4.3.10 Tornado, Windstorm

This section provides a profile and vulnerability assessment for the tornado and windstorm hazard.

Wind is air moving from high to low pressure. It is the rough horizontal movement of air (as opposed to an air current) caused by uneven heating of the earth's surface. Wind occurs at all scales, from local breezes generated by heating of land surfaces and lasting tens of minutes, to global winds resulting from solar heating of the earth (Federal Emergency Management Agency [FEMA] 1997). There are different types of damaging winds: straight-line wind, downdraft, downburst, microburst, gust front, derecho, bow echo, and hook echo. Each wind type is described below:

- **Straight-line wind** is a term used to define any thunderstorm wind that is not associated with rotation. Straight-line winds are the movement of air from areas of higher pressure to areas of lower pressure – the greater the difference in pressure, the stronger the winds. It is used mainly to differentiate from tornadic winds.
- A **downdraft** is a small-scale column of air that rapidly sinks toward the ground and usually results in a downburst.
- A **downburst** is a strong downdraft with horizontal dimensions larger than 2.5 miles, resulting in an outward burst or damaging winds on or near the ground. It is usually associated with thunderstorms but can occur with rainstorms too weak to produce thunder.
- A **microburst** is a small, concentrated downburst that produces an outward burst of damaging winds near the surface. It is typically short-lived, lasting only 5 to 10 minutes, with maximum wind speeds of up to 168 miles per hour (mph).
- A **gust front** is the leading edge of rain-cooled air that clashes with warmer thunderstorm inflow. It is characterized by a wind shift, temperature drop, and gusty winds out ahead of a thunderstorm (National Severe Storms Laboratory [NSSL] 2015a).
- A **derecho** is a widespread and long-lived windstorm associated with thunderstorms that are often curved (Johns and others 2011). The two major influences on the atmospheric circulation are the differential heating between the equator and the poles, and the rotation of the planet (FEMA 1997).
- A **bow echo** is a radar echo that is linear but bent outward in a bow shape. Damaging straight-line winds often occur near the center of a bow echo (crest). A bow echo can be more than 300 kilometers long, last for several hours, and produce extensive swaths of wind damage at the ground (NSSL 2015a).
- A **hook echo** is a radar echo that is the most recognized and well-known radar signature for tornadic supercells. This "hook-like" feature occurs when the strong counter-clockwise winds circling the mesocyclone (rotating updraft) are strong enough to wrap precipitation around the rain-free updraft area of the storm (Prociv 2013).

High winds, other than tornadoes, are experienced in all parts of the United States. Areas that experience the highest wind speeds are coastal regions from Texas to Maine and the Alaskan coast; however, exposed mountain areas experience winds at least as high as those along the coast (FEMA 1997). Wind begins with differences in air pressures and is essentially the horizontal movement of air caused by uneven heating of the earth. Wind occurs everywhere. Effects from high winds can include downed trees and power lines, and damaged roofs and windows. Table 4.3.10-1 describes wind classifications used by the National Weather Service (NWS).

Extreme windstorm events are associated with extra-tropical and tropical cyclones, winter cyclones, severe thunderstorms, and accompanying mesoscale offspring such as tornadoes and downbursts. Wind speeds vary from 0 mph at ground level to 200 mph in the upper atmospheric jet stream 6 to 8 miles above the earth's surface (FEMA 1997).

A derecho is type of windstorm that can occur during a rapidly moving thunderstorm. A derecho is a long-lived windstorm associated with a moving squall line of thunderstorms. It produces straight-line winds gusts of at least

58 mph and often has isolated gusts exceeding 75 mph. As a result, trees generally fall, and debris is blown in one direction. To be considered a derecho, these conditions must continue along a path of at least 240 miles. Derechos are more common in the Great Lakes and Midwest regions of the United States, though, on occasion, can persist into the mid-Atlantic and northeast United States (Office of the New Jersey State Climatologist [ONJSC] Rutgers University 2015).

Tornadoes are nature's most violent storms and can cause fatalities and devastate neighborhoods in seconds. A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 250 mph. Damage paths can be greater than 1 mile wide and 50 miles long. Tornadoes typically develop from either a severe thunderstorm or hurricane as cool air rapidly overrides a layer of warm air. Tornadoes typically move at speeds between 30 and 125 mph and can generate internal winds exceeding 300 mph. The lifespan of a tornado rarely is longer than 30 minutes (FEMA 1997). Tornadoes cause high wind velocity generating wind-blown debris, along with lightning or hail, resulting in additional damage. Destruction caused by tornadoes depends on the size, intensity, and duration of the storm. Tornadoes cause the greatest damage to structures that are light, such as residential and mobile homes, and tend to remain localized during impact (Northern Virginia Regional Commission [NVRC] 2006).

The following sections discuss the location and extent, range of magnitude, previous occurrence, future occurrence, and vulnerability assessment associated with the wind and tornado hazard for Fulton County.

4.3.10.1 Location and Extent

Tornadoes and windstorms can occur throughout Pennsylvania. Tornadoes are usually localized; however, severe thunderstorms can result in conditions favorable to the formation of numerous or long-lived tornadoes. Straight-line winds and windstorms are experienced on a region-wide scale (Pennsylvania Emergency Management Agency [PEMA] 2018).

Tornadoes

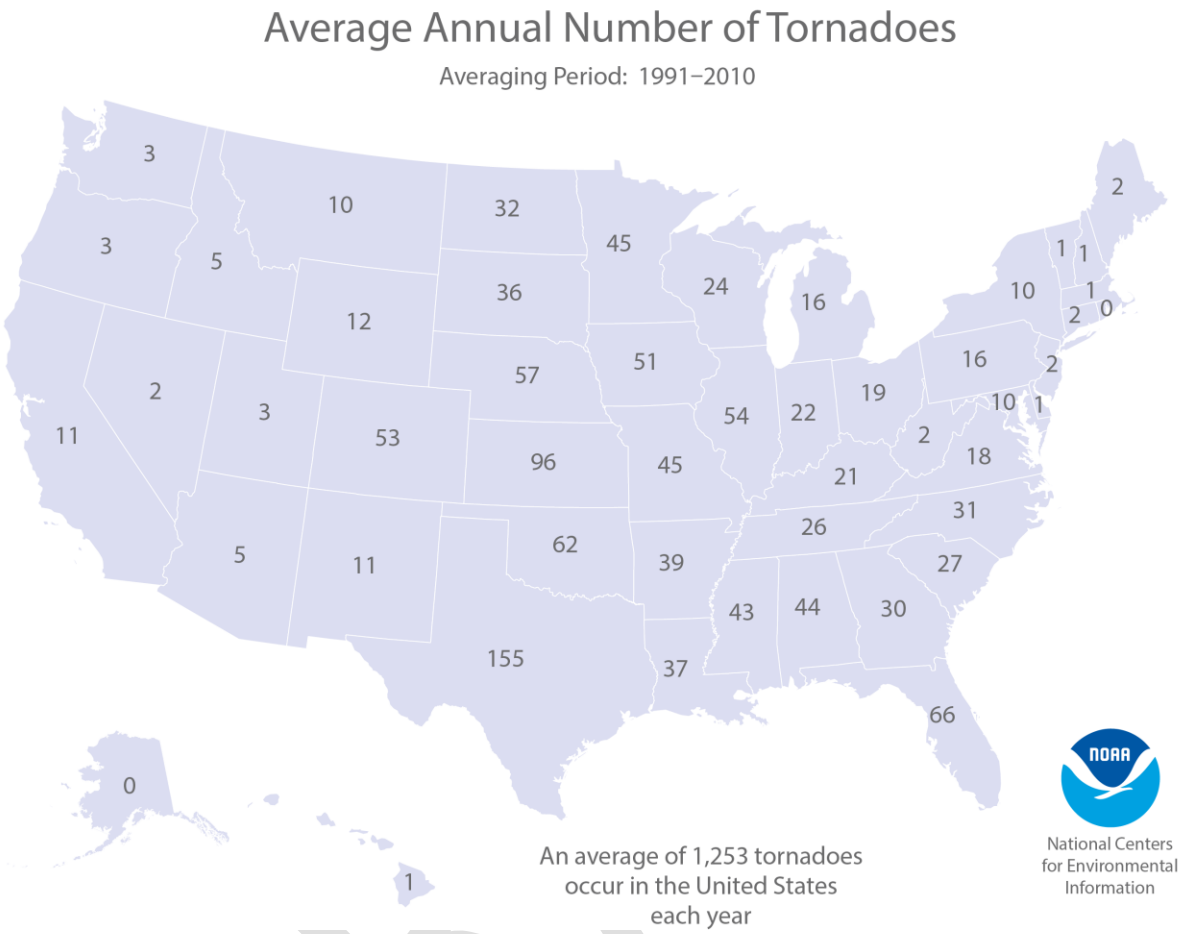
The United States experiences more tornadoes than any other country, with approximately 1,253 occurring in a typical year (NCEI, N.d). Tornadoes can occur at any time during the day or night but are most frequent during late afternoon into early evening, the warmest hours of the day, and most likely to occur during the spring and early summer months of March through June (PEMA 2018).

Tornado movement is characterized in two ways: direction and speed of spinning winds and forward movement of the tornado, also known as the storm track. Most tornadoes have wind speeds of 110 mph (175 km/h) or less, are approximately 250 feet (75 m) across, and travel a few miles (several kilometers) before dissipating. Some attain wind speeds of more than 300 mph (480 km/h), stretch more than a mile (1.6 km) across, and stay on the ground for dozens of miles (more than 100 km). Some tornadoes never touch the ground and are short-lived, while others may touch the ground several times (PEMA 2018).

While the extent of tornado damage is usually localized, the extreme winds of this vortex can be among the most destructive on earth when they move through populated, developed areas.

Figure 4.3.10-1 shows the annual average number of tornadoes between 1981 and 2010 (NCEI, N.d). The Commonwealth of Pennsylvania experienced an average of 16 tornado events annually between 1981 and 2010.

Figure 4.3.10-1. Annual Average Number of Tornadoes in the United States, 1981 to 2010



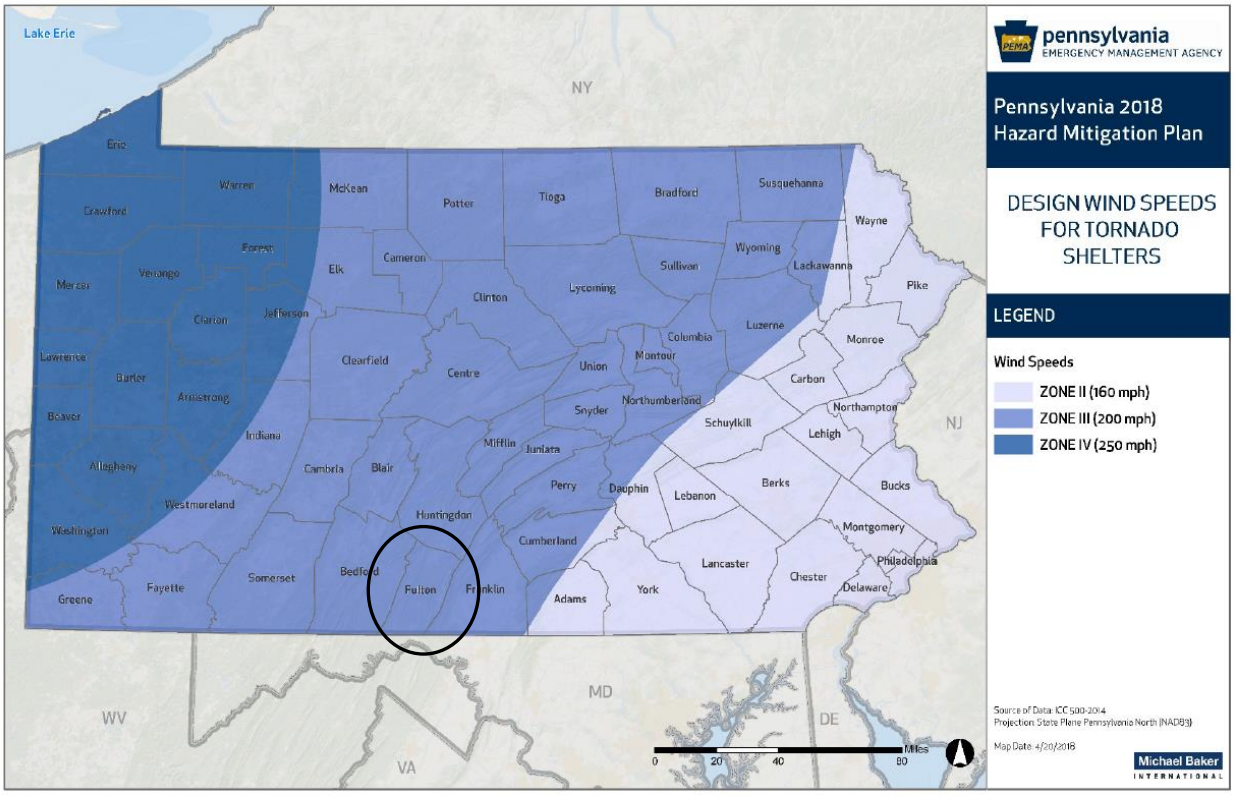
Source: NCEI, N.d.

Figure 4.3.10-2 indicates that a large portion of Pennsylvania is at high risk for tornadoes, with a portion considered to be at the highest risk. According to this graphic, Fulton County has a moderate risk for tornado. Details regarding historical tornado events are discussed in the Past Occurrences section (Section 4.3.10.3) of this profile.

Windstorms

According to the 2018 State Hazard Mitigation Plan (HMP), there are wind speed zones developed for the design of tornado shelters; refer to Figure 4.3.10-2 As displayed, Fulton County is located in wind speed zone III, meaning design wind speeds for shelters and critical facilities should withstand 3-second gusts up to 200 mph, regardless if the wind is from a tornado, hurricane, tropical storm or windstorm event. It should be noted that these windspeeds represent the strongest anticipated throughout the Commonwealth and are not the normal wind speeds expected statewide (PEMA 2018).

Figure 4.3.10-2. Design Wind Speeds for Tornado Shelters



Source: PEMA 2018
Note: The black oval indicates the approximate location of Fulton County.

Table 4.3.10-1. Wind Zones in the United States

Wind Zones	Areas Affected
Zone I (130 mph)	All of Washington, Oregon, California, Idaho, Utah, and Arizona. Western parts of Montana, Wyoming, Colorado, and New Mexico. Most of Alaska, except the east and south coastlines.
Zone II (160 mph)	Eastern parts of Montana, Wyoming, Colorado, and New Mexico. Most of North Dakota. Northern parts of Minnesota, Wisconsin, and Michigan. Western parts of South Dakota, Nebraska, and Texas. All New England States. Eastern parts of New York, Pennsylvania, Maryland, and Virginia. Washington DC.
Zone III (200 mph)	Areas of Minnesota, South Dakota, Nebraska, Colorado, Kansas, Oklahoma, Texas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, Pennsylvania, New York, Michigan, and Wisconsin. Most or all of Florida, Georgia, South Carolina, North Carolina, Virginia, and West Virginia. All of American Samoa, Puerto Rico, and Virgin Islands.
Zone IV (250 mph)	Mid-United States, including all of Iowa, Missouri, Arkansas, Illinois, Indiana, and Ohio and parts of adjoining states of Minnesota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, Pennsylvania, Michigan, and Wisconsin. Guam.
Special Wind Region	Isolated areas in the following states: Washington, Oregon, California, Idaho, Utah, Arizona, Montana, Wyoming, Colorado, and New Mexico. The borders between Vermont and New Hampshire; between New York, Massachusetts, and Connecticut; between Tennessee and North Carolina.
Hurricane Susceptible Region	Southern United States coastline from Gulf Coast of Texas eastward to include entire State of Florida. East coastline from Maine to Florida, including all of Massachusetts, Connecticut, Rhode Island, Delaware, and Washington DC. All of Hawaii, Guam, American Samoa, Puerto Rico, and Virgin Islands.

Source: FEMA 2012
mph Miles per hour

4.3.10.2 Range of Magnitude

The following provides details regarding the range of magnitude for tornadoes and windstorms.

Tornado

Each year, tornadoes account for $1.1 billion in damage and cause over 80 deaths nationally. While the extent of tornado damage is usually localized, the vortex of extreme wind associated with a tornado can result in some of the most destructive forces on earth. Rotational wind speeds can range from 100 mph to more than 250 mph. In addition, the speed of forward motion can range from 0 to 50 mph. Therefore, some estimates place the maximum velocity (combination of ground speed, wind speed, and upper winds) of tornadoes at about 300 mph. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. The most violent tornadoes have rotating winds of 250 miles per hour or more and are capable of causing extreme destruction and turning normally harmless objects into deadly missiles (PEMA 2018).

Damage and deaths can be especially significant when tornadoes move through populated, developed areas. The destruction caused by tornadoes ranges from light to inconceivable depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction such as mobile homes (PEMA 2018).

The magnitude or severity of a tornado was originally categorized using the Fujita Scale (F-Scale) or the Pearson Fujita Scale introduced in 1971, based on a relationship between the Beaufort Wind Scales (B-Scales) (measure of wind intensity) and the Mach number scale (measure of relative speed). It is used to rate the intensity of a tornado by examining the damage caused by the tornado after it has passed over a man-made structure (Tornado Project Date Unknown). The F-Scale categorizes each tornado by intensity and area. The scale is divided into six categories: F0 (Gale) to F5 (Incredible) (Edwards 2013).

Although the F-Scale had been in use for more than 30 years, the scale has limitations. The primary limitations are a lack of Damage Indicators (DI), no account of construction quality and variability, and no definitive correlation between damage and wind speed. These limitations have led to the inconsistent rating of tornadoes and, in some cases, an overestimate of tornado wind speeds. The limitations listed above led to the development of the Enhanced Fujita Scale (EF Scale). The Texas Tech University Wind Science and Engineering (WISE) Center, along with a forum of nationally renowned meteorologists and wind engineers from across the country, developed the EF Scale (Texas Tech University 2015).

The EF Scale was adopted on February 1, 2007. It is used to assign a tornado with a rating based on estimated wind speeds and related damage. When tornado-related damage is surveyed, it is compared with a list of DIs and Degrees of Damage (DOD), which help better estimate the range of wind speeds produced by the tornado. From that, a rating is assigned, similar to that of the F-Scale, with six categories from EF0 to EF5, representing increasing DOD. The EF Scale was revised from the original F-Scale to reflect better examinations of tornado damage. The EF Scale also relates to how most structures are designed (NWS 2016b). Table 4.3.10-2 displays each of its six categories of the EF Scale.

Table 4.3.10-2. Enhanced Fujita Damage Scale

EF Scale Number	Wind Speed (mph)	F-Scale Number	Type of Damage Done
EF0	65–85	F0-F1	**Light damage:** Chimneys are damaged, tree branches are broken, shallow-rooted trees are toppled.
EF1	86-110	F1	**Moderate damage:** Roof surfaces are peeled off, windows are broken, some tree trunks are snapped, unanchored mobile homes are overturned, attached garages may be destroyed.

EF Scale Number	Wind Speed (mph)	F-Scale Number	Type of Damage Done
EF2	111-135	F1-F2	**Considerable damage:** Roof structures are damaged, mobile homes are destroyed, debris becomes airborne, missiles are generated, large trees are snapped or uprooted.
EF3	136-165	F2-F3	**Severe damage:** Roofs and some walls are torn from structures, some small buildings are destroyed, nonreinforced masonry buildings are destroyed, most trees in forest are uprooted.
EF4	166-200	F3	**Devastating damage:** Well-constructed houses are destroyed, some structures are lifted from foundations and blown some distance, cars are blown some distance, large debris becomes airborne.
EF5	>200	F3-F6	**Extreme damage:** Strong frame houses are lifted from foundations, reinforced concrete structures are damaged, automobile-sized missiles become airborne, trees are completely debarked.

Source: PEMA 2018
mph Miles per hour

The EF Scale takes into account more variables than the original F-Scale did in assigning a wind speed rating to a tornado. The EF Scale incorporates 28 DIs, such as building type, structures, and trees. There are eight DODs for each damage indicator, ranging from the beginning of visible damage to complete destruction of the damage indicator. Table 4.3.10-3 lists the 28 DIs. A description is provided for each one of these indicators of the typical construction for that category. Each DOD in every category is assigned an expected estimate of wind speed, a lower bound of wind speed, and an upper bound of wind speed.

Table 4.3.10-3. EF Scale Damage Indicators

Number	Damage Indicator	Abbreviation	Number	Damage Indicator	Abbreviation
1	Small barns, farm outbuildings	SBO	15	School - 1-story elementary (interior or exterior halls)	ES
2	One- or two-family residences	FR12	16	School - junior or senior high school	JHSH
3	Single-wide mobile home	MHSW	17	Low-rise (1-4 story) building	LRB
4	Double-wide mobile home	MHDW	18	Mid-rise (5-20 story) building	MRB
5	Apartment, condominium, townhouse (3 stories or less)	ACT	19	High-rise (over 20 stories)	HRB
6	Motel	M	20	Institutional building (hospital, government. or university)	IB
7	Masonry apartment or motel	MAM	21	Metal building system	MBS
8	Small retail building (fast food)	SRB	22	Service station canopy	SSC
9	Small professional (doctor office, branch bank)	SPB	23	Warehouse (tilt-up walls or heavy timber)	WHB
10	Strip mall	SM	24	Transmission line tower	TLT
11	Large shopping mall	LSM	25	Free-standing tower	FST
12	Large, isolated (“big box”) retail building	LIRB	26	Free-standing pole (light, flag, luminary)	FSP
13	Automobile showroom	ASR	27	Tree - hardwood	TH
14	Automotive service building	ASB	28	Tree - softwood	TS

Source: NWS 2016b

Since the EF Scale went into effect in February 2007, previous occurrences and losses associated with historical tornado events, described in Section 4.3.10.3, Past Occurrences, are classified based on the former Fujita Scale. Events after February 2007 are classified based on the Enhanced Fujita Scale.

Windstorms

Windstorms are generally defined as sustained wind speeds of 40 mph or greater, lasting for 1 hour or longer, or winds of 58 mph or greater for any duration. Wind descriptions used by the National Weather Service are shown in the table below.

Table 4.3.10-4. NWS Wind Descriptions

Descriptive Term	Sustained Wind Speed (mph)
Strong, dangerous, high, damaging (high wind warning criteria	≥40
Very windy	30-40
Windy	20-30
Breezy (mild weather) brisk or blustery (cold weather)	15-25
None	5-15 or 10-20
Light/light and variable wind	0-5

Source: NWS 2011
mph Miles per hour

NWS issues site-specific high wind advisories, watches, and warnings when wind speeds may pose a hazard or may be life-threatening. The criterion for each of these varies from state to state. Wind warnings and advisories for Pennsylvania are as follows:

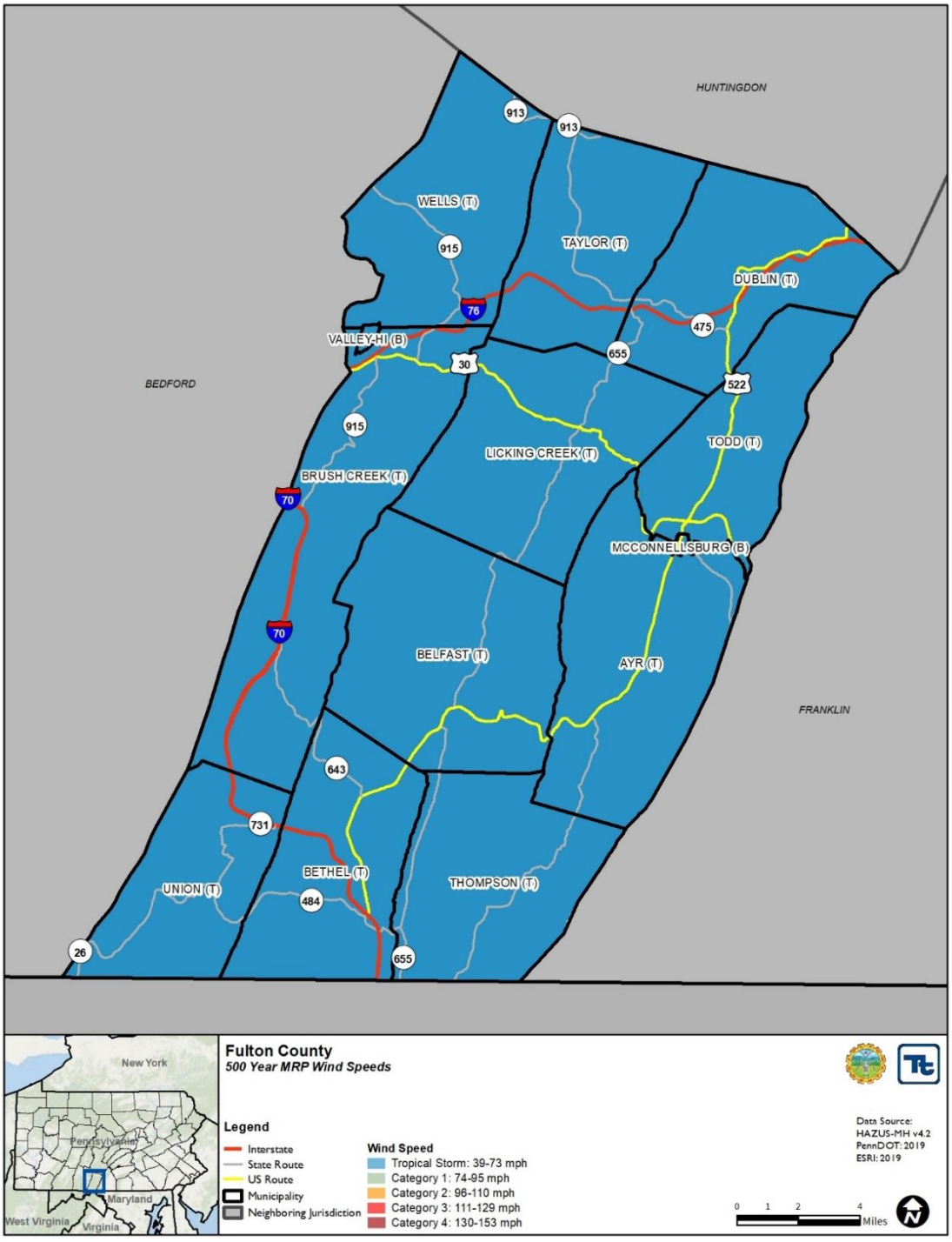
- *High Wind Warnings* are issued when sustained winds of 40 mph or greater are forecast for 1 hour or longer, or wind gusts of 58 mph or greater are forecast for any duration.
- *Wind Advisories* are issued when sustained winds of 30 to 39 mph are forecast for 1 hour or longer, or wind gusts of 46 to 57 mph are forecast for any duration (NWS 2015).

Mean Return Period

In evaluating the potential for hazard events of a given magnitude, a mean return period (MRP) is often used. The MRP provides an estimate of the magnitude of an event that may occur within any given year based on past recorded events. MRP is the average period of time, in years, between occurrences of a particular hazard event, equal to the inverse of the annual frequency of exceedance (Dinicola 2009).

Figure 4.3.10-3 shows the estimated maximum 3-second gust wind speeds that can be anticipated in Fulton County when associated with the 500-year MRP event. These peak wind speed projections were generated using Hazards U.S. Multi-Hazard (HAZUS-MH) model runs. HAZUS-MH v4.2 estimated the maximum 3-second gust wind speeds for Fulton County to be below 39 mph for the 100-year MRP event and not strong enough to be considered a tropical storm. The maximum 3-second gust wind speeds for Fulton County range from 66 to 67 mph for the 500-year MRP event (tropical storm). HAZUS-MH v4.2 did not estimate loss impacts associated with the 100-year MRP event, but the associated impacts and losses from the 500-year MRP wind event model run is reported in the Vulnerability Assessment.

Figure 4.3.10-3. Wind Speeds for the 500-Year Mean Return Period Event



4.3.10.3 Past Occurrence

Many sources provided historical information regarding previous occurrences and losses associated with tornado and windstorm events throughout the Commonwealth of Pennsylvania and Fulton County. With so many sources reviewed for this plan, loss and impact information varies depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP.

According to NOAA's National Centers for Environmental Information (NCEI) storm events database, Fulton County experienced 80 tornado and windstorm events between August 1, 1950, and May 29, 2019. These events include high winds, strong winds, thunderstorm winds, and tornadoes. Total reported property damage as a result of these tornado and windstorm events was estimated at over $239,490. This total also includes damage to other counties.

According to NOAA's NCEI, there were five recorded tornadoes in Fulton County between 1950 and 2019. These tornadoes included two with an intensity of F/EF0 and 3 with an intensity of F/EF1. Fulton County's worst tornado event occurred on April 19, 2019, when an EF1 tornado caused damage around Knobsville. In addition to tornadoes, there have been 72 occurrences of thunderstorm wind or high winds within Fulton County between 1950 and 2019. On June 2, 2000, a thunderstorm occurred near Needmore, which blew five cars and an ambulance off of Route 70 near Exit 33, resulting in $25,000 in reported damages. A high wind event in Fulton County on December 12, 2000 resulted in $13,900 in reported damages.

Between 1954 and 2019, the Commonwealth of Pennsylvania experienced 50 federally declared windstorm or tornado-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types: hurricane, tropical storm, tropical depression, severe storms, flash flooding, flooding, and high winds. Generally, these disasters cover a wide region of the Commonwealth; therefore, they may have affected many counties. However, not all counties were included in the disaster declarations. Fulton County was included in nine of these declared disasters (FEMA 2017). Additionally, PEMA reports that in Pennsylvania there have been 11 confirmed tornadoes and two high windstorms, of which three resulted in major disaster declaration issued by the Governor and President. Fulton County was not identified as impacted in any of these events; however, it could be included under the high winds in April 1975, which had a statewide impact (PEMA 2018).

Based on all sources researched, windstorm and tornado events that have affected Fulton County and its municipalities between 1975 (first available data) and 2019 are identified in Table 4.3.10-5. With tornado and windstorm documentation for the Commonwealth of Pennsylvania being so extensive, not all sources have been identified or researched. Therefore, Table 4.3.10-5 may not include all events that have occurred throughout Fulton County.

Table 4.3.10-5. Tornado and Windstorm Events in Fulton County, 2009 to 2019

Dates of Event	Event Type	Location	Magnitude	Losses / Impacts
12/02/2009	High Wind	Fulton County	50 Kts.	Non-thunderstorm wind gusts between 50 and 60 mph toppled numerous trees and power lines across Fulton County. The high winds caused sporadic power outages to approximately less than 100 Allegheny Power customers. $25,000 in damages were reported.
02/06/2009	Thunderstorm Wind	Knobsville	50 Kts.	A severe thunderstorm snapped off about 30 trees near Cowans Gap State Park near the Fulton/Franklin County border. $5,000 in damages were reported.
7/29/2009	Thunderstorm Wind	Dickey's Mountain	60 Kts.	Thunderstorm winds estimated near 70 mph tore a portion of a metal roof from a large barn and knocked down several trees in Dickeys Mountain. $7,500 in damages were reported.
02/05/2010	Thunderstorm Wind	Dickey's Mountain	50 Kts.	Thunderstorm winds estimated near 60 mph toppled several trees on Creek Road just north of Route 928. $5,000 in damages were reported.
5/26/2011	Thunderstorm Wind	Cove Mills	50 Kts.	Thunderstorm winds estimated near 60 mph produced structural damage near Cove Mills. $5,000 in damages were reported.
5/26/2011	Thunderstorm Wind	Cove Mills	50 Kts.	Thunderstorm winds estimated near 60 mph knocked down numerous trees and utility wires in several communities surrounding Cove Mills. $10,000 in damages were reported.

Dates of Event	Event Type	Location	Magnitude	Losses / Impacts
01/06/2012	Thunderstorm Wind	Needmore	50 Kts.	Thunderstorm winds estimated near 60 mph knocked down trees and utility wires in Needmore. $5,000 in damages were reported.
6/29/2012	Thunderstorm Wind	Needmore	50 Kts.	Thunderstorm winds estimated near 60 mph knocked down trees in Needmore. $5,000 in damages in reported.
05/31/2015	Thunderstorm Wind	Gem	50 Kts.	Thunderstorm winds estimated near 60 mph knocked down trees and wires near the intersection of Great Cove and Timber Ridge Roads near Needmore. $1,000 in damages were reported.
06/16/2016	Tornado	Northcraft	EF-0	Tornado touched down near Barnes Gap in Fulton County. It was a small brief tornado that moved through a wooded area crossing Route 484 Buck Valley Road just northeast of Barnes Gap. Trees were snapped and uprooted in different directions indicating a cyclonic pattern. Much greater damage occurred from a 3-mile-wide swath over 5 miles long of scattered straight-line wind damage and hail from this storm. Peak winds were estimated at 80 mph. There were no injuries or fatalities.
04/08/2017	Tornado	Needmore	EF1	The tornado touched down near Pleasant Grove Road (State Road 3007) and traveled northeastward for about 5 minutes, snapping and uprooting several swaths of trees along its path. It was estimated that approximately 150 trees were snapped or downed by the tornado. $5,000 in damages were reported.
04/08/2017	Thunderstorm Wind	McConnellsburg	52 Kits.	A severe thunderstorm producing winds estimated near 60 mph knocked down trees and wires near McConnellsburg. $4.000 in damages were reported.
04/19/2019	Tornado	Fulton County	EF-1	The tornado touched down approximately one mile west-southwest of Knobsville, just west of East Dutch Corner Road. Trees were uprooted and snapped along the path of the tornado, and a home just off of Breezy Point Road received considerable damage, including the loss of a chimney and a porch roof. Peak winds were estimated at 100 mph. $25,000 in damages were reported.
04/19/2019	Thunderstorm Wind	Knobsville	61 Kts.	A severe thunderstorm producing winds estimated near 70 mph knocked down trees near Knobsville. $12,000 in damages were reported.
05/29/2019	Thunderstorm Wind	Burnt Cabins	52 Kts.	A severe thunderstorm producing winds estimated near 60 mph knocked down a barn and multiple pine trees near Burnt Cabins. $10,000 in damages were reported
05/29/2019	Tornado	Enid		An EF1 tornado touched down near Wells Tannery in Fulton County on the afternoon of May 29, 2019. The tornado produced maximum winds estimated near 100 mph along a path that was about 3/4 of a mile long, and a maximum path width of approximately 50 yards. $35,000 in damages were reported.

Source: FEMA 2017; NOAA-NCEI 2019; Fulton County 2019

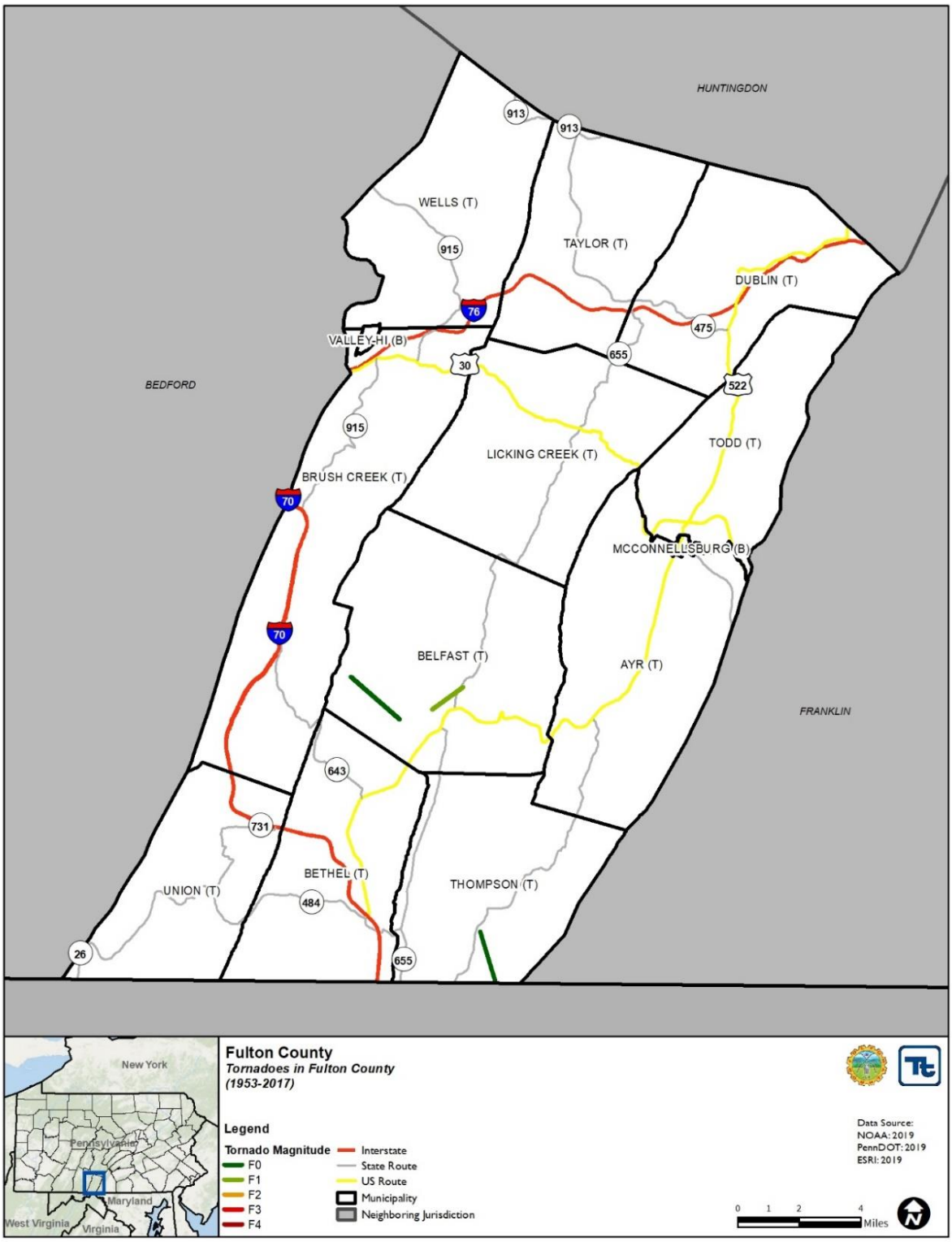
Notes:

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

FEMA	Federal Emergency Management Agency
K	Thousand ($)
Kts.	Knots
M	Million ($)
mph	Miles per hour
NCDC	National Climatic Data Center
NOAA	National Oceanic Atmospheric Administration
PEMA	Pennsylvania Emergency Management Agency
Tstm	Thunderstorm

Figure 4.3.10-4 shows the locations of tornadoes that have touched down in Fulton County between 1953 and 2017. This is the best available spatial data.

Figure 4.3.10-4. Tornado History in Fulton County (1953-2017)



4.3.10.4 Future Occurrence

For the 2019 HMP update, the most up-to-date historic data was collected to calculate the probability of future occurrence of tornado and windstorm events for Fulton County. Information from NOAA-NCEI storm events database, FEMA, and Fulton County. It should be noted that because there are multiple data sources that report information related to severe weather events, it is not possible to capture all possible data. Table 4.3.10-6 presents the probability of future occurrence of tornado events in Fulton County.

Table 4.3.10-6. Probability of Future Tornado and Windstorm Events

Hazard Type	Number of Occurrences Between 1975 and 2019	Recurrence Interval (in years) (# Years/ Number of Events)	Percent chance of occurrence in any given year
High Wind	12	3.75	26.7%
Strong Wind	1	45.0	2.2%
Thunderstorm Wind	61	0.73	100%
Tornado	6	7.5	13.3%
TOTAL	80	**0.56**	**100%**

Sources: NOAA-NCEI 2019

In Section 4.4, the hazards of concern identified for Fulton County are ranked according to relative risk. The probability of occurrence, or likelihood of the event, is one parameter used for ranking hazards. The probability of occurrence for severe tornado and windstorm events in Fulton County is considered *highly likely* (greater than 90 percent annual probability) as defined by the Risk Factor Methodology probability criteria (Section 4.4).

Fulton County experiences strong winds on a frequent basis, and when those winds occur, they can result in significant property damage, downed trees, and utility outages. It can be reasonably assumed that future tornadoes will be similar in nature to those that have affected Fulton County in the past. It is estimated that Fulton County will continue to experience direct and indirect impacts of annual windstorms and tornadoes that may induce secondary hazards, such as infrastructure deterioration or failure; utility failures; power outages; water quality and supply concerns; and transportation delays, accidents, and inconveniences.

4.3.10.5 Vulnerability Assessment

To understand risk, a community must evaluate which assets are exposed and vulnerable in the identified hazard. The entire County has been identified as the hazard area for tornado and other windstorm events. Therefore, all assets in the County (population, structures, critical facilities, and lifelines), as described in the County Profile (Section 2), are potentially vulnerable. The following text evaluates and estimates the potential impact of strong winds on the County, including:

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

The high winds and air speeds of a severe windstorm event, including winds in a tornado, can result in power outages, disruptions to transportation corridors and equipment, loss of workplace access, significant property damage, injuries and loss of life, and the need to shelter and care for individuals affected by the events. A large amount of damage can be inflicted by trees, branches, and other objects that fall onto power lines, buildings, roads, vehicles, and, in some cases, people. The risk assessment for tornadoes and windstorms evaluates available data for a range of storms included in this hazard category.

The entire inventory of the County is at risk of being damaged or lost through the impacts of tornadoes and windstorms. Certain areas, infrastructure, and types of buildings are at greater risk than others because of their proximity to falling hazards or their manner of construction. Potential losses associated with high wind events were calculated for two probabilistic hurricane events: the 100-year and 500-year MRP hurricane events. The impacts on population, existing structures, critical facilities, and the economy are presented below, after a summary of the data and methodology used. Although the estimate is based on a hurricane event, the data can also be used to estimate potential damage from other windstorm events.

Impact on Life, Health, and Safety

The impact of a tornado or windstorm on life, health, and safety depends on several factors, including the severity of the event and whether adequate warning time was provided to residents. It is assumed that the entire population of Fulton County (U.S. Census 2010 population of 14,845 people) is exposed to this hazard.

Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate. The population over the age of 65 is also more vulnerable and, physically, they may have more difficulty evacuating. The elderly are considered most vulnerable because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention that may not be available due to isolation during a storm event. Section 2 presents the statistical information regarding these populations in the County.

Impact on General Building Stock

Damage to buildings is dependent upon several factors, including wind speed, storm duration, path of the storm track or tornado, distance from the tornado funnel and building construction. Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Generally, wood and masonry buildings, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. High-rise buildings are also very vulnerable structures. Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside.

The U.S. Census Bureau defines manufactured homes as "movable dwellings, 8 feet or wider and 40 feet or longer, designed to be towed on its own chassis, with transportation gear integral to the unit when it leaves the factory, and without need of a permanent foundation (Census, 2010)." They can include multi-wides and expandable manufactured homes but exclude travel trailers, motor homes, and modular housing. Due to their lightweight and often unanchored design, manufactured housing is extremely vulnerable to high winds and will generally sustain the most damage.

Table 4.3.10-7 displays the number of manufactured housing units per municipality in Fulton County. Total counts are based on mobile/manufactured homes in the HAZUS-MH v4.2 default database. As noted below, Todd Township has the greatest number of manufactured homes.

Table 4.3.10-7. Manufactured Housing Units per Municipality in Fulton County

Municipality	Number of Manufactured Homes		Municipality	Number of Manufactured Homes
Ayr Township	134		Taylor Township	94
Belfast Township	107		Thompson Township	41
Bethel Township	139		Todd Township	188
Brush Creek Township	91		Union Township	37

Municipality	Number of Manufactured Homes	Municipality	Number of Manufactured Homes
Dublin Township	157	Valley-Hi Borough	7
Licking Creek Township	120	Wells Township	52
McConnellsburg Borough	62	**Fulton County**	**1,229**

According to HAZUS-MH's wind model, direct wind-induced damage (wind pressures and windborne debris) to buildings is dependent upon the performance of components and cladding, including roof covering (shingles, tiles, membrane), roof sheathing (wood frame construction only), windows, and doors and is modeled as such. Structural wall failures can occur for masonry and wood frame walls and uplift of whole roof systems due to failure at the roof/wall connections. Foundation failures (i.e., sliding, overturning and uplift) can potentially take place in manufactured homes.

After the population exposed to the tornado or windstorm hazard has been considered, the general building stock replacement value exposed to and damaged by 100- and 500-year MRP events was examined. Wind-only impacts are reported based on the probabilistic hurricane runs using HAZUS-MH v4.2. Potential damage is the modeled loss that could occur to the exposed inventory, including damage to structural and content value based on the wind-only impacts associated with a hurricane (using the methodology described in Section 4.4). Although the estimate is based on a hurricane event, the data can also be used to estimate potential damage from other windstorm events.

It is assumed that the entire County's general building stock is exposed to the wind hazard (greater than $3.4 billion for structures only). Expected building damage was evaluated by HAZUS-MH v4.2 across the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction.

Table 4.3.10-8 summarizes the definitions of the damage categories.

Table 4.3.10-8. Description of Damage Categories

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
No Damage or Very Minor Damage Little or no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very limited water penetration.	≤ 2%	No	No	No	No	No
Minor Damage Maximum of one broken window, door, or garage door. Moderate roof cover loss that can be covered to prevent additional water entering the building. Marks or dents on walls requiring painting or patching for repair.	> 2% and ≤ 15%	One window, door, or garage door failure	No	< 5 Impacts	No	No
Moderate Damage Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water.	> 15% and ≤ 50%	> the larger of 20% & 3 and ≤ 50%	1 to 3 Panels	Typically, 5 to 10 Impacts	No	No

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
Severe Damage Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	> 50%	> one and ≤ the larger of 20% & 3	> 3 and ≤ 25%	Typically, 10 to 20 Impacts	No	No
Destruction Complete roof failure or failure of wall frame. Loss of more than 50 percent of roof sheathing.	Typically, > 50%	> 50%	> 25%	Typically, > 20 Impacts	Yes	Yes

Source: FEMA 2013

As noted earlier in the profile, HAZUS-MH v4.2 estimates the 100-year MRP peak gust wind speeds for Fulton County to be less than 39 mph with no associated building stock damage. HAZUS-MH v4.2 estimates the 500-year MRP peak gust wind speeds for Fulton County to range from 66 to 67 mph. This wind speed equates to a *Tropical Storm* and approximately $640,000 in damage to the general building stock (structure only). This amount is less than 1 percent of the County's building inventory. Table 4.3.10-9 summarizes the building value (structure only) damage estimated for the 500-year MRP wind-only event by occupancy class.

Table 4.3.10-9. Estimated Building Replacement Value (Structure Only) Damaged by the 500-Year Mean Return Period Winds for All Occupancy Classes

Municipality	Total Building Replacement Value (Structure Only)	Total Building Damage (All Occupancies)	Residential Buildings	Commercial Buildings
		500-Year Probable Loss	500-Year Probable Loss	500-Year Probable Loss
Ayr Township	$203,163,000	$102,862	$99,601	$719
Belfast Township	$111,757,000	$62,167	$59,835	$1,078
Bethel Township	$152,457,000	$77,574	$75,096	$1,419
Brush Creek Township	$70,479,000	$31,695	$31,123	$220
Dublin Township	$95,778,000	$39,983	$38,418	$757
Licking Creek Township	$129,459,000	$53,075	$51,518	$1,082
McConnellsburg Borough	$157,058,000	$50,882	$43,739	$5,008
Taylor Township	$87,204,000	$42,078	$40,371	$706
Thompson Township	$101,824,000	$61,250	$60,778	$242
Todd Township	$164,001,000	$58,207	$51,542	$2,123
Union Township	$69,402,000	$41,299	$40,876	$117
Valley-Hi Borough	$3,885,000	$1,598	$1,598	$0
Wells Township	$37,498,000	$16,875	$16,410	$212
Fulton County	**$1,383,965,000**	**$639,545**	**$610,904**	**$13,682**

Source: HAZUS-MH 4.2

Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings, regardless of their occupancy class, usually experience more damage than concrete or steel buildings. The damage counts include buildings damaged at all severity levels, from minor damage to total destruction. Total damage dollar amounts reflect the overall impact to buildings at an aggregate level.

Of the more than $1.3 billion in total replacement cost value (structure) for the entire County, an estimated over $610,904 in residential building damage can be anticipated for the 500-year event. Residential building damage accounts for nearly 100-percent of total damage for the 500-year wind-only event. This information illustrates residential structures are the most vulnerable to the wind hazard. Annualized losses were also examined, but HAZUS-MH v4.2 did not estimate any annualized losses for wind-only events in Fulton County.

Impact on Critical Facilities

HAZUS-MH v4.2 estimates the probability that critical facilities (medical facilities, fire/emergency medical services, police, emergency operation centers, schools, and user-defined facilities such as shelters and municipal buildings) may sustain damage as a result of 100-year and 500-year MRP wind-only events. Additionally, HAZUS-MH estimates the loss of use for each facility in number of days. HAZUS-MH v4.2 estimates that there will be no structural losses to critical facilities in Fulton County, and continuity of operations at these facilities will not be interrupted (loss of use is estimated to be 0 days) as a result of the 100-year and 500-year MRP events.

At this time, HAZUS-MH v4.2 does not estimate losses to transportation lifelines and utilities as part of the hurricane model. Transportation lifelines are not considered particularly vulnerable to the wind hazard; they are more vulnerable to cascading effects such as flooding and falling debris. Impacts to transportation lifelines affect both short-term (evacuation activities) and long-term (day-to-day commuting) transportation needs.

Utility structures could suffer damage associated with falling tree limbs or other debris, resulting in the loss of power, which can impair business operations and can affect heating or cooling provision to citizens (including the young and elderly, who are particularly vulnerable to temperature-related health impacts).

Impact on Economy

Severe storms also affect the economy, including loss of business function (for example, to tourism and recreation), damage to inventory, relocation costs, wage loss, and rental loss from repair or replacement of buildings. HAZUS-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are considered the estimated costs to repair or replace the damage caused to the building. These losses are reported in the "Impact on General Building Stock" section discussed earlier. Business interruption losses are the losses associated with the inability to operate a business because of the wind damage sustained during the storm or the temporary living expenses for those displaced from their home because of the event.

HAZUS-MH estimates business interruption losses for Fulton County for the 100-year MRP and 500-year MRP events (<$1,000), which includes loss of inventory, income, relocation costs, rental costs, and lost wages.

Table 4.3.10-10. Estimated Debris Production for 100-Year and 500-Year Mean Return Period Hurricane-Related Winds

Municipality	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year
Ayr Township	0	1	0	0	0	288	0	158
Belfast Township	0	0	0	0	0	502	0	236
Bethel Township	0	0	0	0	0	286	0	190
Brush Creek Township	0	0	0	0	0	155	0	106
Dublin Township	0	0	0	0	0	90	0	116

Municipality	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year
Licking Creek Township	0	0	0	0	0	235	0	113
McConnellsburg Borough	0	1	0	0	0	3	0	49
Taylor Township	0	0	0	0	0	285	0	138
Thompson Township	0	0	0	0	0	185	0	99
Todd Township	0	0	0	0	0	122	0	130
Union Township	0	0	0	0	0	181	0	98
Valley-Hi Borough	0	0	0	0	0	2	0	2
Wells Township	0	0	0	0	0	97	0	79
Fulton County	**0**	**2**	**0**	**0**	**0**	**2,431**	**0**	**1,515**

Source: HAZUS-MH 4.2

Impact on the Environment

Tornado events are typically localized; therefore, environmental impacts are rarely widespread. Severe damage to plant species is likely from both tornado and windstorm events. This includes uprooting or total destruction of trees and increased threat to wildfire in areas of tree debris. Hazardous material facilities should meet design requirements for the wind zones identified in Figure 4.3.10-2 above (PEMA 2018).

Future Growth and Development

As discussed and illustrated in Section 2.4, areas targeted for future growth and development have been identified across Fulton County. Any areas of growth could be affected by the tornado and windstorm hazard because the entire County is exposed and vulnerable to the wind hazard, particularly when associated with severe storms.

Effect of Climate Change on Vulnerability

An increase in storms will produce more wind events and may increase tornado activity. Additionally, an increase in temperature will provide more energy to produce storms that generate tornadoes (Climate Central 2016). With an increased likelihood of strong winds and tornado events, all of the County's assets will experience additional risk for losses as a result of extreme wind events.

Additional Data and Next Steps

In time, HAZUS-MH will be released with modules that address straight-line wind and tornado events. As updated versions of HAZUS-MH are released, the County can run analyses for an overall picture of the wind damages and debris generated from tornado events. Over time, Fulton County can obtain additional data to support the analysis of this hazard. Data that will support the analysis would include additional detail on past hazard events and impacts, and an updated building inventory to include specific building information such as type of construction and details on protective features (for example, shutters and safe rooms).