4.3.1 Drought

A drought can be defined by rainfall amounts, vegetation conditions, agricultural productivity, soil moisture, reservoir levels and stream flow. Simply put, a drought is a significant deficit in moisture availability due to lower than normal rainfall. As rainfall provides the basis for both ground and surface water resources in the Commonwealth, the earliest indicator of a potential drought is precipitation deficits.

Pennsylvania is a member of interstate compact commissions that include the Delaware River Basin (DRB) of which the Lehigh Valley is a part. These commissions have regulatory authority over the waters of the basin. While basin commissions have authority to declare drought emergencies, they rely on respective member states to implement and enforce any actions they may dictate during a drought emergency. The Delaware River Basin Commission (DRBC) monitors the combined storage at three large water supply reservoirs (Pepacton, Neversink and Cannonsville) in the New York City Delaware reservoir system to identify drought conditions. Pennsylvania Department of Environmental Protection (PADEP) coordinates closely with the basin commission in all its drought management activities. The basin commission's primary role is one of ensuring effective coordination among member states (LVPC, 2006).

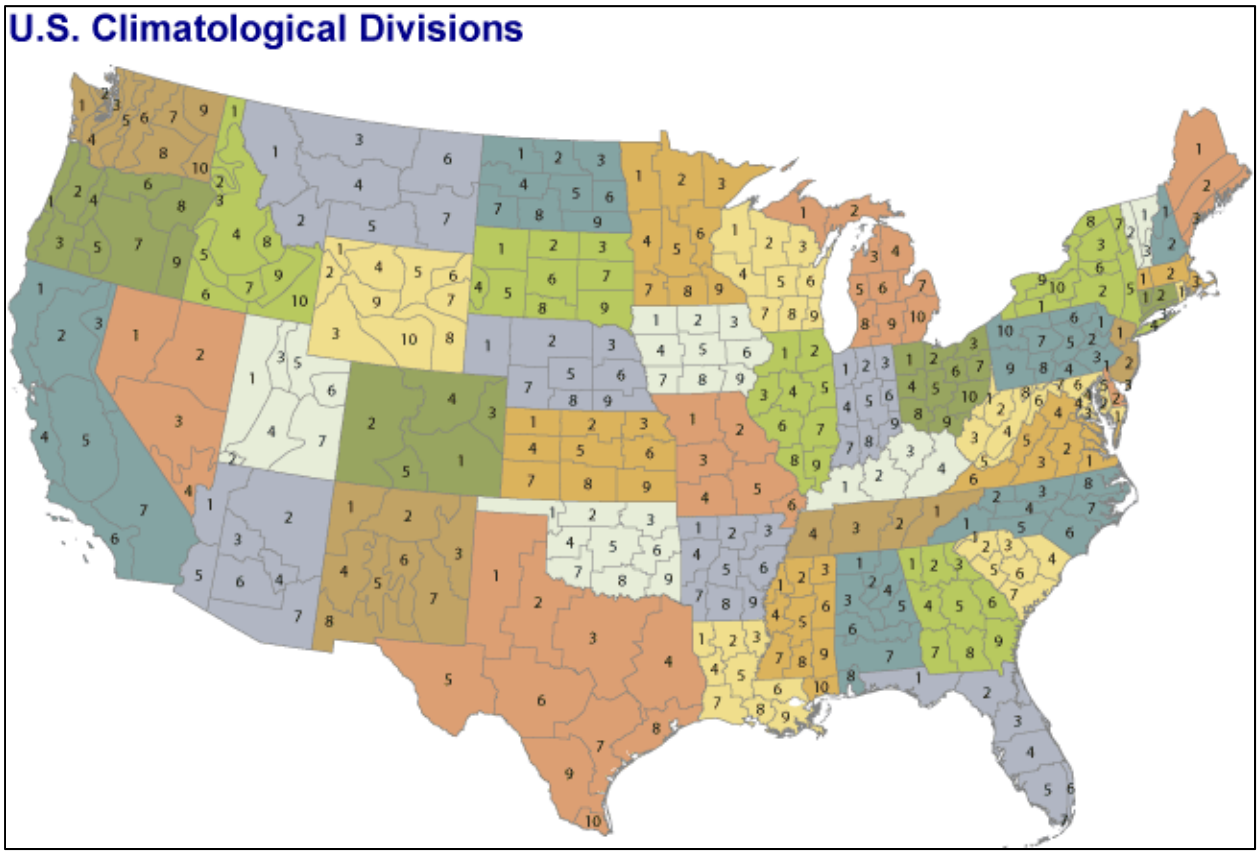
4.3.1.1 Location and Extent

Droughts are regional in nature and may affect the entire Lehigh Valley, as opposed to individual municipalities within the counties. In general, areas along waterways will show drought conditions later than those areas away from waterways.

Climate divisions are regions within a state that are climatically homogenous. The National Oceanic and Atmospheric Administration (NOAA) has divided the U.S. into 359 climate divisions. The boundaries of these divisions typically coincide with the county boundaries, except in the western U.S., where they are based largely on drainage basins (Energy Information Administration, 2005).

According to NOAA, Pennsylvania is made up of 10 climate divisions: Pocono Mountains, East Central Mountains, Southeastern Piedmont, Lower Susquehanna, Middle Susquehanna, Upper Susquehanna, Central Mountains, South Central Mountains, Southwest Plateau, and Northwest Plateau Climate Division (NOAA, Date Unknown). Figure 4.3.1-1 shows the climate divisions throughout the U.S. and Figure 4.3.1-2 shows more specifically the climate divisions of Pennsylvania. The Lehigh Valley is located in the East Central Mountains climate division.

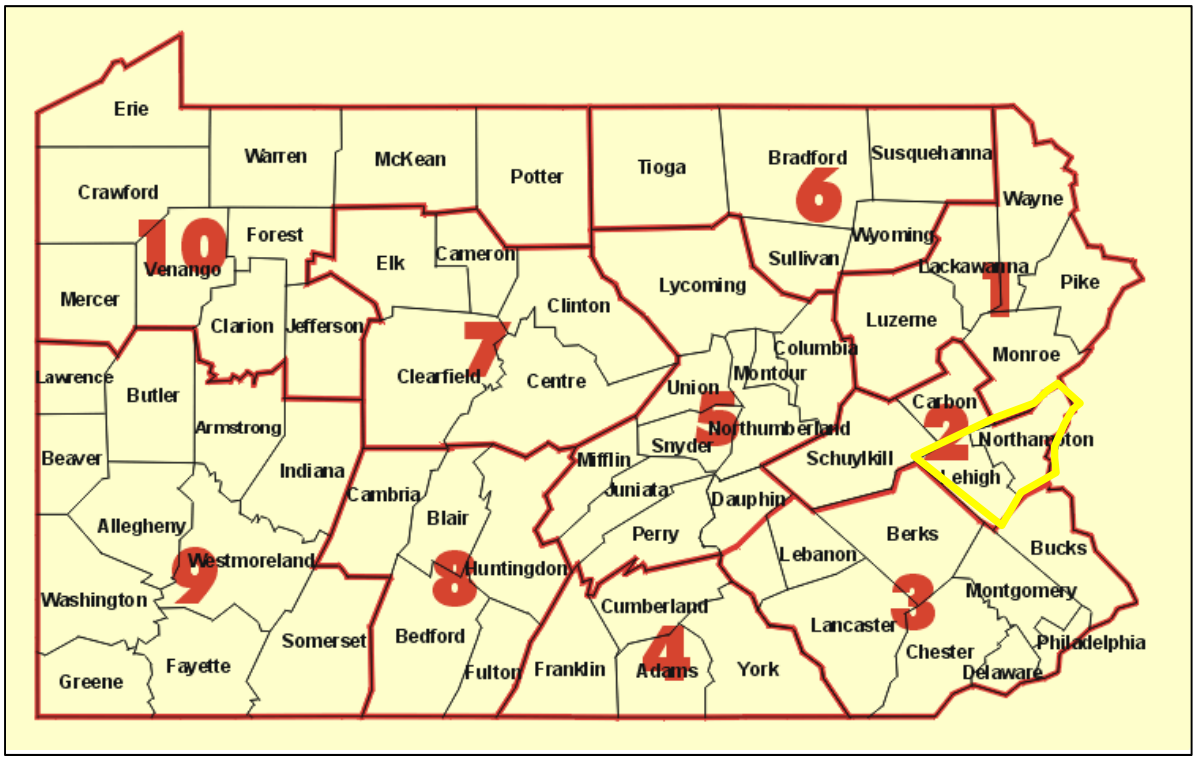
Figure 4.3.1-1. Climate Divisions in the U.S.



Source: NOAA, 2012

Note (1): The climate division names vary from state to state. The climate divisions for Pennsylvania are: 1 = Pocono Mountains; 2 = East Central Mountains; 3 = Southeastern Piedmont; 4 = Lower Susquehanna; 5 = Middle Susquehanna; 6 = Upper Susquehanna; 7 = Central Mountains; 8 = South Central Mountains; 9 = Southwest Plateau; 10 = Northwest Plateau

Figure 4.3.1-2. Climate Divisions of Pennsylvania



Source: NOAA NWS Climate Prediction Center, 2005
Note: Highlight added.
The climate divisions for Pennsylvania are:
1 = Pocono Mountains; 2 = East Central Mountains; 3 = Southeastern Piedmont; 4 = Lower Susquehanna; 5 = Middle Susquehanna; 6 = Upper Susquehanna; 7 = Central Mountains; 8 = South Central Mountains; 9 = Southwest Plateau; 10 = Northwest Plateau

4.3.1.2 Range of Magnitude

Droughts can have varying effects depending on their severity, timing, duration and location. Some droughts may have their greatest impact on agriculture, while others may impact water supply or recreation. When droughts occur, they can have significant adverse effects on the following:

- Public water supplies for human consumption
- Rural water supplies for livestock consumption and agricultural operations
- Water quality
- Natural soil water or irrigation water for agriculture
- Water for forests and for fighting forest fires
- Water for navigation and recreation

As described in the Commonwealth of Pennsylvania 2010 Standard Hazard Mitigation Plan (PA HMP), PADEP and Pennsylvania Emergency Management Agency (PEMA) manage water supply droughts in Pennsylvania using four drought phase conditions. These drought phase conditions are defined in the PA HMP as follows:

- Drought Watch: A period to alert government agencies, public water suppliers, water users, and the public regarding the potential for future drought-related problems. The focus is on increased

monitoring, awareness, and preparation for response if conditions worsen. A request for voluntary water conservation is made. The objective of voluntary water conservation measures during a drought watch is to reduce water use by five-percent in the affected areas. Because of varying conditions, individual water suppliers or municipalities may ask for more stringent conservation actions.

- Drought Warning: This phase involves a coordinated response to imminent drought conditions and potential water supply shortages through concerted voluntary conservation measures to avoid or reduce shortages, relieve stressed sources, develop new sources, and if possible forestall the need to impose mandatory water use restrictions. The objective of voluntary water conservation measures during a drought warning is to reduce overall water use by 10 to 15 percent in the affected areas. Because of varying conditions, individual water suppliers or municipalities may ask for more stringent conservation actions.

- Drought Emergency: This stage is a phase of concerted management operations to marshal all available resources to respond to actual emergency conditions, to avoid depletion of water sources, to ensure at least minimum water supplies to protect public health and safety, to support essential and high-priority water uses, and to avoid unnecessary economic dislocations. It is possible during this phase to impose mandatory restrictions on nonessential water uses as provided for in 4 Pa. Code Chapter 119, if deemed necessary and if ordered by the governor. The objective of water use restrictions (mandatory or voluntary) and other conservation measures during this phase is to reduce consumptive water use in the affected areas by 15 percent, and to reduce total use to the extent necessary to preserve public water system supplies, to avoid or mitigate local or area shortages, and to ensure equitable sharing of limited supplies.

- Local Water Rationing: Although not a drought phase, local municipalities may, with the approval of the Pennsylvania Emergency Management Council, implement local water rationing to share a rapidly dwindling or severely depleted water supply in designated water supply service areas. These individual water rationing plans, authorized through provisions of 4 Pa. Code Chapter 120, will require specific limits on individual water consumption to achieve significant reductions in use. Under both mandatory restrictions imposed by the Commonwealth and local water rationing, procedures are provided for granting of variances to consider individual hardships and economic dislocations (PEMA, 2010).

Pennsylvania uses five parameters to assess drought conditions: precipitation deficits, stream flows, reservoir storage levels, groundwater levels, and a measure of soil moisture. These are described in detail below.

Precipitation Deficits: As rainfall provides the basis for both ground and surface water resources, precipitation deficits are the earliest indicators of a potential drought. The National Weather Service (NWS) records “normal” monthly precipitation data for each county in Pennsylvania. These figures are generated from long-term monthly and decennial averages of precipitation, updated at the end of each decade based upon the most recent 30 years. Monthly totals that are less than the normal values represent precipitation deficits, which are then converted to percentages of the normal values. Table 4.3.1-1 lists the drought conditions, as defined in the PA HMP and noted above, that are indicated by various precipitation deficit percentages (PEMA, 2010).

Table 4.3.1-1. Precipitation Deficit Drought Indicators for Pennsylvania

Duration of Deficit Accumulation (months)	Drought Watch (deficit as percent of normal precipitation)	Drought Warnings (deficit as percent of normal precipitation)	Drought Emergency (deficit as percent of normal precipitation)
3	25	35	45
4	20	30	40
5	20	30	40
6	20	30	40
7	18.5	28.5	38.5
8	17.5	27.5	37.5
9	16.5	26.5	36.5
10	15	25	35
11	15	25	35
12	15	25	35

Source: PEMA, 2010

Table 4.3.1-2 shows the precipitation normal, from 1971 to 2000, for the City of Allentown. These numbers are available through the National Climatic Data Center (NCDC), which compiles monthly and annual total precipitation (inches) normals data retrieved from both National Weather Service Cooperative Network (COOP) and Principal Observation (First-Order) locations throughout the U.S. While historical records show COOP stations in both the cities of Allentown and Bethlehem, the NCDC report only provides data for the former station (NC State University, 2012).

Table 4.3.1-2. Monthly and Annual Precipitation Normal (total in inches) from 1971 to 2000 for Select Municipalities in the Lehigh Valley

Station Name	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
Allentown	3.5	2.75	3.56	3.49	4.47	3.99	4.27	4.35	4.37	3.33	3.7	3.39	45.17

Source: NOAA, 2002

Stream Flows: Stream flows, which typically lag up to two months behind precipitation normals in signaling a drought, offer the second earliest indication of drought conditions. PADEP uses 73 U.S. Geological Survey (USGS)-maintained stream gauges throughout the State as its drought monitoring network, computing 30-day average stream flow values for each of the stream gages based on the entire period of record for each gage. For example, the Lehigh River gage in the City of Bethlehem has more than 100 years of record from which the long-term 30-day average, or normal, flows are now determined. Drought status is determined from stream flows based on exceedances, rather than percentages. The various stages of drought watch, warning and emergency conditions are indicated by the 75-, 90-, and 95-percent exceedance 30-day average flows, respectively (PEMA, 2010). Detailed methodology for these data collections is provided in the PA HMP.

Reservoir Storage Levels: Water level storage in three New York City reservoirs in the Upper Delaware River Basin and several other large public water supply reservoirs is another indicator used by PADEP for

drought monitoring. PADEP considers the percentage of storage drawdown for various reservoirs to determine drought stages, based on the length of refill period and total quantity of storage.

Groundwater Levels: Groundwater level can be an indicator of a developing drought, though low readings may lag up to three months behind drought-indicative precipitation readings. This is due to the nearly 80 trillion gallons of groundwater stored throughout the Commonwealth, which disguises precipitation deficits for many months before experiencing significant and noticeable effects of the lack of groundwater recharge (PEMA, 2010).

The USGS also maintains groundwater monitoring wells in each county throughout the Commonwealth. Groundwater measurements taken from these wells at exceedances of 75, 90 and 95 percent are used to indicate drought watch, warning and emergency statuses, respectively. Amongst the USGS well network, the 30-day average depth to groundwater readings are analyzed in relation to long-term 30-day averages based on the period of record for each county well (USGS, 2010).

Soil Moisture: NOAA's Palmer Drought Severity Index (PDSI) provides soil moisture information for evaluating the scope, severity, and frequency of prolonged periods of abnormally dry or wet weather. The tool is frequently used to indicate the availability of irrigation water supplies, reservoir levels, range conditions, amount of stock water, and forest fire potential. The PDSI is a notably ineffective tool for short-term drought monitoring forecasts; however it is the most effective for determining long-term droughts, and as such is most frequently used to delineate disaster areas (NWS CPC, 2005).

Table 4.3.1-3 lists the Palmer Classifications. Zero is used to reflect normal status, and droughts are indicated by negative numbers. For example, 0 is no drought, -2 is moderate drought, and -4 is extreme drought. Positive numbers represent excess precipitation (NOAA, Date Unknown).

Table 4.3.1-3. Palmer Drought Severity Index (PDSI) Classifications

Severity Category	PDSI Value	Drought Status
Extremely wet	4.0 or more	None
Very wet	3.0 to 3.99	None
Moderately wet	2.0 to 2.99	None
Slightly wet	1.0 to 1.99	None
Incipient wet spell	0.5 to 0.99	None
Near normal	0.49 to -0.49	None
Incipient dry spell	-0.5 to -0.99	None
Mild drought	-1.0 to -1.99	None
Moderate drought	-2.0 to -2.99	Watch
Severe drought	-3.0 to -3.99	Warning
Extreme drought	-4.0 or less	Emergency

Source: Hayes, 2006; PEMA, 2010

Water supply availability and management is discussed in the 2009 Pennsylvania State Water Plan, a joint effort by the Statewide Water Resources Committee and PADEP. In 2009, the PADEP Secretary approved an updated State Water Plan to guide the management of the State's water resources over a 15-year planning horizon. As a functional planning tool for all Pennsylvania municipalities, counties, and regional planning partnerships, the State Water Plan profiles drought and resource constraints and encourages the implementation of new technology and use policies to facilitate reduced water uses and resource demands at critical peak times. The plan provides inventories of water availability, as well as an assessment of current and future water use demands and trends. It also offers strategies for improving the

management of water resources and waterway corridors which aim to reduce damages from extreme drought and flooding conditions (PADEP, 2009).

4.3.1.3 Past Occurrence

Many sources provided historical information regarding previous occurrences and losses associated with drought events throughout Pennsylvania and more specifically 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 NOAA's NCDC storm events database, the Lehigh Valley experienced 42 drought events between April 30, 1950 and November 30, 2011. This total also includes damages in 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, eight drought events occurred within the Lehigh Valley. These numbers may vary from the NCDC accounts due to the database identifying the location of the hazard event in various forms or throughout multiple counties or regions.

Since 1930, the Commonwealth of Pennsylvania experienced ten significant droughts. Since 1955, the Commonwealth experienced 12 drought events that resulted in a governor's proclamation or a Federal Emergency Management Agency (FEMA) declared disaster or emergency. The Lehigh Valley was included in five of these events. In addition to these events, the PADEP indicated that the Lehigh Valley has experienced nine drought watch declarations, 11 drought warning declarations, and five drought emergency declarations between the years of 1980 and 2009 (PEMA, 2010).

Between 1954 and 2011, FEMA declared that Pennsylvania experienced one drought-related disaster (DR) or emergency (EM) classified as one or a combination of the following disaster types: drought or water shortage. Generally, these disasters cover a wide region of the Commonwealth; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations. Of those events, the FEMA, PEMA and other sources indicate that Northampton County has been declared as a disaster area as a result of a 1964-1966 drought-related event (FEMA, 2011).

Based on all sources researched, known drought events between 1895 and 2011 that have affected the Lehigh Valley are identified in Table 4.3.1-4. Not all sources have been identified or researched; therefore, Table 4.3.1-4 may not include all events that have occurred throughout the region.

Table 4.3.1-4. Past Occurrences of Drought Events from 1960 to 2011

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts	Source(s)
November 1895 – January 1896	Drought	N/A	N/A	Lowest PDSI of -3.97	NRCC
November 1900 – February 1901	Drought	N/A	N/A	Lowest PDSI of -4.06	NRCC
September 1909 – January 1910	Drought	N/A	N/A	Lowest PDSI of -4.43	NRCC
July – August 1910	Drought	N/A	N/A	Lowest PDSI of -3.27	NRCC
October 1910 – March 1911	Drought	N/A	N/A	Lowest PDSI of -4.08	NRCC
May – July 1911	Drought	N/A	N/A	Lowest PDSI of -3.76	NRCC
October – December 1914	Drought	N/A	N/A	Lowest PDSI of -3.82	NRCC
November – December 1922	Drought	N/A	N/A	Lowest PDSI of -3.90	NRCC
May – December 1923	Drought	N/A	N/A	Lowest PDSI of -4.29	NRCC
August 1930 – July 1931	Drought	N/A	N/A	Lowest PDSI of -4.95	NRCC
September 1931 – February 1932	Drought	N/A	N/A	Lowest PDSI of -4.40	NRCC
April – September 1932	Drought	N/A	N/A	Lowest PDSI of -4.24	NRCC
November 1939 – January 1940	Drought	N/A	N/A	Lowest PDSI of -3.90	NRCC

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts	Source(s)
September 1941 – February 1942	Drought	N/A	N/A	Lowest PDSI of -4.16	NRCC
September – November 1957	Drought	N/A	N/A	Lowest PDSI of -3.07	NRCC
August 1964 – January 1966	Drought, Water Shortage	DR-206	Northampton	In August, the Delaware River Basin was included in a FEMA disaster declaration. Lowest PDSI of -4.95	NRCC, PEMA, FEMA
June – November 1966	Drought	N/A	N/A	Lowest PDSI of -4.21	NRCC
January – February 1967	Drought	N/A	N/A	Lowest PDSI of -3.40	NRCC
August 1980 – January 1981	Drought	N/A	N/A	The Lehigh Valley was under a declared drought emergency in November. Lowest PDSI of -5.07	NRCC, PADEP, PEMA
March – July 1985	Drought	N/A	N/A	The Lehigh Valley was under a declared drought emergency between April and July. Lowest PDSI of -4.30	NRCC, PADEP, PEMA
August 1991 – February 1992	Drought	N/A	N/A	Lowest PDSI of -3.53	NRCC
September – November 1995	Drought	N/A	N/A	The Lehigh Valley was under a drought warning in early September and November. A drought emergency was declared for the Lehigh Valley in mid-September. Preliminary crop losses caused by the drought were $300 million statewide and $26,799 in the Lehigh Valley. No data on water supply problems/shortages for the Lehigh Valley was available.	PADEP, PEMA
December 1998 – July 1999	Drought	N/A	N/A	The Lehigh Valley was under a drought warning. The DRBC also declared a drought warning for the entire basin. The 0.62-inches of precipitation in December at the Lehigh Valley International Airport was the second driest December on record. In March 1999, the drought warning was downgraded to a drought watch due to a trend of above normal precipitation. By June, the state declared a drought warning again in 47 counties including all of eastern Pennsylvania due to unseasonably dry weather. Groundwater levels were extremely low in several counties in the lower part of the basin. The drought intensified in July and was the driest July on record at the Lehigh Valley International Airport. Open fires were banned in Northampton	PADEP

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts	Source(s)
				County. The Jordan Creek in South Whitehall Township stopped flowing.	
July – August 1999	Drought	N/A	N/A	The Lehigh Valley was under a drought emergency in July. It was estimated that the corn crop loss in the state could reach $100 million. In the Lehigh Valley, alfalfa cutting was expected to be one quarter of normal, the soybean crop one third of normal and the corn crop one half of normal. Low water levels made it difficult or impossible to use waterways for fishing and boating. Fish were dying due to low stream flows. By August, many farms in the Lehigh Valley and Berks County reported corn losses around 9%. The continued lack of rain resulted in wells going dry. Hardest hit were wells in Berks, Carbon and Montgomery counties. Lowest PDSI of -3.54. The drought emergency was lifted on September 30, 1999 after Hurricane Floyd. Agricultural losses throughout the state were estimated at about $700 million. Crop loss figures in the Lehigh Valley were $214,388 for 1998 and $2.2 million for 1999, totaling over $2.4 million for the two years. No data on water supply problems/shortages for the Lehigh Valley was available.	NRCC
December 18, 2001 - November 25, 2002	Drought	N/A	N/A	In November 2001, a drought warning was issued for eastern Pennsylvania due to unseasonably dry weather. Due to low groundwater levels caused by the drought, a well in East Allen Township ran dry, cutting off water service to 73 area homes. Water was trucked in to restore water service between August and November. From February to September, the Lehigh Valley was under a drought emergency. Groundwater levels were continuing to decline with streamflow levels reaching record low levels in some cases. Private wells were running dry in some areas including Chester and Montgomery Counties. Shallow wells were also going dry in Bucks and Carbon Counties. In August 2002, water once again had to be trucked in to serve customers at the East Allen Gardens subdivision in East Allen Township. It was estimated the drought cost farmers approximately $300 million across the state. Crop losses due to drought in the Lehigh Valley for 2002 were $4.2 million. No additional water supply problems/shortages for the Lehigh Valley were reported.	DIR, PA DEP, PEMA, PA HMP

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts	Source(s)
June – November 2005	Drought	N/A	N/A	A drought warning was put into effect September 12 by the Sellersville Borough Council; non-essential water use was prohibited. The warning was directed at the 1,800 water users because water levels at all three municipal wells were falling, with one well approximately 40 feet below normal. The Borough water treatment plant, which treats reservoir water, was closed for renovations. The reservoir had also fallen below normal levels and was about three-quarters empty. The reservoir normally holds about 14 million gallons, but was down to four or five million gallons. The Pennsylvania governor asked for $128 million in subsidence for farmers who lost a majority of their soybean, corn, hay, and alfalfa crops in 2005. After being declared a drought disaster, farmers were eligible for low interest loans from the USDA. The counties eligible for assistance were Armstrong, Bedford, Bradford, Centre, Clearfield, Clinton, Elk, Erie, Fayette, Fulton, Greene, Jefferson, Lackawanna, Lehigh, Luzerne, McKean, Pike, Potter, Sullivan, Susquehanna, Tioga, Washington, and Wayne.	DIR
June 2007 – January 2008	Drought	N/A	N/A	As a result of a dry summer, the Lehigh Valley remained under a declared drought watch as of January 1, 2008. Surface and groundwater conditions had improved during the last quarter of 2007 and the trend continued during the first few weeks of 2008. In response to the improvement, PADEP lifted drought watch declarations in the Lehigh Valley, along with 9 other Delaware River Basin counties on January 11, 2008.	DRBC
April – November 2010	Drought	N/A	N/A	The hot, dry summer and decreasing water supplies led Pennsylvania environmental authorities to issue a drought warning for 24 counties and asked residents to reduce their water use by 10 to 15 percent. The counties in the warning were Allegheny, Beaver, Bedford, Berks, Bucks, Carbon, Fayette, Franklin, Fulton, Greene, Huntingdon, Lackawanna, Lawrence, Lehigh, Luzerne, Mercer, Monroe, Montgomery, Northampton, Philadelphia, Pike, Schuylkill, Somerset, and Washington. Sixteen counties in Pennsylvania were declared to be natural disaster areas by the USDA due to an ongoing drought that started on May 25. The counties affected by the declaration included Bucks, Franklin, Monroe, Schuylkill, Carbon, Fulton, Montgomery, Snyder, Chester, Lehigh, Northampton, Union,	DIR, PADEP

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts	Source(s)
				Dauphin, Luzerne, Northumberland and York Counties. This declaration permitted impacted farmers, ranchers, and other agricultural producers to apply for low-interest emergency loans from the Farm Service Agency. In Northampton County, there was no significant rainfall since June 11th. Lawns were very brown and dry, small stream flow was reduced. Corn crops were dying.	

Sources: NRCC, 2012; DIR, 2012; DRBC, 2008; PEMA, 2010; PADEP, 2012.
Notes:
DIR: National Drought Mitigation Center Drought Impact Reporter
DRBC: Delaware River Basin Commission
NRCC: Northeast Regional Climate Center
PA HMP: Pennsylvania 2010 Standard All Hazard Mitigation Plan
PADEP: Pennsylvania Department of Environmental Protection
PEMA: Pennsylvania Emergency Management Agency

Table 4.3.1-5 displays the crop loss insurance payments on claims from the Lehigh Valley due to drought events since 1948.

Table 4.3.1-5. Crop Loss Insurance Claims Due to Drought

Crop Year	Total Claims	Crop Year	Total Claims
1948 - 1988	$346,721	2000	$3,466
1989	$0	2001	$440,747
1990	$0	2002	$4,223,046
1991	$69,113	2003	$0
1992	$0	2004	$0
1993	$36,390	2005	$848,019
1994	$0	2006	$152,694
1995	$26,799	2007	$237,300
1996	$0	2008	$456,108
1997	$8,755	2009	$0
1998	$214,388	2010	$1,077,812
1999	$2,230,116	2011	$8,264

Source: USDA, 2012

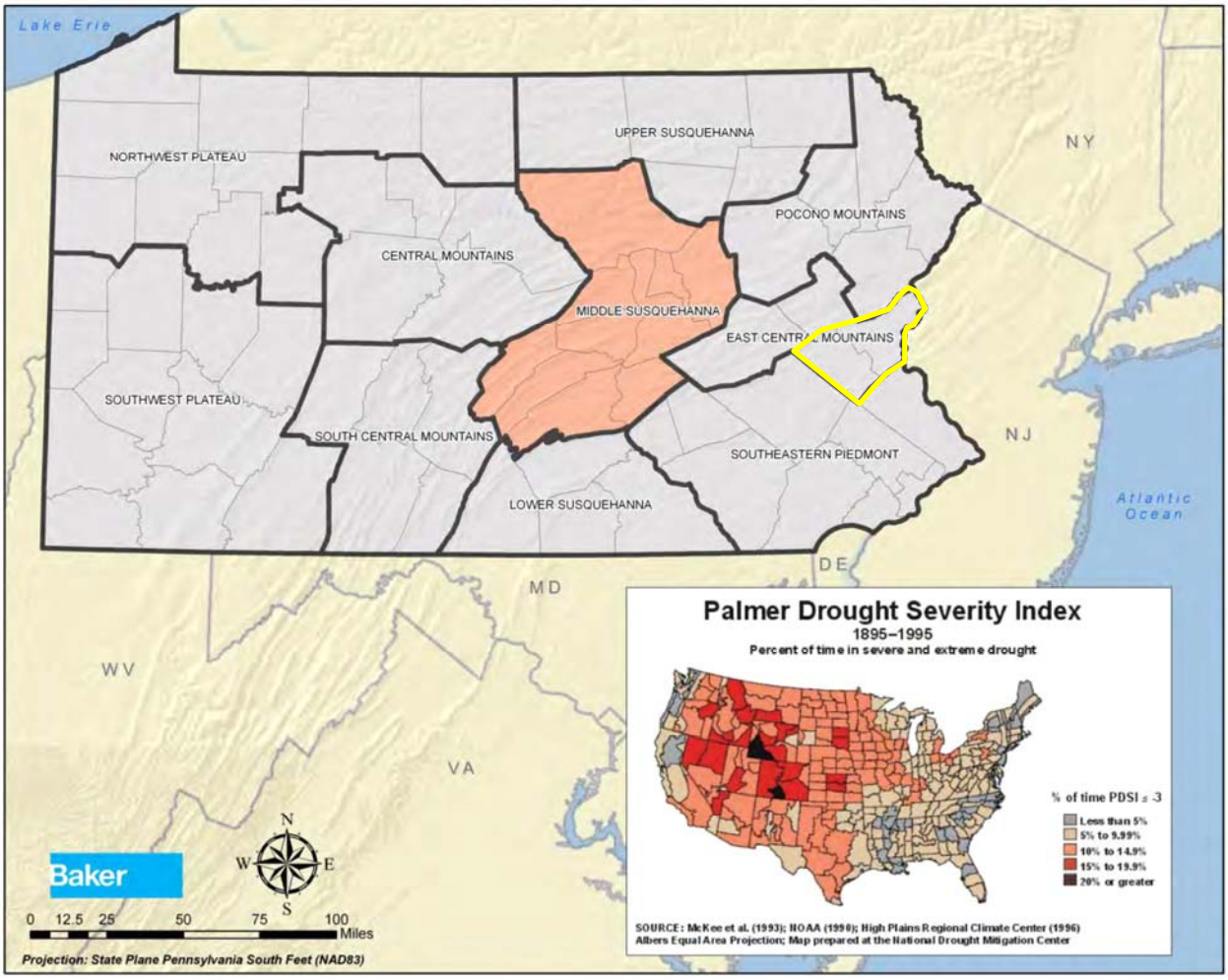
4.3.1.4 Future Occurrence

The frequency of droughts is difficult to forecast. It appears that the occurrences of drought are cyclical in nature and thus will occur in the future. The 2002 Lehigh Valley Planning Commission (LVPC) preliminary assessment indicates that water supply sources at the basin level should meet the needs of existing and future users through 2030 during a 25-year drought; however, more localized problems may occur as with the East Allen Township shortages reported during 2001 and 2002. Further details on the LVPC preliminary assessment are discussed in the 'Vulnerability Assessment' later in this Risk Assessment.

Based on national annual data from 1895 to 1995, the Lehigh Valley was in severe or extreme drought conditions approximately 5 to 9.9% of the time (refer to Figure 4.3.1-3). Based on national annual data from 1895 to 2011, the East Central Mountains (climate division 2), in which the Lehigh Valley is located, had an average PDSI of -.25. This climate division has been in severe or extreme drought during approximately 11 percent of the 117 years on record.

The future occurrence of drought events is considered *likely* as defined by the Risk Factor Methodology probability criteria (refer to Section 4.4).

Figure 4.3.1-3. Palmer Drought Severity Index for Pennsylvania (1895 to 1995)



Source: PEMA, 2010 (highlight added)
Note: Highlight added.

4.3.1.5 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed and vulnerable in the identified hazard area. For the drought hazard, all of the 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 to a drought. The following text evaluates and estimates the potential impact of the drought hazard on the Lehigh Valley including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (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

4.3.1.5.1 Overview of Vulnerability

All of the Lehigh Valley is vulnerable to drought. Assets at particular risk would include any open land or structures located along the wildland/urban interface (WUI) that could become vulnerable to the wildfire hazard due to extended periods of low rain and high heat, usually associated with a drought. In addition, water supply resources could be impacted by extended periods of low rain. Finally, vulnerable populations could be particularly susceptible to the drought hazard and cascading impacts due to age, health conditions, and limited ability to mobilize to shelter, cooling and medical resources.

4.3.1.5.2 Data and Methodology

At the time of this Plan, insufficient data was available to model the long-term potential impacts of a drought 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.

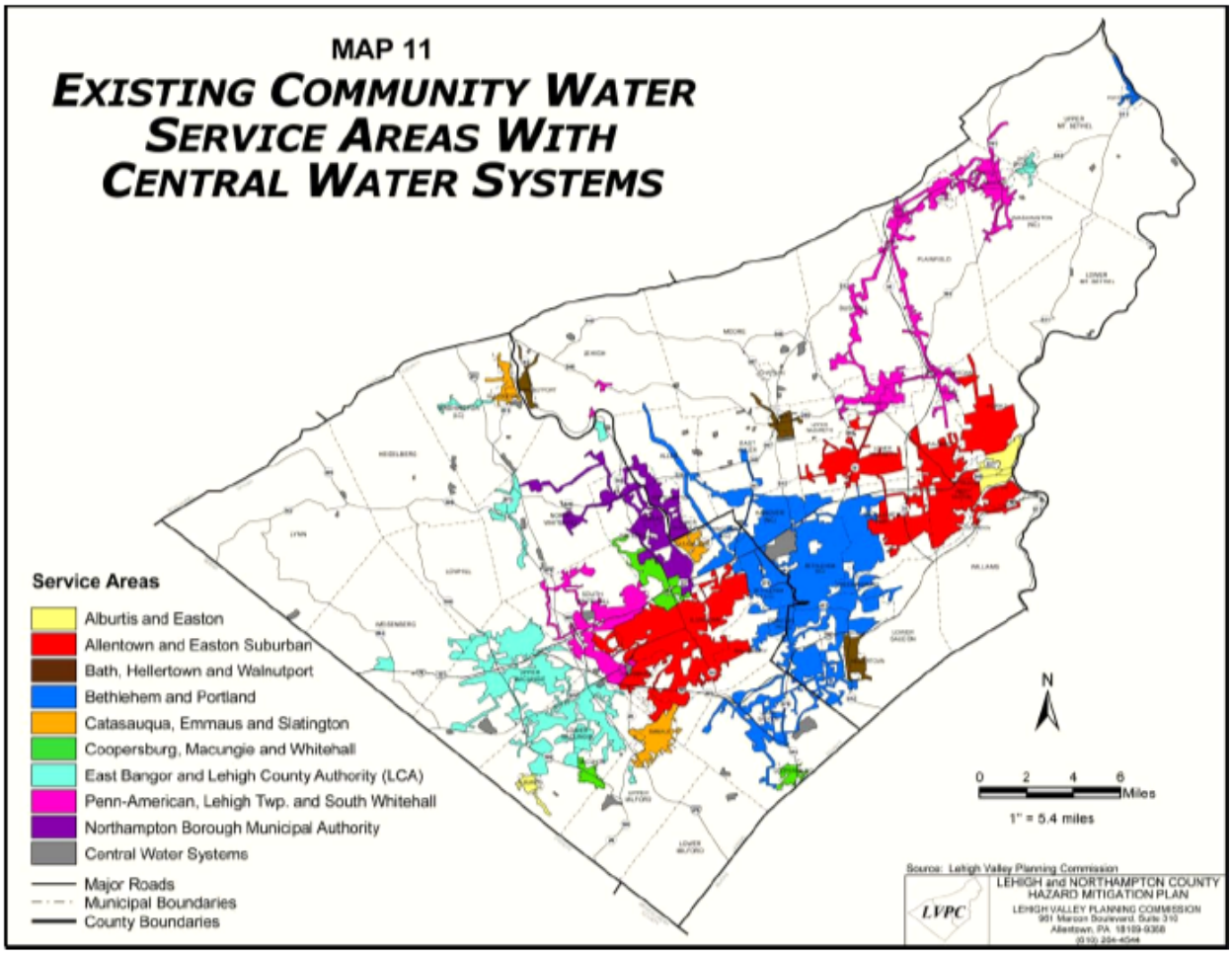
4.3.1.5.3 Impact on Life, Health and Safety

Drought conditions can cause a shortage of water for human consumption and reduce local firefighting capabilities. The drought hazard is a concern because private water supply sources in the Lehigh Valley come from local groundwater sources.

In 2002, the LVPC completed a preliminary assessment report of the Lehigh Valley's water resources. The purpose of the assessment was to identify current and future well water users of all types through 2030 and groundwater availability during normal and drought conditions. Types of users include community and central water systems, as shown on Figure 4.3.1-4 below, and users with their own individual well such as commercial agriculture production operations, golf courses, residential, commercial/industrial and water bottling operations. For the study, the LVPC defined 22 groundwater basins based on surface water divides and geology. From published data, groundwater recharge rates for the different geologic units in the Lehigh Valley were selected. In addition to average year recharge conditions, two drought conditions were included: 10-year and 25-year droughts. The study also included a standard condition used by the DRBC in the special groundwater protected areas in southeastern Pennsylvania that identifies when a basin has become potentially stressed.

For the study, groundwater recharge was compared with the estimated amount of well withdrawals now and in the future under average year and drought conditions. From the available data, it was found that well water demand should not exceed groundwater supply during normal and drought conditions through 2030 on a basin level. It should be noted that one of the main findings of the assessment was the lack of up-to-date, reliable data on water usage and groundwater recharge from PADEP, DRBC and USGS.

Figure 4.3.1-4. Existing Community Water Service Areas with Central Water Systems



Source: LVPC, 2006

Social impacts of a drought include mental and physical stress, public safety (increased threat from forest/grass fires), health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts and disaster relief. The infirm, young, and elderly are particularly susceptible to drought and extreme temperatures, sometimes associated with drought conditions, due to their age, health conditions and limited ability to mobilize to shelters, cooling and medical resources. Impacts on the economy and environment may have social implications as well (NYSDPC, 2011). For the purposes of this Plan, the entire population in the Lehigh Valley is vulnerable to drought events.

4.3.1.5.4 Impact on General Building Stock and Critical Facilities

No structures are anticipated to be directly affected by a drought, and all are expected to be operational during a drought event. However, droughts contribute to conditions conducive to wildfires. Risk to life and property is greatest in those areas where forested areas adjoin urbanized areas (high density residential, commercial and industrial), also known as the WUI. Therefore, all assets in and adjacent to the WUI zone, including population, structures, critical facilities, lifelines, and businesses are considered vulnerable to wildfire. Please refer to Section 4.3.10 regarding the wildfire hazard in the Lehigh Valley.

4.3.1.5.5 Impact on the Economy

A prolonged drought can have serious direct and indirect economic impacts on a community or across the Lehigh Valley. A summary of impacts on the economy is presented in Table 4.3.1-6.

Table 4.3.1-6. Impacts on the Economy

Losses to Agricultural Producers	Losses to Livestock Producers	Loss from Timber Production
Annual and perennial crop losses	Reduced productivity of rangeland	Wildland fires
Damage to crop quality	Reduced milk production	Tree disease
Income loss for farmers due to reduced crop yields	Forced reduction of foundation stock	Insect infestation
Reduced productivity of cropland (wind erosion, long-term loss of organic matter, etc.)	High cost/unavailability of water for livestock	Impaired productivity of forest land
Insect infestation	Cost of new or supplemental water resource development (wells, dams, pipelines)	Direct loss of trees, especially young ones
Plant disease	High cost/unavailability of feed for livestock	**Transportation Industry**
Wildlife damage to crops	Increased feed transportation costs	Loss from impaired navigability of streams, rivers, and canals
Increased irrigation costs	High livestock mortality rates	**Decline in food production/disrupted food supply**
Cost of new or supplemental water resource development (wells, dams, pipelines)	Disruption of reproduction cycles (delayed breeding, more miscarriages)	Increase in food prices
Loss from Fishery Production	Decreased stock weights	Increased importation of food (higher costs)
Damage to fish habitat	Increased predation	**Water Suppliers**
Loss of fish and other aquatic organisms due to decreased flows	Grass fires	Revenue shortfalls and/or windfall profits
Loss to Recreation and Tourism Industry	**Energy-related Effects**	Cost of water transport or transfer
Loss to manufacturers and sellers of recreational equipment	Increased energy demand and reduced supply because of drought-related power curtailments	Cost of new or supplemental water resource development
Losses related to curtailed activities: hunting and fishing, bird watching, boating, etc.	Costs to energy industry and consumers associated with substituting more expensive fuels (oil) for hydroelectric power	

Source: NYSDPC, 2011

Loss estimation stems from lost agricultural revenues statewide. Table 4.3.1-7 below enumerates each county's farmland acreage exposure to the drought hazard as well as the annual market value of all agricultural products sold, as documented in the 2007 USDA Census of Agriculture. Lehigh County is threatened with higher agricultural losses than Northampton County. If a drought were to eliminate the entire Lehigh Valley's agricultural yield, total losses may exceed $100 million which would be devastating to the local economy (PEMA, 2010).

Table 4.3.1-7. Estimated County Losses Relating to Agricultural Production

County	Farmland Acreage Exposed	Market Value Of All Agricultural Products
Lehigh	84,643	$72,059,000
Northampton	68,252	$31,762,000

Source: PEMA, 2010

4.3.1.5.6 Impact on the Environment

As summarized in the PA HMP, environmental impacts of drought include:

- Hydrologic effects – lower water levels in reservoirs, lakes and ponds; reduced streamflow; loss of wetlands; estuarine impacts; groundwater depletion and land subsidence; effects on water quality such as increases in salt concentration and water temperature;
- Damage to animal species – lack of feed and drinking water; disease; loss of biodiversity; migration or concentration; and reduction and degradation of fish and wildlife habitat;
- Damage to plant communities – loss of biodiversity; loss of trees from urban landscapes and wooded conservation areas;
- Increased number and severity of fires;
- Reduced soil quality;
- Air quality effects – dust and pollutants; and
- Loss of quality in landscape through loss in plants and plant diversity (PEMA, 2010).

4.3.1.5.7 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 drought on agriculture will likely decrease. There are no potential losses likely for existing and future structures associated with drought conditions.

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 HMP. 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 drought hazard.

4.3.1.5.8 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 droughts. While predicting changes of drought 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 Pennsylvania Climate Impact Assessment's main findings indicate it is very likely that

Pennsylvania will experience increased temperatures in the 21st century. Increases in temperature will likely lead to increased evapotranspiration and thus an increase in soil-moisture-related droughts throughout late spring and early fall. Pennsylvania's precipitation climate is projected to become more extreme in the future, with longer dry periods and greater intensity of precipitation. Most models indicate the maximum number of consecutive dry days in a year, a drought indicator, is projected to increase (Shortle et. al, 2009).

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, storm frequency, and intensity in Pennsylvania and thus provide better indication for future drought events (Shortle et. al, 2009).

4.3.1.5.9 Additional Data and Next Steps

For future plan updates, localized concerns and impacts will be collected and analyzed.