4.3.2 Drought

This section provides a profile and vulnerability assessment of the drought hazard in Pike County. Drought is a period characterized by long durations of below normal precipitation. Drought conditions occur in virtually all climatic zones, yet characteristics of drought vary significantly from one region to another, relative to normal precipitation within respective regions. Drought can affect agriculture, water supply, aquatic ecology, wildlife, and plant life. Drought is a temporary irregularity in typical weather patterns and differs from aridity, which reflects low rainfall within a specific region and is a permanent feature of the climate of that area.

Drought can be defined or grouped in four categories:

- Meteorological drought is a measure of departure of precipitation from normal, defined solely by reference to relative degree of dryness. Because of climatic differences, dryness considered a drought at one location of the country may not be considered drought at another location.
- Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and other parameters. Agricultural drought occurs when not enough water is available for a particular crop to grow at a particular time. Agricultural drought is defined in terms of soil moisture deficiencies relative to water demands of plant life, primarily crops.
- Hydrological drought is associated with below normal surface or subsurface water supply resulting from periods of precipitation shortfalls (including snowfall). Hydrological drought is related to effects of precipitation shortfalls on stream flows and water levels in reservoirs, lakes, and groundwater.
- Socioeconomic drought is associated with supply and demand of an economic good, with elements of meteorological, hydrological, and agricultural drought. This differs from the aforementioned types of drought because its occurrence depends on supply and demand to identify or classify droughts. Supplies of many economic goods such as water, silage, food grains, fish, and hydroelectric power depend on weather. Socioeconomic drought occurs when demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply (National Drought Mitigation Center [NDMC] 1985).

Drought can affect many sectors of an economy and can reach beyond an area undergoing physical drought. Because water is essential for producing goods and providing services, drought can reduce crop yield, increase fire hazard, lower water levels, and damage wildlife and fish habitat. Further consequences of these impacts include reductions in crop yields, rangeland, and forest productivity that may lower incomes of farmers and agribusinesses; increased prices of food and timber; increased unemployment; reduction in tax revenues as expenditures decline; increased crime, foreclosures, and migration; and exhausted disaster relief funds. The many impacts of drought can be categorized as economic, environmental, or social.

Scientists at this time do not know how to predict drought more than 1 month in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades. How long they last depends on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and accumulated influence of weather systems on the global scale (NDMC Date Unknown).

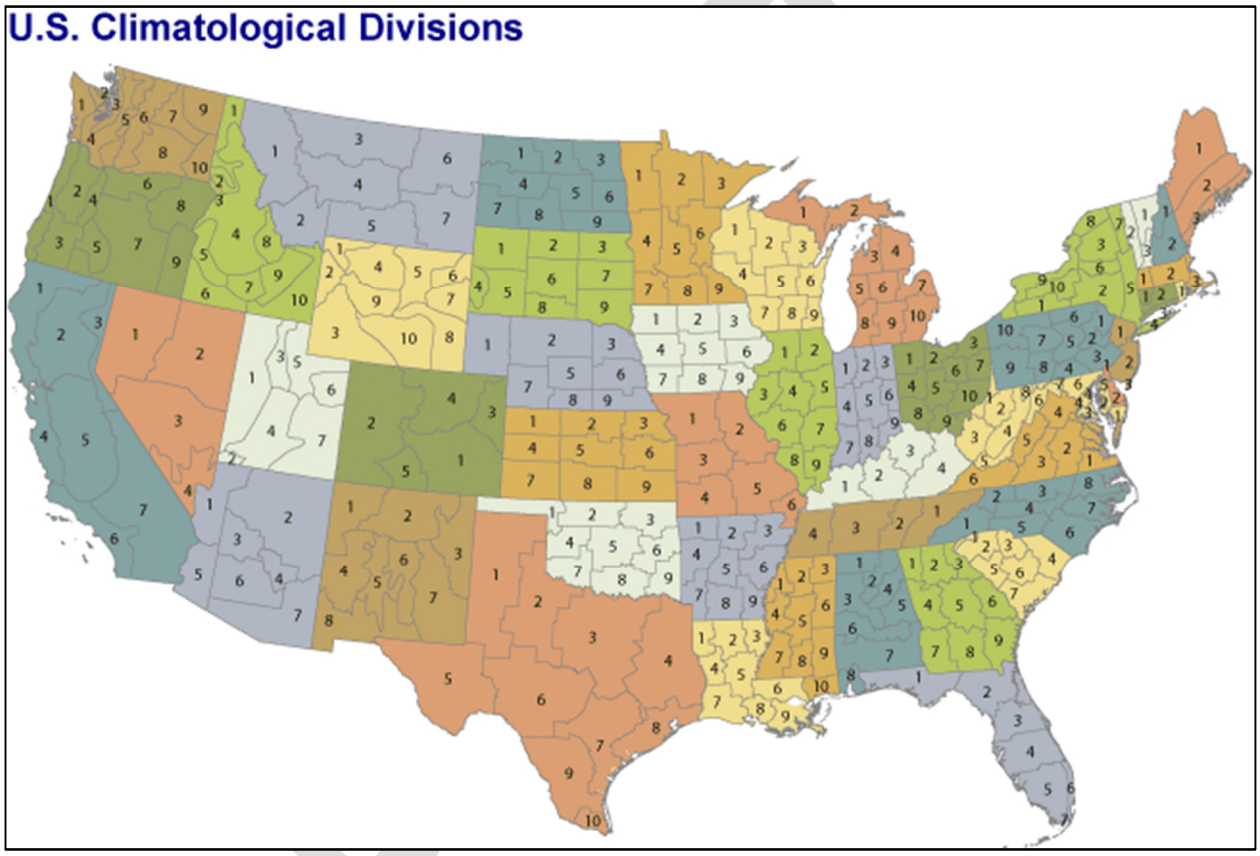
Location and Extent

Droughts are regional in scope and may affect the entirety of Pike County rather than only individual municipalities within the County. Droughts may also concurrently affect counties near Pike County, or even the entire State. Generally, areas along waterways will indicate drought conditions later than 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 United States into 359 climate divisions. The boundaries of these divisions typically coincide with county boundaries, except in the western United States where they are based largely on drainage basins (Climate Prediction Center [CPC] 2005).

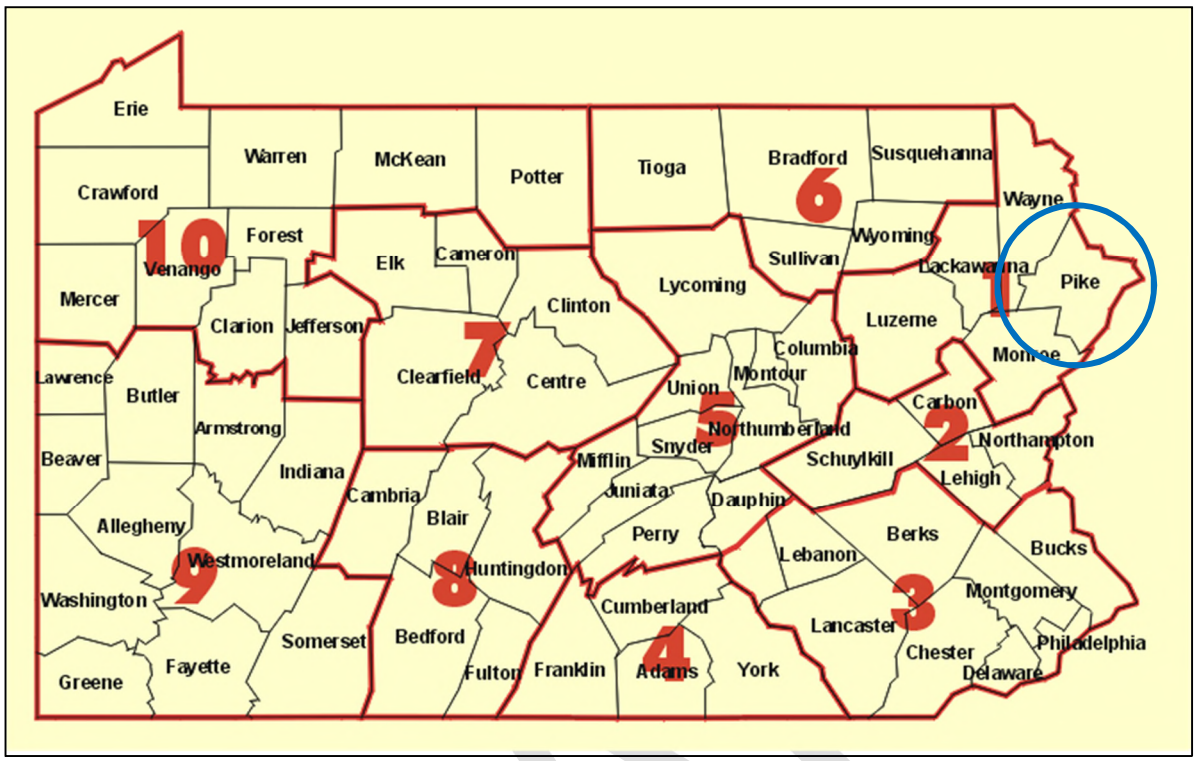
According to NOAA, Pennsylvania includes 10 climate divisions: Pocono Mountains, East Central Mountains, Southeastern Piedmont, Lower Susquehanna, Middle Susquehanna, Upper Susquehanna, Central Mountains, South Central Mountains, Southwest Plateau, and Northwest Plateau Climate Division (National Climatic Data Center [NCDC] 2015). Figure 4.3.2-1 shows the climate divisions throughout the United States, and Figure 4.3.2-2 shows the climate divisions of Pennsylvania. Pike County is within the Pocono Mountains climate division.

Figure 4.3.2-1. Climate Divisions in the United States



Source: NCDC 2012
Notes: 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 4.3.2-2. Climate Divisions of Pennsylvania



Source: CPC 2005
Note (1): 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
Note (2): The blue circle indicates the location of Pike County.

Particularly at locations where citizens rely on wells for drinking water, water supplies are vulnerable to effects of drought and thus can impact the severity of a drought. Residents depending on well water can more easily handle short-term droughts without major inconveniences than can populations that rely on surface water. However, longer-term droughts inhibit groundwater aquifers from recharging and can thus extend the problems of well owners for an indeterminate amount of time—Pike County residents who depend on private domestic wells have this greater "hidden vulnerability" to droughts.

According to the Pennsylvania Groundwater Information System (PaGWIS) there are 4,315 domestic private wells in Pike County. PaGWIS is maintained by Pennsylvania Department of Conservation and Natural Resources (DCNR) and relies on voluntary submissions of well record data by well drillers; as a result, it is not a complete database of all domestic wells in the County. It is, however, the most complete dataset of domestic wells available. Refer to the Vulnerability Assessment for further discussion.

In addition to domestic wells in the County, residents may also receive their water from municipal water providers. According to the U.S. Environmental Protection Agency (EPA), there are 38 community water systems in Pike County. These systems provide water year-round to over 41,000 people. Public water systems in the County procure their water from groundwater. Additionally, there are 214 non-transient or transient non-community water systems that provide water to over 51,000 people. Non-transient, non-community water systems provide water to the same people, but not year round (e.g. schools that have their own water system). Transient, non-community water systems do not consistently provide water to the same people (e.g. rest stops,

campgrounds, gas stations). These systems all receive water from groundwater sources. Table 4.3.2-1 below provides information regarding the community water systems located within Pike County, as identified by the U.S. EPA.

Table 4.3.2-1. Community Water Systems in Pike County

Water System Name	Population Served	Primary Water Source Type
Aqua PA Fawn Lake Forest	6,533	Ground water
Aqua PA Tafton Wilson Hill	80	Ground water
Aqua PA Tanglewood Lakes	1,321	Ground water
Aqua PA Woodledge Village	58	Ground water
Crescent Lake North Comm Assoc	80	Ground water
Deerhaven White Beauty View Es	53	Ground water
Grampas Woods Estates	45	Ground water
Happy Hollow	89	Ground water
Hemlock Farms (Main)	8,321	Ground water
Hitching Post Assoc	90	Ground water
Killiam Tract	39	Ground water
Lake Wallenpaupack Estates POA	204	Ground water
Laurel Lane Development Assoc	179	Ground water
Laurel Woods Mobile Home Park	70	Ground water
Milford Senior Care	110	Ground water
Milford Water Authority	2,420	Groundwater under influence of surface water
Moon Valley Falls	120	Ground water
Muni Auth Of Boro Of Matamoras	2,900	Ground water
Oak Manor Estates	46	Ground water
Pawc All Seasons System	100	Ground water
Pawc Marcel Lakes	845	Ground water
Pawc Milford Landing	468	Ground water
Pawc Pocono Mtn Lake Forest	180	Ground water
Pawc Saw Creek Estates	6,833	Ground water
Pawc Wild Acres	2,943	Ground water
Pike County Correctional Facil	376	Ground water
Pine Ridge System	2,450	Ground water
Poc Mtn Lake Est Sect 1e	140	Ground water
Pocono Mtn Lake Estates Sect5a	150	Ground water
Pocono Ranch Lands Sect 4	225	Ground water
Rustic Acres Mhp	73	Ground water
Tamiment Resort	1,200	Ground water
Tanglewood Ski Aqua PA	690	Ground water
The Escape	1,100	Ground water
Tranquility Falls	121	Ground water
Twin Lakes Utilities Inc	300	Ground water
Wheatfield Village	35	Ground water

Water System Name	Population Served	Primary Water Source Type
White Sand Springs	40	Ground water

Source: U.S. EPA 2016

Range of Magnitude

Effects of droughts vary depending on their severity, timing, duration, and location. Some droughts may exert their greatest impact on agriculture, while others may have stronger effects on water supply or recreational activities. Droughts can adversely affect the following significantly:

- 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.

Pennsylvania Department of Environmental Protection (PADEP) and Pennsylvania Emergency Management Agency (PEMA) manage water supply droughts in Pennsylvania according to the following four conditions of drought defined in the Commonwealth of Pennsylvania 2013 Standard Hazard Mitigation Plan (PA HMP):

- Drought Watch: A period to alert government agencies, public water suppliers, water users, and the public regarding potential for future drought-related problems. The focus is on increased monitoring, awareness, and preparation for response in the event that conditions worsen. A request for voluntary water conservation is issued. The objective of voluntary water conservation measures during a drought watch is to reduce water use by 5 percent within the affected areas. Because of varying conditions, individual water suppliers or municipalities may ask for more stringent conservation actions.
- Drought Warning: This is a drought stage involving 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 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 within the affected areas. Because of varying conditions, individual water suppliers or municipalities may ask for more stringent conservation actions.
- Drought Emergency: During this drought stage, water management entities marshal all available resources to respond to actual emergency conditions, avoid depletion of water sources, ensure at least minimum water supplies to protect public health and safety, support essential and high-priority water uses, and avoid unnecessary economic dislocations. If deemed necessary and if ordered by the Governor during this stage, imposition of mandatory restrictions on nonessential water usage could occur as provided for in 4 *Pa. Code* Chapter 119. Objectives of water use restrictions (mandatory or voluntary) and other conservation measures during a drought emergency are to reduce consumptive water use within the affected areas by 15 percent, and to reduce total use to the extent necessary to preserve public water system supplies, avoid or mitigate local or area shortages, and ensure equitable sharing of limited supplies.
- Local Water Rationing: This fourth condition of drought is not defined as a drought stage. 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 within designated water supply service areas. These individual water rationing plans, authorized through provisions of 4 *Pa. Code* Chapter 120, 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 practices, procedures are specified for granting variances in consideration of individual hardships and economic dislocations (PEMA 2013).

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 groundwater 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, and are updated at the end of each decade based on the most recent 30 years. Monthly totals less than normal values represent precipitation deficits, which are then converted to percentages of the normal values. Table 4.3.3-3 lists the drought conditions (defined in the PA HMP and noted above) that are indicated by various precipitation deficit percentages (PEMA 2013).

Table 4.3.2-2. Precipitation Deficit Drought Indicators for Pennsylvania

Duration of Deficit Accumulation (months)	Drought Watch (deficit as percent of normal precipitation)	Drought Warning (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 2013

- Stream Flows: Stream flows, which typically lag up to 2 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 stream gauge based on the entire period of record for each gauge. For example, the Tonoloway Creek gauge near Needmore has data records as far back as October 1965 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, respectively, by 75-, 90-, and 95-percent exceedances of 30-day average flows (PEMA 2013). Detailed descriptions of these data collection methods appear in the PA HMP.
- Reservoir Storage Levels: Water level storage in several large public water supply reservoirs is another indicator that PADEP uses for drought monitoring. Depending on total quantity of storage and length of the refill period for the various reservoirs, PADEP uses varying percentages of storage drawdown to indicate the three drought stages for each reservoir (PEMA 2013).
- Groundwater Levels: Groundwater levels can be an indicator of a developing drought, although low readings may lag up to 3 months behind drought-indicative precipitation readings. This lag occurs because storage of nearly 80 trillion gallons of groundwater throughout the Commonwealth disguises precipitation deficits before significant lack of groundwater recharge becomes noticeable (PEMA 2013).

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. Within 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 (PEMA 2013).

- 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 availability of irrigation water supplies, reservoir levels, range conditions, amount of stock water, and forest fire potential. Although notably ineffective for monitoring short-term drought, the PDSI is effective for determining long-term droughts, and as such is most frequently used to delineate disaster areas (CPC 2005).

Table 4.3.2-3 lists PDSI classifications. The PDSI uses 0 to reflect normal status, and negative numbers indicate droughts. For example, 0 is no drought, -2 is moderate drought, and -4 is extreme drought. Positive numbers signify excess precipitation (NDMC 2013).

Table 4.3.2-3. 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: NDMC 2013; PEMA 2013

Availability and management of water supply are 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 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 implementation of new technology and application of 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 management of water resources and waterway corridors that aim to reduce damages from extreme drought and flooding conditions (PADEP 2009).

Past Occurrence

Historical information has been drawn from many sources to recount previous occurrences and losses associated with drought events throughout Pennsylvania and Pike County. Because so many sources were reviewed for the purpose of developing this plan, loss and impact information pertaining to many events could vary depending on the source. Therefore, accuracy of cited monetary values is based only on the available information identified during research for this plan.

According to the National Centers for Environmental Information (NCEI) Storm Events Database, Pike County underwent three drought events between January 1, 1950 and June 30, 2016. Overall, these events led to $200,000 in crop damages (NCEI 2016).

Since November 1980, PADEP indicated that Pike County has undergone 18 drought-watch declarations, 16 drought-warning declarations, and 13 drought-emergency declaration between November 1980 and August 2016 (PADEP 2016). Additionally, according to the Cornell Northeast Regional Climate Center (NRCC), Pike County is located within the Pocono Mountains Climate Division, which has experienced seven drought periods of two or more months within severe or extreme drought (NRCC 2016).

According to FEMA, between 1954 and 2016, Pennsylvania underwent one drought-related disaster (DR) or emergency (EM) classified as one or a combination of the following disaster types: drought or water shortage. Because these disaster types generally cover a wide region of the Commonwealth, this single disaster impacted many counties. However, not all counties were included in the disaster declaration. FEMA, PEMA, and other sources indicate that Pike County was included in the major disaster declaration (DR-206) as a result of a drought-related event (FEMA 2016).

Based on all sources researched, drought events between 1963 and 2016 that have affected Pike County are identified in Table 4.3.2-4. Please note that not all sources have been identified or researched, and therefore Table 4.3.2-4 may not include all events that have occurred throughout the County.

Table 4.3.2-4. Pike County Declared Drought Status from 1963 to 2016

Date	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts / PDSI Value	Source(s)
October – December 1963	Drought	N/A	N/A	Three month duration of severe to extreme drought conditions in the Pocono Mountains Climate Division, which includes Pike County. Lowest PDSI for the Climate Division was -3.64 recorded in October 1963	NRCC
August 1964 – April 1966	Water Shortage / Drought	DR-206	Yes	Twenty-one month duration of severe to extreme drought conditions in the Pocono Mountains Climate Division, which includes Pike County. Lowest PDSI for the Climate Division was -5.47 recorded in July 1965.	FEMA, NRCC
June – November 1966	Drought	N/A	N/A	Six month duration of severe to extreme drought conditions in the Pocono Mountains Climate Division, which includes Pike County. Lowest PDSI for the Climate Division was -4.29 recorded in August 1966	NRCC
January – February 1967	Drought	N/A	N/A	Two month duration of severe to extreme drought conditions in the Pocono Mountains Climate Division, which includes Pike County. Lowest PDSI for the Climate Division was -3.95 recorded in February 1967.	NRCC
1977	Drought	N/A	N/A	The Matamoras Municipal Water Authority was forced to drill several new wells when their original artesian wells began to dry up. For several weeks, water was pumped across the Delaware River Bridge from Port Jervis, New York into the Matamoras system.	Pike County HMP 2012
November 18, 1980 – April 20, 1982	Drought Emergency	N/A	N/A	According to the NRCC, there was a two month duration of severe to extreme drought conditions in the Pocono Mountains Climate Division, which includes Pike County, from December 1980 to January 1981. Lowest PDSI for the Climate Division during this time frame was -3.95 recorded in January 1981.	PADEP, NRCC
November 10, 1982 – February 8, 1983	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP
February 8, 1983 – March 28, 1983	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP
January 23, 1985 – April 26, 1985	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP
April 26, 1985 – December 19, 1985	Drought Emergency	N/A	N/A	No impacts and/or losses identified for this event.	PADEP
July 7, 1988 - August 24, 1988	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
August 24, 1988 - December 12, 1988	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
June 28, 1991 - July 24, 1991	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
July 24, 1991 - August 16, 1991	Drought Emergency	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
August 16, 1991 -	Drought	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike

Date	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts / PDSI Value	Source(s)
September 13, 1991	Emergency				County HMP 2012
September 13, 1991 - October 21, 1991	Drought Emergency	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
October 21, 1991 - January 16, 1992	Drought Emergency	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
January 17, 1992 - April 20, 1992	Drought Emergency	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
April 20, 1992 - June 23, 1992	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
September 1, 1995 - September 20, 1995	Drought Warning	N/A	N/A	Lowest PDSI for the Pocono Mountains Climate Division was -3.64 recorded in September 1995	PADEP, NRCC, Pike County HMP 2012
September 20, 1995 - November 8, 1995	Drought Emergency	N/A	N/A	Lowest PDSI for the Pocono Mountains Climate Division was -3.64 recorded in September 1995	PADEP, NRCC, Pike County HMP 2012
November 8, 1995 - December 18, 1995	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
August 1997	Drought	N/A	N/A	The impacted counties had approximately $1.4 million in crop damage. Pike County had approximately $200,000 in crop damage as a result of this drought event.	NCEI
December 3, 1998 - December 8, 1998	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
December 8, 1998 - December 14, 1998	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
December 14, 1998 - December 16, 1998	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
December 16, 1998 - January 15, 1999	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
January 15, 1999 - March 15, 1999	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
March 15, 1999 - June 10, 1999	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
June 10, 1999 - June 18, 1999	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
June 18, 1999 - July 20, 1999	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
July 20, 1999 - September 30,1999	Drought Emergency	N/A	N/A	The lowest PDSI for the Pocono Mountains Climate Division was -3.65 recorded in August 1999.	PADEP, NRCC, Pike County HMP 2012

Date	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts / PDSI Value	Source(s)
July 1999	Drought	N/A	N/A	Governor Tom Ridge – Governor's Proclamation, Individual Assistance, Hazard Mitigation Grant Program – Amended to include all 67 counties for an agricultural disaster.	PEMA
September 30, 1999 - December 16, 1999	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
December 16, 1999 - Feb 25,2000	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
Feb 25, 2000 - May 5, 2000	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
August 24, 2001 - November 6, 2001	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
November 6, 2001 - December 5, 2001	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
December 5, 2001 - Feb 12, 2002	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
Feb 12, 2002 - May 13, 2002	Drought Emergency	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
September 5, 2002 - November 7, 2002	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
April 11, 2006 - June 30, 2006	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
August 8, 2007 - September 5, 2007	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
September 16, 2010 – November 10, 2010	Drought Warning	N/A	N/A	No impacts and/or losses identified for this event.	PADEP, Pike County HMP 2012
June 28, 2012 – November 8, 2012	Drought	N/A	N/A	The combined effects of drought, high winds, hail, excessive heat, excessive rain, flash flooding, Hurricane sandy, snowstorms, and Nor'Easters, led to the USDA disaster declaration (S3487) for Pike County.	USDA
2014	Drought	N/A	N/A	Drought conditions led to a USDA disaster declaration (S3759) for Pike County.	USDA
March 24, 2015 – June 17, 2015	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP
June 17, 2015 – July 10, 2015	Drought Watch	N/A	N/A	No impacts and/or losses identified for this event.	PADEP
April – September 2015	Drought	N/A	N/A	Excessive heat and drought led to a USDA disaster declaration (S3930) for Pike County.	USDA
November 2016	Drought Warning/Watc	N/A	N/A	The PADEP declared a drought watch for Pike County on November 9th and the county is still under a drought watch as of November 23rd. The PADEP	PADEP

Date	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts / PDSI Value	Source(s)
	h			encourages those under a drought watch to reduce their nonessential water use by 5%.	

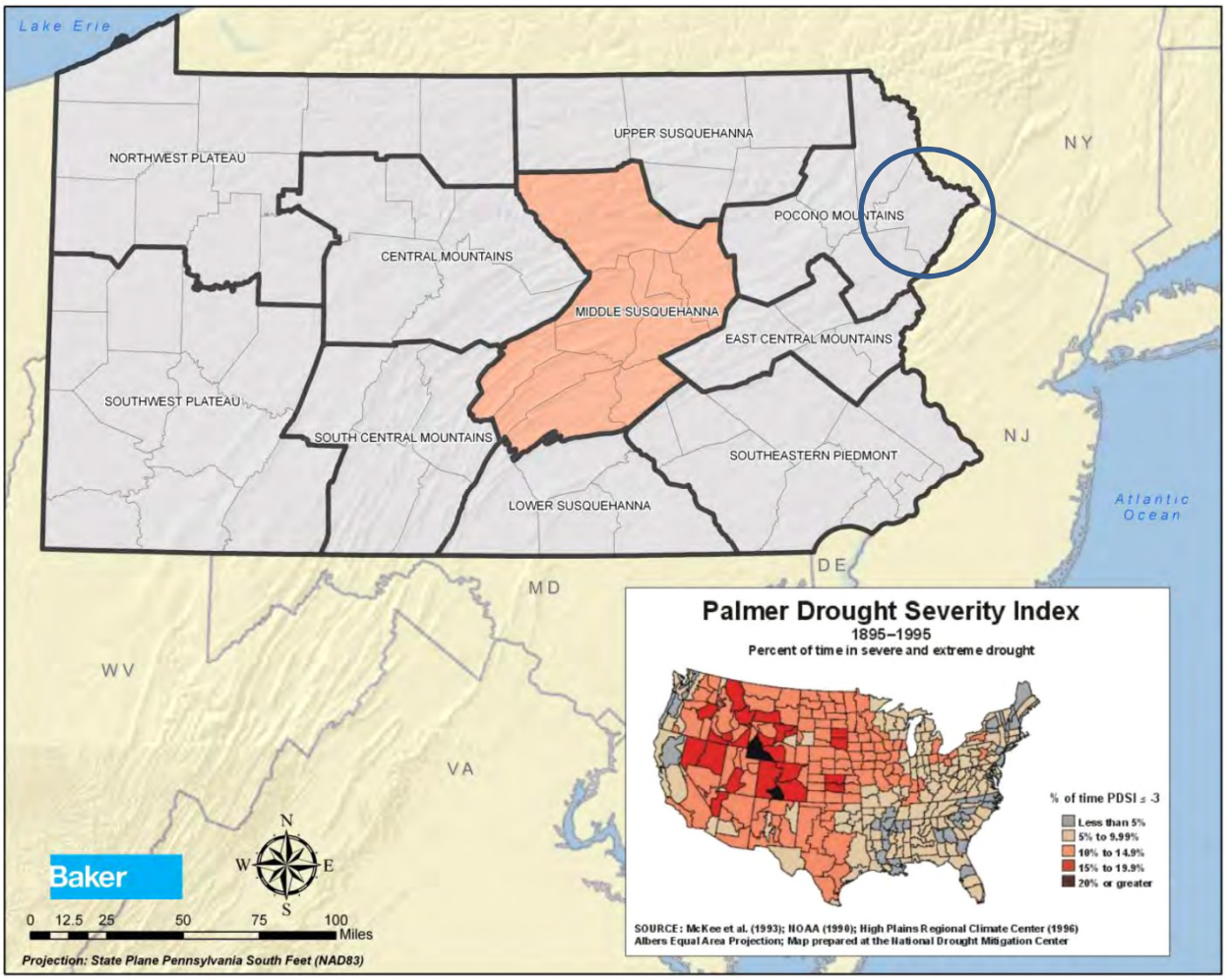
Sources: *FEMA 2016; NCEI 2016; NRCC 2016; Pike County HMP 2012; PADEP 2016*

FEMA *Federal Emergency Management Agency*
N/A *Not applicable*
NCEI *National Centers for Environmental Information*
NRCC *Northeast Regional Climate Center*
PADEP *Pennsylvania Department of Environmental Protection*
PDSI *Palmer Drought Severity Index*
PEMA *Pennsylvania Emergency Management Agency*
USDA *U.S. Department of Agriculture*

Future Occurrence

Based on the monthly Palmer Drought Severity Index, as computed by the National Centers for Environmental Information, the Pocono Mountains Climate Division (includes Pike County) was in extreme drought for 1.2% of the time and in severe drought for 3.4% of the time (based on data from January 1895 to November 2016). As presented in the 2013 Pennsylvania State Hazard Mitigation Plan, between 1895 and 1995, Pike County was in severe or extreme drought for less than 5 percent of the time period (see Figure 4.3.2-3). This is equivalent to a PDSI value less than or equal to -3.

Figure 4.3.2-3. Palmer Drought Severity Index for Pennsylvania (1895 to 1995)



Source: *PEMA 2013*

Note: *The blue circle indicates the approximate location of Pike County*

It is estimated that Pike County will continue to experience direct and indirect impacts of drought and its impacts on occasion, with secondary effects causing potential disruption or damage to agricultural activities and creating shortages in water supply within communities. For the 2017 HMP update, the most up-to-date data was collected to calculate the probability of future occurrence of drought events for Pike County. Information from PADEP, NOAA-NCEI storm events database, NRCC, and the 2012 County HMP were used to identify the number of drought events that occurred between 1950 and 2015. Using these sources ensures the most accurate probability estimates possible. The table below shows these statistics, as well as the annual average number of events and the estimate percent chance of an incident occurring in a given year. Based on

these statistics, there is an estimated 80.3-percent chance of a drought occurring in any given year in Pike County.

Table 4.3.2-5. Probability of Future Drought Events

Hazard Type	Number of Occurrences Between 1950 and 2015	Rate of Occurrence or Annual Number of Events (average)	Recurrence Interval (in years) (# Years/Number of Events)	Probability of Event in any given year	Percent Chance of occurrence in any given year
Drought	53	0.82	1.25	0.80	80.3%

Sources: Pike County HMP 2012; NOAA-NCEI 2016; NRCC 2016; PADEP 2016

The future occurrence of drought in Pike County can be considered *highly likely* as defined by the Risk Factor Methodology probability criteria (see Table 4.4-1). Due to the increasing demand for water by the increasing population base and the growing tourist population, droughts will continue to be a problem.

Vulnerability Assessment

To understand risk, a community must evaluate assets exposed and vulnerable within the identified hazard area. For the drought hazard, all of Pike County has been identified as the hazard area. Therefore, all assets (population, structures, critical facilities, and lifelines) described in the County Profile (Section 2) are potentially vulnerable to a drought. This section evaluates and estimates potential impacts of the drought hazard on Pike County in the following subsections:

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

Overview of Vulnerability

Pike County is vulnerable to drought. Assets at particular risk include any open land or structures along the wildland/urban interface (WUI) that could become vulnerable to the wildfire hazard caused by extended periods of low rain and high heat, usually associated with 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 because of age, health conditions, and limited ability to mobilize to shelter, cooling, and medical resources.

Data and Methodology

At the time this HMP was updated, insufficient data were available to model long-term potential impacts of a drought on Pike County. Over time, additional data will be collected to allow better analysis of this hazard. Preliminary assessments based on available data are provided below.

Impact on Life, Health, and Safety

Drought conditions can cause a shortage of water available for human consumption and can reduce local firefighting capabilities. Social impacts of a drought include mental and physical stress, public safety threats (increased threat from forest/grass fires), health threats, conflicts among water users, reduced quality of life, and inequities in 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 (New York State Disaster Preparedness Commission [NYSDPC] 2011). For the purposes of this HMP, the entire population of the County is considered vulnerable to drought events.

All of Pike County's water supply is provided by groundwater, either through private wells, municipal water authorities or community water systems. There are two municipal water supply districts in Pike County (US Census GID, 2007). These districts serve residents in Matamoras and Milford Boroughs. Future droughts will quickly affect those systems relying on surface supplies while those on wells should be able to handle short-term droughts without any major problem. However, longer-term droughts which inhibit recharging of groundwater aquifers will extend the problems for water suppliers and well owners for an undetermined length of time. With a limited number of exceptions, few of the water systems in the County provide large storage capacity. Many of the small water systems operate with limited funds and little money is being invested for any improvements. As the county's population grows, more water is being removed from the aquifer. Unless significant improvements to the infrastructure are made to improve storage capability, many suppliers could find it increasing difficult to meet the demands over extended periods of below normal precipitation when the aquifer is not being adequately recharged.

Pike County residents that use private domestic wells are also vulnerable to droughts because their wells can dry up. There are 4,312 of these domestic wells in Pike County, with at least one in every municipality. Table 4.3.2-5 shows the number of domestic wells per municipality as collected by the Pennsylvania Groundwater Information System (PaGWIS). According to this dataset, residents in Dingman Township are the most vulnerable to the water supply issues related to droughts because of the high amount of wells that are reported there. It is important to note, however, that the well data collected by PaGWIS relies on voluntary submissions of well record data by well drillers; therefore, it is not a complete database of all domestic wells in the County.

Table 4.3.2-6. Number of Reported Domestic Wells in Pike County

Municipality	Number of Reported Domestic Wells	Municipality	Number of Reported Domestic Wells
Blooming Grove Township	122	Milford Borough	N/A
Delaware Township	516	Milford Township	178
Dingman Township	1,415	Palmyra Township	187
Greene Township	525	Porter Township	58
Lackawaxen Township	337	Shohola Township	330
Lehman Township	444	Westfall Township	152
Matamoras Borough	3	Unidentified Municipality	45
TOTAL	**4,312**		

Source: PaGWIS, 2016
N/A Information for this municipality was not reported

Impact on General Building Stock and Critical Facilities

A drought is not expected to directly affect any structures, 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 regions 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.

Impact on the Economy

A prolonged drought can exert serious direct and indirect economic impacts on a community or across the County. A summary of impacts on the economy is presented in Table 4.3.2-6.

Table 4.3.2-7. Impacts on the Economy

Losses to Agricultural Producers	Losses to Livestock Producers	Losses of 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	**Losses to 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
Losses of Fishery Production	Decreased stock weights	Increased importation of food (higher costs)
Damage to fish habitat	Increased predation	**Losses to Water Suppliers**
Loss of fish and other aquatic organisms due to decreased flows	Grass fires	Revenue shortfalls and/or windfall profits
Losses 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
Note: Dark blue cell boxes indicate a new category of economic loss; all losses immediately underneath that category pertain to that loss type.

Loss estimates are based on lost agricultural revenues statewide. Table 4.3.2-7 below enumerates the 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 2012 USDA Census of Agriculture. If the County would lose its agricultural yield due to drought, total losses could amount to almost $2.97 million. Table 4.3.2-8 details

potential losses associated with County livestock by providing livestock totals for the County and their associated market value. Livestock, poultry, and associated products have a potential loss value of nearly $259,000 (USDA 2012).

Table 4.3.2-8. Estimated County Losses Relating to Agricultural Production

Impacted Farmland Acreage	Market Value Of All Agricultural Products
28,260	$2,965,000

Source: USDA 2012

Table 4.3.2-9. Estimated County Losses Relating to Agricultural Production

Livestock and Poultry	Inventory	Market Value Of All Livestock, Poultry, and Their Products
Cattle and Calves	(D)	$259,000
Hogs and Pigs	N/A	
Sheep and Lambs	$5,000	
Layers	$2,175	
Poultry and Egg	$5,000	
Total	**$12,175**	

Source: USDA 2012
Note: Market value of livestock and poultry is provided only by total value and not available by category.
(D) – Amount omitted from report

According to the USDA, Pike County has experienced $0 in crop loss insurance payments on claims caused by drought events since 1948.

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
- Loss of quality in landscape through loss in plants and plant diversity
- Increase in nitrate levels, which can negatively affect health of pregnant women and children (PEMA 2013).

Future Growth and Development

Areas targeted for potential future growth and development within the next 5 to 10 years have been identified across the County (further discussed in Section 2.4 of this HMP). Exposure of any new development and new residents to the drought hazard is anticipated.

Effect of Climate Change on Vulnerability

Climate is defined not just as average temperature and precipitation but also by type, frequency, and intensity of weather events. Both globally and at the local level, climate change can alter prevalence and severity of weather extremes such as droughts. While predicting changes in drought events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating effects of future climate change on human health, society, and the environment (U.S. Environmental Protection Agency [EPA] 2014).

The PADEP was directed by the Climate Change Act (Act 70 of 2008) to initiate a study of potential impacts of global climate change on the Commonwealth. The June 2009 Pennsylvania Climate Impact Assessment and October 2013 Pennsylvania Climate Impact Assessment Updates' main findings indicate that Pennsylvania is very likely to undergo 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 (although the number of severe storms may in fact decrease). Most models project an increase in the maximum number of consecutive dry days in a year, a drought indicator (Shortle et al. 2009, 2013).

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. Understanding this information can help provide better indications of future drought events (Shortle et al. 2009).