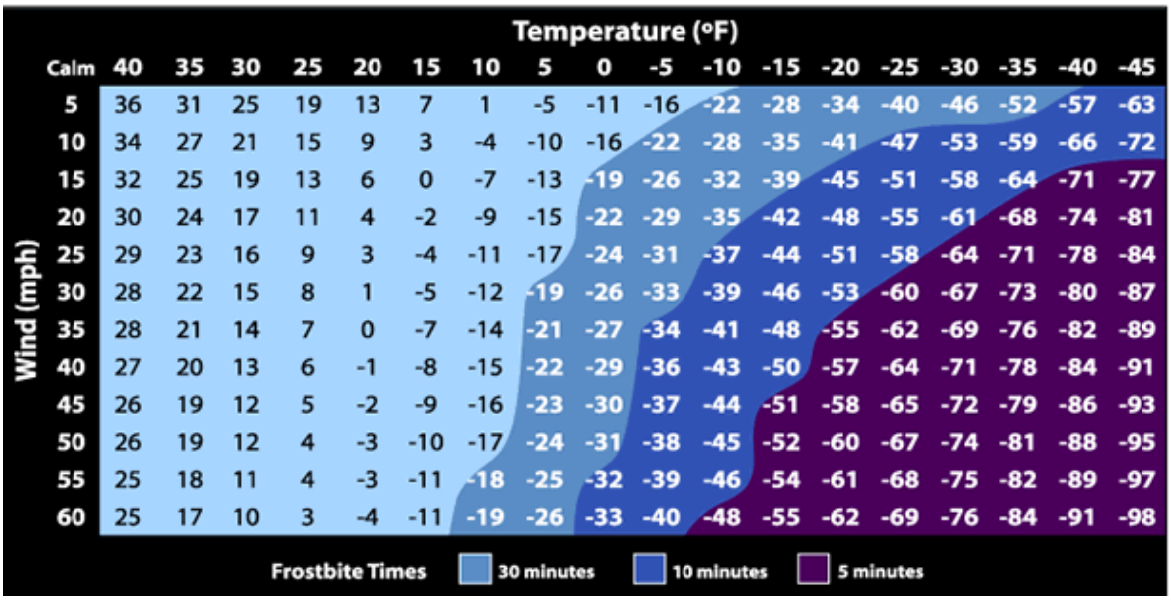
Figure 4.3.3-3. Extreme Heat and Heat Index



Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	126	130					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Source: NOAA NWS, 2012

Figure 4.3.3-4. Extreme Cold and Wind Chill



Wind (mph)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Source: NOAA NWS, 2012

The following impacts can be observed following an extreme temperature event:

Health Impacts – The health impacts of extreme cold are greater in terms of mortality in humans, but often after more prolonged exposure versus a cold snap. Extreme heat waves, however, can prove more deadly over a shorter duration. At greatest risk of death in heat waves are the urban-dwelling elderly without access to an air-conditioned environment for at least part of the day.

Transportation – Cold weather can impact automotive engines, possibly stranding motorists, and stress metal bridge structures. Highways and railroad tracks can become distorted in high heat. Disruptions to the transportation network and accidents due to extreme temperatures represent an additional risk.

Agriculture – Absolute temperature and duration of extreme cold can have devastating effects on trees and winter crops. Livestock is especially vulnerable to heat, and crop yields can be impacted by heat waves that occur during key development stages.

Energy – Energy consumption rises significantly during extreme cold weather. Residents are placed in extreme danger when any fuel shortages or utility failures prevent the heating of a dwelling. Extreme heat can also result in utility interruptions, and sagging transmission lines due to the heat can lead to shorting out.

The range of these impacts, especially health effects, can be mitigated through improved forecasts, warnings, community preparedness, and appropriate community-based response.

The Lehigh Valley's worst-case extreme heat scenario would be an excessive heat spell occurring during a summer holiday weekend, such as Independence Day weekend. Summer holiday weekends bring people out of their air-conditioned work environments and into the outdoors, often despite dangerous heat and humidity. This took place in July 1999. High temperatures reached the 90s for the first time on July 3rd, but sweltering humidity and record breaking maximum temperatures of approximately 100°F occurred from Independence Day through July 6th. The combination of the temperature and humidity produced heat indices of around 110°F during the afternoon of each day. Record high temperatures of 100°F were reported on July 5th at the Lehigh Valley International Airport and in the City of Easton. Two heat-related deaths were reported in the Lehigh Valley; although there were 74 heat-related deaths and over 100 reported heat related injuries across the 10 Pennsylvania counties impacted.

The Lehigh Valley's worst-case extreme cold temperature scenario would involve below zero temperatures and chilling winds accompanied by snow and/or ice accumulation and power failure. The Lehigh Valley's worst-case extreme cold temperature scenario took place in January 2003 when temperatures were between 8 and -11°F. There were four deaths related to this event.

4.3.3.3 Past Occurrence

The Lehigh Valley has been subject to more than 50 extreme temperature events over the last 18 years, as shown in Table 4.3.3-2. Please note that extreme temperature data is regional and the temperatures, deaths, injuries, and damage described were not necessarily in the Lehigh Valley.

Table 4.3.3-2. Extreme Temperature Events

Date	Type	Actual Temperature (not including Wind Chill/Heat Index)	Deaths	Injuries
6/13/1994	Heat Waves	95 to 100	5	0
2/6/1995	Extreme Cold	9 to -8	1	0
7/13/1995	Heat Wave	Unknown	4	0
8/16/1995	Heat Wave	93	0	0
8/31/1995	Heat Wave	93 to 98	6	0
12/9/1995	Unseasonably Cold	-10 to -20	2	0
2/4/1996	Extreme Cold	-6 to -12	0	0
5/19/1996	Excessive Heat	92 to 98	1	4
1/17/1997	Extreme Cold	-7 to 8	3	0
7/12/1997	Excessive Heat	94 to 100	24	60
7/21/1998	Hot Weather	93 to 95	0	0
9/27/1998	Unseasonably Hot	88 to 93	0	0
6/7/1999	Unseasonably Hot	91 to 98	0	0
7/4/1999	Excessive Heat	92 to 104	74	135
7/16/1999	Excessive Heat	93 to 100	0	0
7/23/1999	Excessive Heat	96 to 102	4	0
8/1/1999	Excessive Heat	96 to 102	5	0
5/2/2001	Unseasonably Hot	87 to 92	0	0
8/6/2001	Excessive Heat	98 to 104	22	0
7/1/2002	Excessive Heat	94 to 102	15	0
7/15/2002	Excessive Heat	94 to 98	2	0
7/28/2002	Excessive Heat	93 to 101	3	0
8/1/2002	Excessive Heat	91 to 102	9	0
8/11/2002	Excessive Heat	97 to 100	8	0
1/14/2003	Extreme Cold/wind Chill	-11 to 8	4	0
1/9/2004	Extreme Cold/wind Chill	-10 to 4	2	0
1/15/2004	Extreme Cold/wind Chill	-32 to -14	1	0
12/20/2004	Extreme Cold/wind Chill	-5 to 10	0	0
1/18/2005	Extreme Cold/wind Chill	-20 to 10	2	1
1/23/2005	Extreme Cold/wind Chill	-5 to 5	1	0
1/28/2005	Extreme Cold/wind Chill	-6 to 6	0	0
7/25/2005	Excessive Heat	93 to 98	7	0
8/2/2005	Excessive Heat	93 to 98	5	0
8/11/2005	Excessive Heat	94 to 98	2	0
12/14/2005	Cold/wind Chill	-4 to -2	0	0
8/1/2006	Excessive Heat	90 to 98	24	40
1/26/2007	Extreme Cold/wind Chill	-7 to 10	0	0
2/6/2007	Extreme Cold/wind Chill	-9 to 10	0	0
2/16/2007	Cold/wind Chill	-3 to 11	0	0
2/19/2007	Cold/wind Chill	1 to 11	0	0

Date	Type	Actual Temperature (not including Wind Chill/Heat Index)	Deaths	Injuries
3/6/2007	Cold/wind Chill	-10 to 17	0	0
6/26/2007	Excessive Heat	92 to 95	0	0
7/9/2007	Excessive Heat	92 to 98	0	0
8/8/2007	Excessive Heat	94 to 97	0	0
8/25/2007	Excessive Heat	92 to 96	0	0
6/7/2008	Excessive Heat	89 to 99	0	5
7/16/2008	Excessive Heat	94 to 98	0	0
7/29/2008	Heat	87	0	1
1/16/2009	Cold/wind Chill	-14 to 14	0	0
4/26/2009	Heat	90 to 93	0	0
7/5/2010	Excessive Heat	94 to 104	0	0
6/8/2011	Excessive Heat	94 to 99	0	0
7/21/2011	Excessive Heat	94 to 106	0	0
		Total	***236***	***246***

Source: NCDC, 2010

4.3.3.4 Future Occurrence

Due to its location and geography, the Lehigh Valley is more likely to encounter excessive heat than extreme cold weather. Topography and vegetation can impact temperature differentials across the Lehigh Valley.

The Commonwealth of Pennsylvania 2010 Standard All-Hazard Mitigation Plan provides information on the probability of extreme maximum and minimum temperatures using data from 30 recording stations throughout the State. These stations produce location-specific data, which is more precise than the broader geographic area averages referenced under the "Location and Extent" section of this chapter. According to those data, high temperatures of 90°F or above occur on the average of 10 to 20 days per year in the Lehigh Valley; with the fewest events occurring in the northeast areas of Northampton County, and the greatest frequency occurring in the south and southwest portions of both counties. There are, on average, three days per year where temperatures in the Lehigh Valley reach or exceed 95°F. For temperatures greater than 100°F, the number of years between occurrences ranges between 10 and 50. Extreme cold temperatures less than 0°F occur on the average of four days annually with the greatest number of occurrences in the northeast areas of Northampton County, and the fewest days occurring in the southwest portions of Lehigh County. For temperatures lower than -10°F, the number of years between occurrences ranges between 20 and 30, and the number of years between occurrences for temperatures lower than -20°F ranges between 50 and 70.

The future occurrence of extreme temperatures can be considered *likely* as defined by the Risk Factor Methodology probability criteria (refer to Section 4.4).

4.3.3.5 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. Most extreme temperature events involve a large region; therefore, the entire Lehigh Valley has been identified as the hazard area. The following text evaluates and estimates the potential impact of extreme temperature events on the Lehigh Valley including:

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

4.3.3.5.1 Overview of Vulnerability

Extreme temperatures generally occur for a short period of time but can cause a range of impacts, particularly to vulnerable populations that may not have access to adequate cooling or heating. This natural hazard can also cause impacts to agriculture (crops and animals), infrastructure (e.g., through pipe bursts associated with freezing, power failure) and the economy.

4.3.3.5.2 Data and Methodology

At the time of this Plan, insufficient data is available to model the long-term potential impacts of extreme temperature on the Lehigh Valley. Over time, additional data will be collected to allow better analysis for this hazard. Available information and a preliminary assessment are provided below.

4.3.3.5.3 Impact on Life, Health and Safety

For the purposes of this Plan, the entire population in the Lehigh Valley is vulnerable to extreme temperature events. Extreme temperature events have potential health impacts including injury and death.

According to the Centers for Disease Control and Prevention, populations most at risk to extreme cold and heat events include the following: 1) the elderly, who are less able to withstand temperatures extremes due to their age, health conditions and limited mobility to access shelters; 2) infants and children up to four years of age; 3) individuals who are physically ill (e.g., heart disease or high blood pressure), 4) low-income persons that cannot afford proper heating and cooling; and 5) the general public who may overexert during work or exercise during extreme heat events or experience hypothermia during extreme cold events.

Meteorologists can accurately forecast extreme heat event development and the severity of the associated conditions with several days lead time. These forecasts provide an opportunity for public health and other officials to notify vulnerable populations, implement short-term emergency response actions and focus on surveillance and relief efforts on those at greatest risk. Adhering to extreme temperature warnings can significantly reduce the risk of temperature-related deaths.

Refer to Section 2 which summarizes population in the Lehigh Valley over the age of 65, and population with an annual income below the poverty threshold.

4.3.3.5.4 Impact on General Building Stock

All of the building stock in the Lehigh Valley is exposed to the extreme temperature hazard. Refer to Section 2 which summarizes the building inventory in the Lehigh Valley. Extreme heat generally does not impact buildings. Losses may be associated with the overheating of HVAC systems. Extreme cold temperature events can damage buildings through freezing/bursting pipes and freeze/thaw cycles. Additionally, manufactured homes (mobile homes) and antiquated or poorly constructed facilities may have inadequate capabilities to withstand extreme temperatures.

4.3.3.5.5 Impact on Critical Facilities

All critical facilities in the Lehigh Valley are exposed to the extreme temperature hazard. Impacts to critical facilities are the same as described for general building stock (above). Additionally, it is essential that critical facilities remain operational during natural hazard events. Extreme heat events can sometimes cause short periods of utility failure commonly referred to as "brown-outs", due to increased usage from air conditioners, appliances, etc. Similarly, heavy snowfall and ice storms, associated with extreme cold temperature events, can cause power interruption as well. Backup power is recommended for critical facilities and infrastructure.

4.3.3.5.6 Impact on the Economy

Extreme temperature events also have impacts on the economy, including loss of business function and damage/loss of inventory. Business-owners may be faced with increased financial burdens due to unexpected repairs caused to the building (e.g., pipes bursting), higher than normal utility bills or business interruption due to power failure (i.e., loss of electricity, telecommunications).

The agricultural industry is most at risk in terms of economic impact and damage due to extreme temperature events. Extreme heat events can result in drought and dry conditions and directly impact livestock and crop production.

4.3.3.5.7 Future Growth and Development

Development trends indicate that farmland is being converted to housing, commercial and industrial uses at a rate of 3.5 square miles per year in the Lehigh Valley. Farmland is under intense development pressure that is expected to continue through 2030. With the continuing loss of farmland, the impacts of extreme temperature on agriculture will likely decrease.

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. It is anticipated that any new development and new residents will be exposed to the extreme temperature hazard.

4.3.3.5.8 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 as extreme temperature events. While predicting changes of extreme temperature 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).

Pennsylvania's Department of Environmental Protection was directed by the Climate Change Act (Act 70 of 2008) to initiate a study of the potential impacts of global climate change on the Commonwealth. The June 2009 PA Climate Impact Assessment's main findings indicate it is very likely that Pennsylvania will experience increased temperatures in the 21st century. Higher summer temperatures will result in higher ozone concentrations in urban areas which can negatively impact vulnerable population's respiratory health. Increased winter temperatures will mean fewer cold-related deaths (Shortle et. al, 2009).

With one to three-degree increases in temperature, Pennsylvania farmers' yield of hay, corn and soybeans may increase while yields of cool-temperature adapted fruits such as apples and potatoes may decrease. However, changes in these crop yields will greatly depend on the exact temperature change. Dairy producers may experience the greatest challenges because they rely on their own-crop production, their animals may experience heat stress, and productivity may be impacted (Shortle et. al, 2009). It is clear that temperature changes will impact the agricultural industry, which is a large part of the Lehigh Valley's economy.

4.3.3.5.9 Additional Data and Next Steps

For future plan updates, the Lehigh Valley can track data on extreme temperature events, obtain additional County- and jurisdiction-specific information on past and future events, particularly in terms of any injuries, deaths, shelter needs, pipe freeze, agricultural losses and other impacts. This will help to identify any concerns or trends for which mitigation measures should be developed or refined. In time, quantitative modeling of estimated extreme heath/cold events may be feasible as data is gathered and improved.