# 5.4.3 SEVERE STORM

This section provides a profile and vulnerability assessment for the severe storm hazards.

## HAZARD PROFILE

Hazard profile information is provided in this section, including information on description, extent, location, previous occurrences and losses and the probability of future occurrences within Tioga County.

### Description

For the purpose of this HMP and as deemed appropriated by Tioga County, the severe storm hazard includes hailstorms, windstorms, lightning, thunderstorms, tornadoes, and tropical cyclones (e.g. hurricanes, tropical storms, and tropical depressions), which are defined below. Since most northeasters, (or Nor'Easters) a type of an extra-tropical cyclone, generally take place during the winter weather months, Nor'Easters have been grouped as a type of severe winter weather storm, further discussed in Section 5.4.2 (Severe Winter Storm).

Hailstorm: According to the National Weather Service (NWS), hail is defined as a showery precipitation in the form of irregular pellets or balls of ice more than five millimeters in diameter, falling from a cumulonimbus cloud (NWS, 2009). Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until, having developed sufficient weight; they fall as precipitation, in the form of balls or irregularly shaped masses of ice. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size. Hailstorms are a potential damaging outgrowth of severe thunderstorms (Northern Virginia Regional Commission [NVRC], 2006). They cause over $1 billion in crop and property damages each year in the U.S., making hailstorms one of the most costly natural disasters (Federal Alliance for Safe Homes, Inc., 2006).

Windstorm: According to the Federal Emergency Management Agency (FEMA), wind is air moving from high to low pressure. It is rough horizontal movement of air (as opposed to an air current) caused by uneven heating of the Earth's surface. It 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 (FEMA, 1997). A type of windstorm that is experienced often during rapidly moving thunderstorms is a derecho. A derecho is a widespread and long-lived windstorm associated with thunderstorms that are often curved in shape (Johns et al., 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. Windstorm events are associated with cyclonic storms (for example, hurricanes, thunderstorms and tornadoes (FEMA, 1997).

Lightning: According to the NWS, lightning is a visible electrical discharge produced by a thunderstorm. The discharge may occur within or between clouds or between a rain cloud and the ground (NWS, 2005). The discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm creates a "bolt" when the buildup of charges becomes strong enough. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit (°F). Lightning rapidly heats the sky as it flashes but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes thunder. Annually, on average, 300 people are injured and 89 people are killed due to lightning strikes in the U.S. (NVRC, 2006).

Thunderstorm: According to the NWS, a thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS, 2005). A thunderstorm forms from a combination of moisture, rapidly rising warm air and a force capable of lifting air such as a warm and cold front, a sea breeze, or a mountain. Thunderstorms form from the equator to as far north as Alaska. These storms occur most commonly in the tropics. Many tropical land-based locations experience over 100 thunderstorm days each year (Pidwirny, 2007). Although thunderstorms generally affect a small area when they occur, they are very dangerous because of their ability to generate tornadoes, hailstorms, strong winds, flash flooding, and damaging lightning. A thunderstorm produces wind gusts less than 57 miles per hour (mph) and hail, if any, of less than 3/4-inch diameter at the surface. A severe thunderstorm has thunderstorm related surface winds (sustained or gusts) of 57 mph or greater and/or surface hail 3/4-inch or larger (NWS, 2005). Wind or hail damage may be used to infer the occurrence/existence of a severe thunderstorm (Office of the Federal Coordinator for Meteorology, 2001).

Tornado: A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. It is spawned by a thunderstorm (or sometimes as a result of a hurricane) and produced when cool air overrides a layer of warm air, forcing the warm air to rise rapidly. Tornado season is generally March through August, although tornadoes can occur at any time of year. Tornadoes tend to strike in the afternoons and evening, with over 80 percent (%) of all tornadoes striking between noon and midnight (New Jersey Office of Emergency Management [NJOEM], 2007). The average forward speed of a tornado is 30 mph, but can vary from nearly stationary to 70 mph (NWS, 1995). The NOAA Storm Prediction Center (SPC) indicates that the total duration of a tornado can last between a few seconds to over one hour; however, a tornado typical lasts less than 10 minutes (Edwards, 2011). High-wind velocity and wind-blown debris, along with lightning or hail, result in the damage caused by tornadoes. 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 homes and mobile homes, and tend to remain localized during impact (NVRC, 2006).

Tropical Cyclone: Tropical cyclone is a generic term for a cyclonic, low-pressure system over tropical or sub-tropical waters (National Atlas, 2011); containing a warm core of low barometric pressure which typically produces heavy rainfall, powerful winds and storm surge (New York City Office of Emergency Management [NYCOEM], 2008). It feeds on the heat released when moist air rises and the water vapor in it condenses (Dorrego, Date Unknown). Depending on their location and strength, there are various terms by which tropical cyclones are known, such as hurricane, typhoon, tropical storm, cyclonic storm and tropical depression (Pacific Disaster Center, 2006). While tropical cyclones begin as a tropical depression, meaning the storm has sustained winds below 38 miles per hour (mph), it may develop into a tropical storm (with sustained winds of 39 to 73 mph) or a hurricane (with winds of 74 mph and higher).

Tropical Depression: A tropical depression is an organized system of clouds and thunderstorms with a defined surface circulation and maximum sustained winds of less than 38 mph. It has no “eye” (the calm area in the center of the storm) and does not typically have the organization or the spiral shape of more powerful storms (Emanuel, Date Unknown; Miami Museum of Science, 2000).

Tropical Storm: A tropical storm is an organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds between 39 and 73 mph (FEMA, 2011). Once a storm has reached tropical storm status, it is assigned a name. During this time, the storm itself becomes more organized and begins to become more circular in shape, resembling a hurricane. The rotation of a tropical storm is more recognizable than a tropical depression. Tropical storms can cause a lot of problems, even without becoming a hurricane; however, most of the problems stem from heavy rainfall (University of Illinois, Date Unknown).

Hurricane: A hurricane is an intense tropical cyclone with wind speeds reaching a constant speed of 74 mph or more (FEMA, 2011). It is a category of tropical cyclone characterized by thunderstorms and defined surface wind circulation. They are caused by the atmospheric instability created by the collision of warm air with cooler air. They form in the warm waters of tropical and sub-tropical oceans, seas, or Gulf of Mexico (NWS, 2011). Most hurricanes evolve from tropical disturbances. A tropical disturbance is a discrete system of organized convection (showers or thunderstorms), that originate in the tropics or subtropics, does not migrate along a frontal boundary, and maintains its identity for 24 hours or more (NWS, 2004). Hurricanes begin when areas of low atmospheric pressure move off the western coast of Africa and into the Atlantic, where they grow and intensify in the moisture-laden air above the warm tropical ocean. Air moves toward these atmospheric lows from all directions and circulates clock-wise under the influence of the Coriolis Effect, thereby initiating rotation in the converging wind fields. When these hot, moist air masses meet, they rise up into the atmosphere above the low pressure area, potentially establishing a self-reinforcing feedback system that produces weather systems known to meteorologists as tropical disturbances, tropical depressions, tropical storms, and hurricanes (Frankenberg, Date Unknown).

Almost all tropical storms and hurricanes in the Atlantic basin, which includes the Gulf of Mexico and Caribbean Sea, form between June 1st and November 30th. This time frame is known as hurricane season. August and September are peak months for hurricane development. The threats caused by an approaching hurricane can be divided into three main categories: storm surge, wind damage and rainfall/flooding:

- *Storm Surge* is simply water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with the normal tides to create the hurricane storm tide, which can increase the mean water level 15 feet or more. Storm surge is responsible for nearly 90-percent of all hurricane-related deaths and injuries.
- *Wind Damage* is the force of wind that can quickly decimate the tree population, down power lines and utility poles, knock over signs, and damage/destroy homes and buildings. Flying debris can also cause damage to both structures and the general population. When hurricanes first make landfall, it is common for tornadoes to form which can cause severe localized wind damage.
- *Rainfall / Flooding* the torrential rains that normally accompany a hurricane can cause serious flooding. Whereas the storm surge and high winds are concentrated around the "eye", the rain may extend for hundreds of miles and may last for several days, affecting areas well after the hurricane has diminished (Mandia, 2011).

## Extent

The extent (that is, magnitude or severity) of a severe storm is largely dependent upon sustained wind speed. Straight-line winds, winds that come out of a thunderstorm, in extreme cases, can cause wind gusts exceeding 100 mph. These winds are most responsible for hailstorm and thunderstorm wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado (NVRC, 2006).

### Hail

Hail can be produced from many different types of storms. Typically, hail occurs with thunderstorm events. The size of hail is estimated by comparing it to a known object. Most hail storms are made up of a variety of sizes, and only the very largest hail stones pose serious risk to people, if exposed (Draft NYS

HMP, 2011; NSSL, Date Unknown). Table 5.4.3-1 shows the different types of hail and the comparison to real-world objects.

Table 5.4.3-1. Hail Size

| Description | Diameter (in inches) |
|---|---|
| Pea | 0.25 |
| Marble or mothball | 0.50 |
| Penny or dime | 0.75 |
| Nickel | 0.88 |
| Quarter | 1.00 |
| Half Dollar | 1.25 |
| Walnut or Ping Pong Ball | 1.50 |
| Golf ball | 1.75 |
| Hen's Egg | 2.00 |
| Tennis Ball | 2.75 |
| Baseball | 2.75 |
| Tea Cup | 3.00 |
| Grapefruit | 4.00 |
| Softball | 4.50 |

Source: Draft NYS HMP, 2011

### Tornado

The magnitude or severity of a tornado was originally categorized using the Fujita Scale (F-Scale) or 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, 2012). Table 5.4.3-2 explains each of the six F-Scale categories.

Table 5.4.3-2. Fujita Damage Scale

| Scale | Wind Estimate (MPH) | Typical Damage |
|---|---|---|
| F0 | < 73 | Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged. |
| F1 | 73-112 | Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads. |
| F2 | 113-157 | Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground. |
| F3 | 158-206 | Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown. |

| Scale | Wind Estimate (MPH) | Typical Damage |
|---|---|---|
| F4 | 207-260 | Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated. |
| F5 | 261-318 | Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yards); trees debarked; incredible phenomena will occur. |

Source: SPC, 2012

Although the F-Scale has been in use for over 30 years, there are limitations of the scale. The primary limitations are a lack of damage indicators, 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 (NOAA, 2008).

The EF Scale became operational on February 1, 2007. It is used to assign tornadoes a 'rating' based on estimated wind speeds and related damage. When tornado-related damage is surveyed, it is compared to a list of Damage Indicators (DIs) and Degree 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 degrees of damage. The EF Scale was revised from the original F-Scale to reflect better examinations of tornado damage surveys. This new scale has to do with how most structures are designed (NOAA, 2008). Table 5.4.3-3 displays the EF Scale and each of its six categories.

Table 5.4.3-3. Enhanced Fujita Damage Scale

| F-Scale Number | Intensity Phrase | Wind Speed (mph) | Type of Damage Done |
|---|---|---|---|
| EF0 | Light tornado | 65–85 | Light damage. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. |
| EF1 | Moderate tornado | 86-110 | Moderate damage. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken. |
| EF2 | Significant tornado | 111-135 | Considerable damage. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground. |
| EF3 | Severe tornado | 136-165 | Severe damage. Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some distance. |
| EF4 | Devastating tornado | 166-200 | Devastating damage. Well-constructed houses and whole frame houses completely leveled; cars thrown and small missiles generated. |
| EF5 | Incredible tornado | >200 | Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 m (109 yd); high-rise buildings have significant structural deformation; incredible phenomena will occur. |

Source: SPC, Date Unknown

In the Fujita Scale, there was a lack of clearly defined and easily identifiable damage indicators. The EF Scale takes into account more variables than the original F-Scale did when assigning a wind speed rating to a tornado. The EF Scale incorporates 28 DIs, such as building type, structures, and trees. For each damage indicator, there are eight DODs, ranging from the beginning of visible damage to complete destruction of the damage indicator. Table 5.4.3-4 lists the 28 DIs. Each one of these indicators has a description of the typical construction for that category of indicator. Each DOD in every category is given an expected estimate of wind speed, a lower bound of wind speed, and an upper bound of wind speed.

Table 5.4.3-4. 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 - jr. or sr. high school | JHSH |
| 3 | Single-wide mobile home (MHSW) | MHSW | 17 | Low-rise (1-4 story) bldg. | LRB |
| 4 | Double-wide mobile home | MHDW | 18 | Mid-rise (5-20 story) bldg. | MRB |
| 5 | Apt, condo, townhouse (3 stories or less) | ACT | 19 | High-rise (over 20 stories) | HRB |
| 6 | Motel | M | 20 | Institutional bldg. (hospital, govt. or university) | IB |
| 7 | Masonry apt. or motel | MAM | 21 | Metal building system | MBS |
| 8 | Small retail bldg. (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 bldg. | 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: SPC, Date Unknown

Since the EF Scale recently went into effect in February 2007, previous occurrences and losses associated with historic tornado events, described in the next section (Previous Occurrences and Losses) of this hazard profile, are based on the former Fujita Scale. Events after February 2007 are based on the Enhance Fujita Scale.

**Hurricanes**

The extent of a hurricane is categorized by the Saffir-Simpson Hurricane Scale. This scale categorizes or rates hurricanes from 1 (Minimal) to 5 (Catastrophic) based on their intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline, in the landfall region (National Hurricane Center [NHC], 2010). Table 5.4.3-5 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes land fall.

Table 5.4.3-5. The Saffir-Simpson Scale

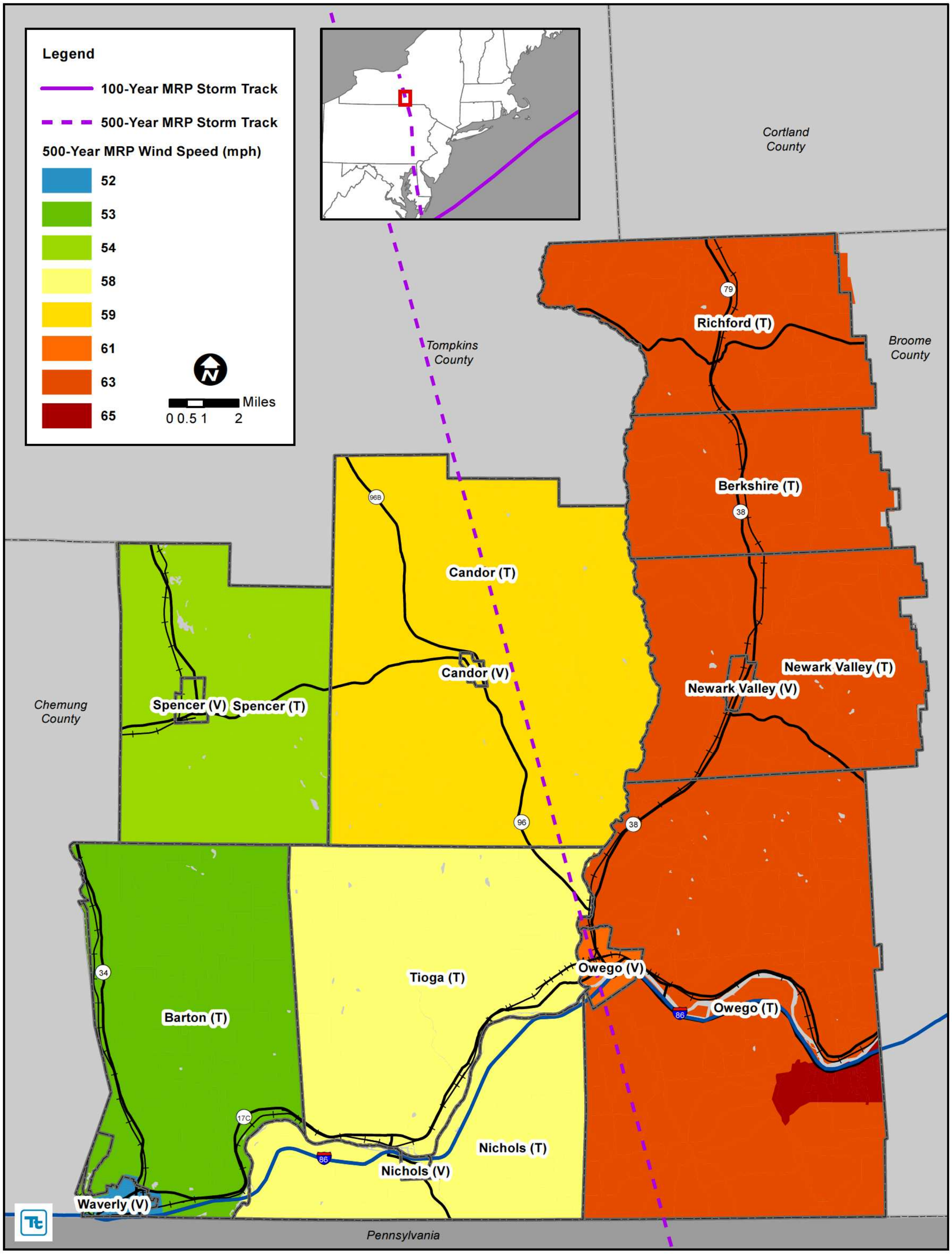
| Category | Wind Speed (mph) | Storm Surge (above normal sea level) | Expected Damage |
|---|---|---|---|
| 1 | 74-95 | 4 – 5 feet | Minimal: Damage is done primarily to shrubbery and trees, unanchored mobile homes are damaged, some signs are damaged, and no real damage is done to structures. |
| 2 | 96-110 | 6 – 8 feet | Moderate: Some trees are toppled, some roof coverings are damaged, and major damage is done to mobile homes. |
| 3 | 111-130 | 9 – 12 feet | Extensive: Large trees are toppled, some structural damage is done to roofs, mobile homes are destroyed, and structural damage is done to small homes and utility buildings. |
| 4 | 131-155 | 13 – 18 feet | Extreme: Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; and some curtain walls fail. |
| 5 | > 155 | > 18 feet | Catastrophic: Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures, and entire buildings could fail. |
| **Additional Classifications** | | | |
| Tropical Storm | 39-73 | 0 - 3 feet | NA |
| Tropical Depression | < 38 | 0 | NA |

Source: FEMA, 2010
mph = Miles per hour
> = Greater than
NA = not applicable or not available

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). For example, a flood that has a 1-percent chance of being equaled or exceeded in any given year is also referred to as the base flood and has a MRP of 100. This is known as a 100-year flood. The term “100-year flood” can be misleading; it is not the flood that will occur once every 100 years. Rather, it is the flood elevation that has a one-percent chance of being equaled or exceeded each year. Therefore, the 100-year flood could occur more than once in a relatively short period of time or less than one time in 100 years (Dinicola, 2009).

Figure 5.4.3-1 shows the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP HAZUS-MH model runs. The estimated hurricane track for the 100- and 500-year event is also shown. For the 100-year MRP event, there is no wind (0 mph) associated with the storm event in Tioga County. For the 500-year MRP event, the maximum 3-second gust wind speeds for the County range from 52 to 65 mph, characteristic of a tropical storm. The associated impacts and losses from these 100-year and 500-year MRP hurricane event model runs are reported in the Vulnerability Assessment later in this section.

Figure 5.4.3-1. Wind Speeds and Storm Track for the 100-Year and 500-Year Mean Return Period Event in Tioga County.




Source: HAZUS-MH 2.0
Note: The wind speeds are zero miles per hour for the 100-year MRP event.

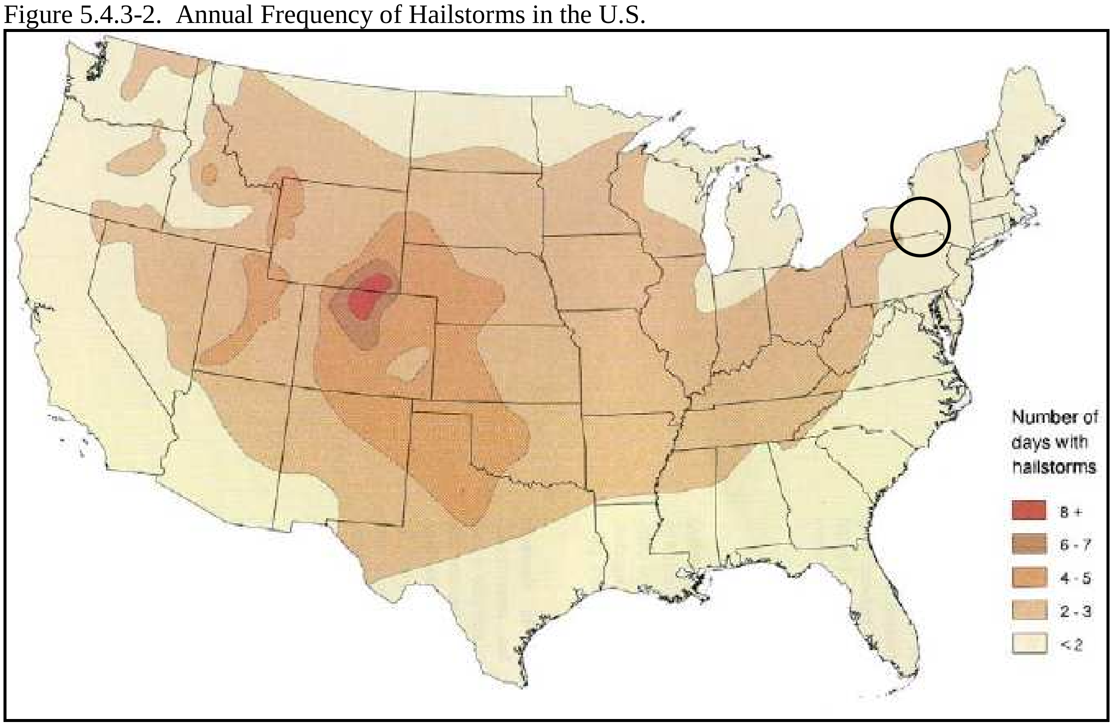
## Location

Severe storms are a common natural hazard in New York State because the State exhibits a unique blend of weather (geographically and meteorological) features that influence the potential for severe storms and associated flooding. Factors include temperature, which is affected by latitude, elevation, proximity to water bodies and source of air masses; and precipitation which includes snowfall and rainfall. Precipitation intensities and effects are influenced by temperature, proximity to water bodies, and general frequency of storm systems. The Cornell Climate Report also indicates that the geographic position of the State (Northeast U.S.) makes it vulnerable to frequent storm and precipitation events. This is because nearly all storms and frontal systems moving eastward across the continent pass through, or in close proximity to New York State. Additionally, the potential for prolonged thunderstorms or coastal storms and periods of heavy precipitation is increased throughout the state because of the available moisture that originates from the Atlantic Ocean (Draft NYS HMP, 2011).

### Hailstorms

Hailstorms are more frequent in the southern and central plain states, where the climate produces violent thunderstorms. However, hailstorms have been observed in almost every location where thunderstorms occur (Federal Alliance for Safe Homes, Inc, 2006). Figure 5.4.3-2 illustrates that Tioga County and most of New York State experience less than two hailstorms per year.

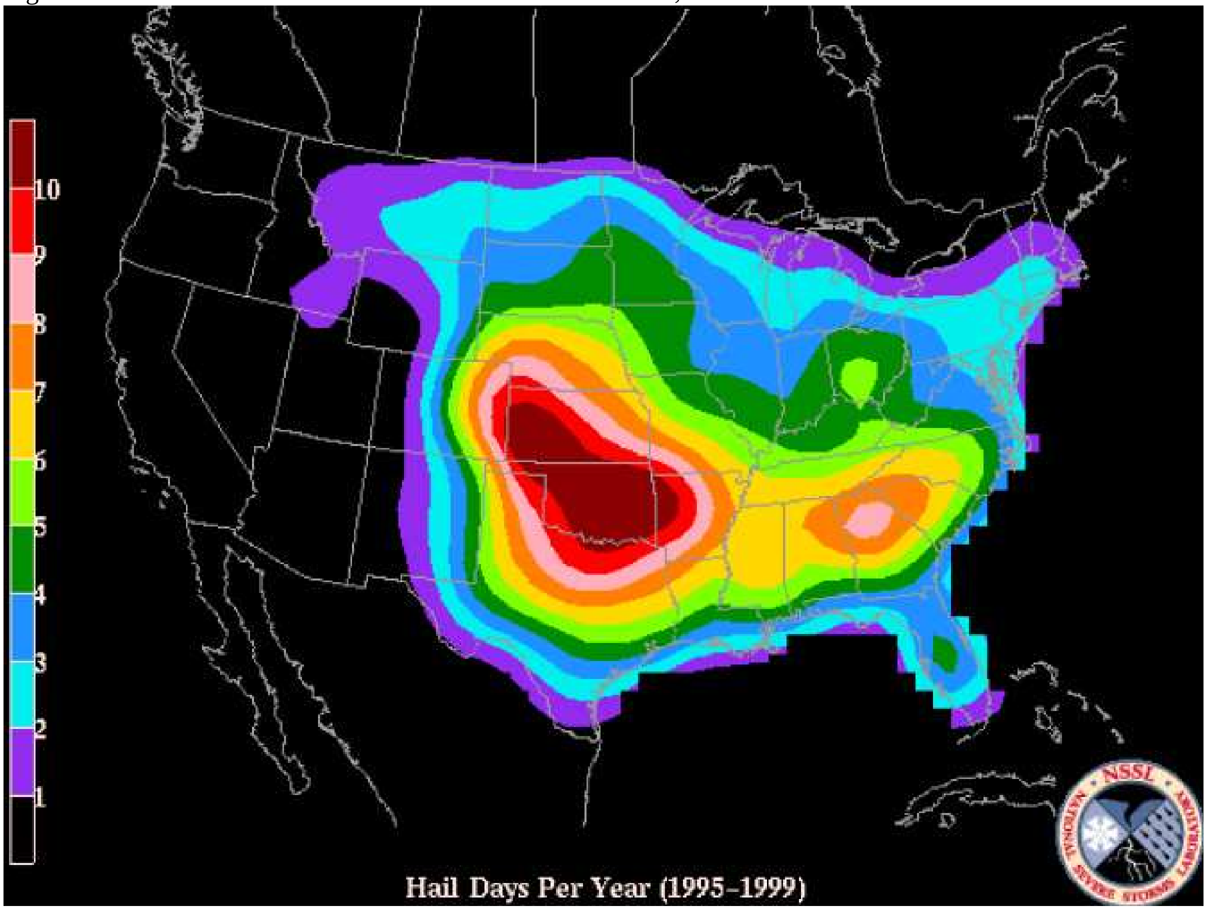
Figure 5.4.3-2. Annual Frequency of Hailstorms in the U.S.




Source: NVRC, 2006
Note: The black circle indicates the approximate location of Tioga County.

Figure 5.4.3-3 illustrates the number of hail days, per year, between 1995 and 1999 in the U.S. According to this figure, New York State experiences between one and three days of hail each year, with Tioga County experiencing between one and two days.

Figure 5.4.3-3. Total Annual Threat of Hail Events in the U.S., 1995-1999



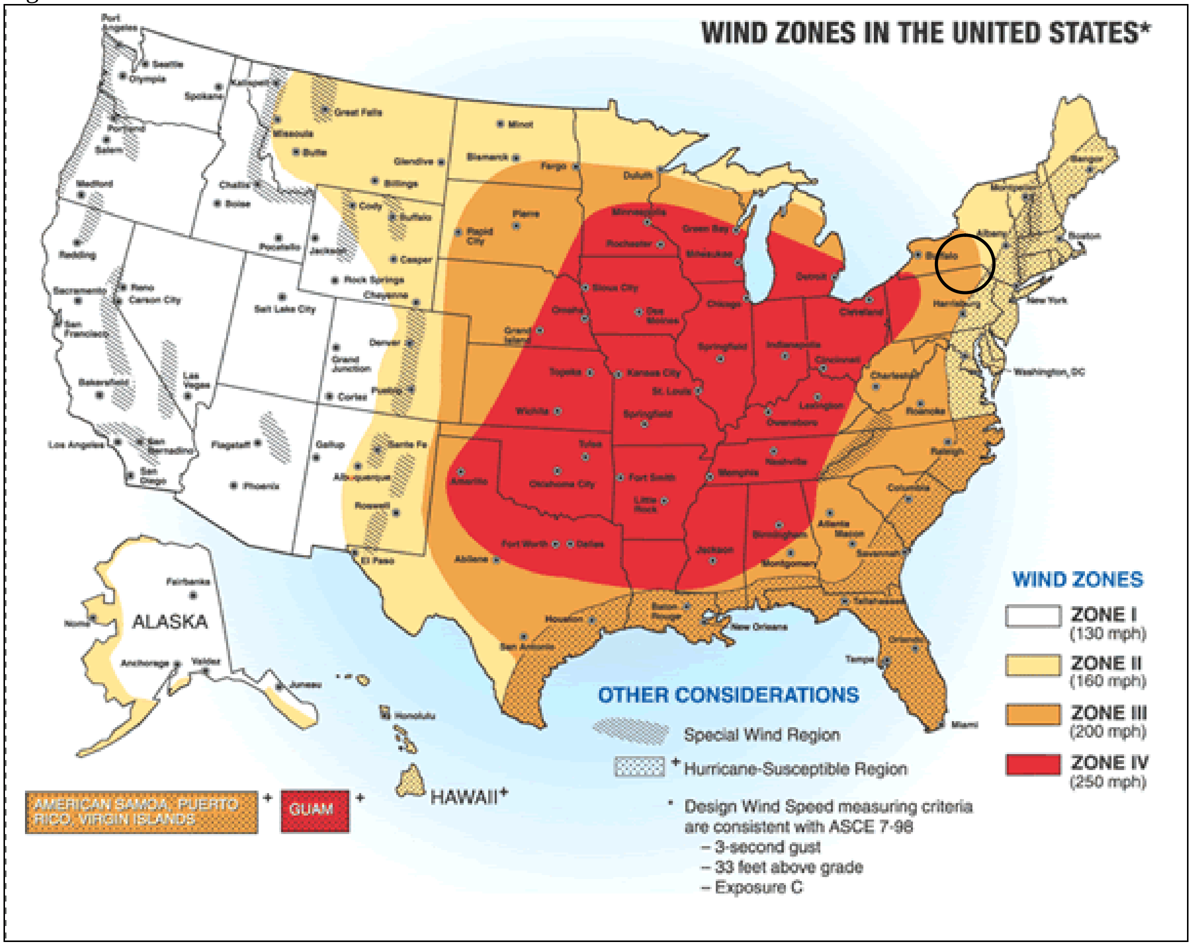

Source: Draft NYS HMP, 2011; NSSL, 2003

Note: The mean number of days per year with one or more events within 25 miles of a point is shown here. The fill interval for tornadoes is 0.2, with the purple starting at 0.2 days. For the nontornadic threats, the fill interval is 1, with the purple starting at 1. For the significant (violent), it's 5 days per century (millennium)

### Windstorms

Figure 5.4.3-4 indicates how the frequency and strength of windstorms impacts the U.S. and the general location of the most wind activity. This is based on 40 years of tornado history and 100 years of hurricane history, collected by FEMA. States located in Wind Zone IV have experienced the greatest number of tornadoes and the strongest tornadoes (NVRC, 2006). Tioga County is located in Wind Zone III with speeds up to 200 miles per hour (FEMA, 2008). The New York State Hazard Mitigation Plan (NYS HMP) identifies counties most vulnerable to wind, as determined by a rating score. Counties accumulate points based on the value of each vulnerability indicator, the higher then indication for wind exposure the more points assigned, resulting in a final rating score. Tioga County was given a rating score of 10 (Draft NYS HMP, 2011).

Figure 5.4.3-4. Wind Zones in the U.S.




Source: FEMA, 2010

Note: The black circle indicates the approximate location of Tioga County.

Table 5.4.3-6. Wind Zones in the U.S.

| 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, West Virginia. All of American Samoa, Puerto Rico, and Virgin Islands. |
| Zone IV (250 mph) | Mid US 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, New Mexico. The borders between Vermont and New Hampshire; between New York, Massachusetts and Connecticut; between Tennessee and North Carolina. |

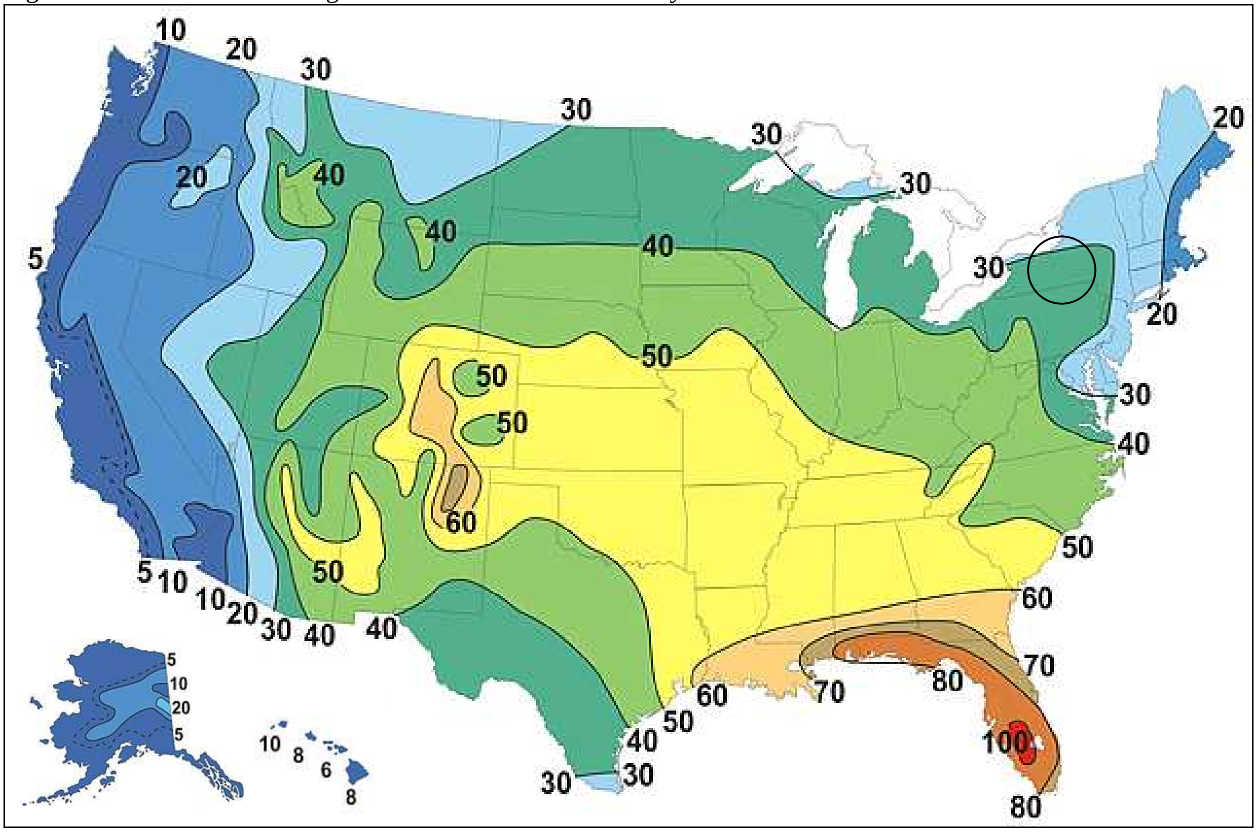
| Wind Zones | Areas Affected |
|---|---|
| Hurricane Susceptible Region | Southern US coastline from Gulf Coast of Texas eastward to include entire state of Florida. East Coastline from Maine to Florida, including all of Massachusetts, Connecticut, Rhode Island, Delaware, and Washington DC. All of Hawaii, Guam, American Samoa, Puerto Rico and Virgin Islands. |

Source: Draft NYS HMP, 2011

**Thunderstorms**

Thunderstorms affect relatively small localized areas, rather then large regions much like winter storms, and hurricane events (NWS, 2005). Thunderstorms can strike in all regions of the U.S.; however, they are most common in the central and southern states. The atmospheric conditions in these regions of the country are most ideal for generating these powerful storms (NVRC, 2006). It is estimated that there are as many as 40,000 thunderstorms each day world-wide. Figure 5.4.3-5 shows the average number of thunderstorm days throughout the U.S. The most thunderstorms are seen in the southeast states, with Florida having the highest incidences (80 to over 100 thunderstorm days each year) (NWS, 2010). This figure indicates that Tioga County experiences between 30 and 40 thunderstorm days each year.

Figure 5.4.3-5. Annual Average Number of Thunderstorm Days in the U.S.

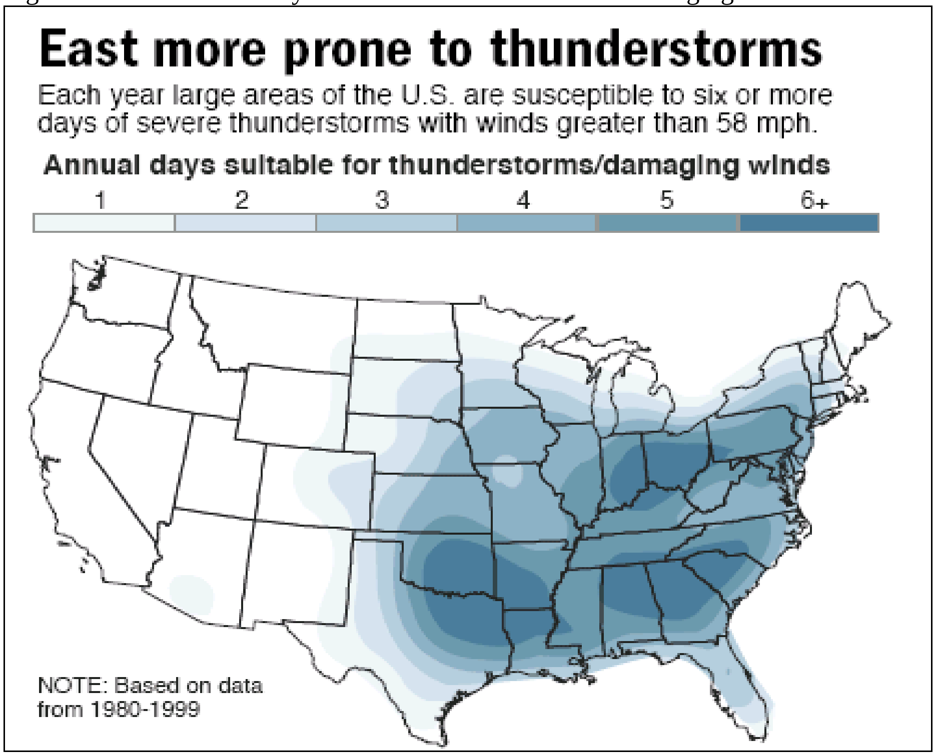



Source: NWS, 2010

Note: The black circle indicates the approximate location of Tioga County.

NASA scientists suggest that the U.S. will face more severe thunderstorms in the future, with deadly lightning, damaging hail and the potential for tornadoes in the event of climate change (Borenstein, 2007). A recent study conducted by NASA predicts that smaller storm events like thunderstorms will be more dangerous due to climate change (Figure 5.4.3-6). As prepared by the NWS, Figure 5.4.3-7 identifies those areas, particularly within the eastern U.S. that are more prone to thunderstorms, which includes New York State.

Figure 5.4.3-6. Annual Days Suitable for Thunderstorms/Damaging Winds

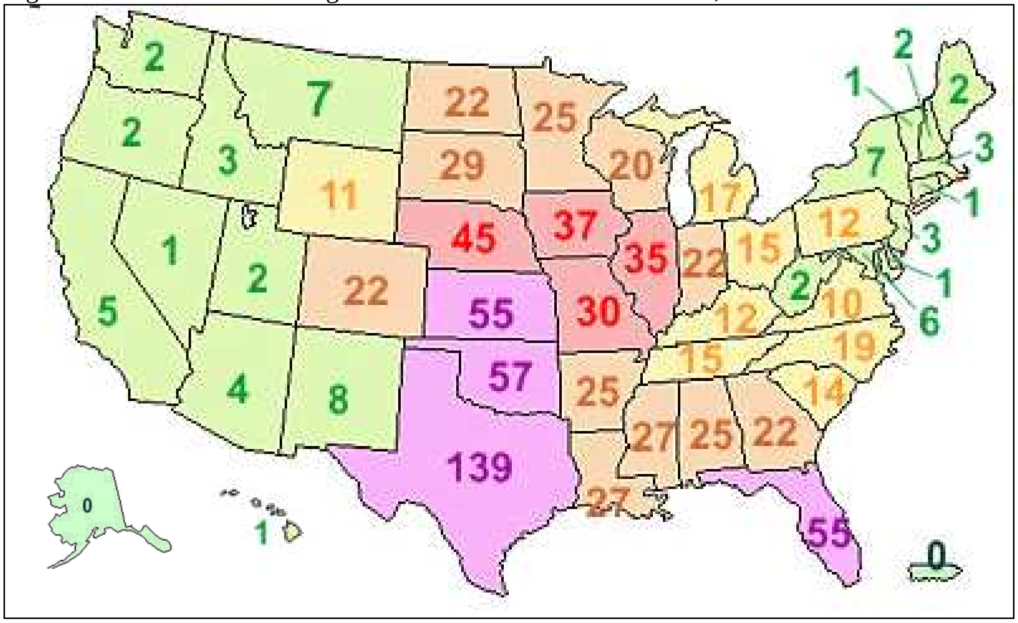



Source: MSNBC.com, 2007

**Tornado**

The U.S. experiences more tornadoes than any other country. In a typical year, approximately 1,000 tornadoes affect the U.S. The peak of the tornado season is April through June, with the highest concentration of tornadoes in the central U.S. Figure 5.4.3-7 shows the annual average number of tornadoes between 1953 and 2004 (NWS, 2010). New York State experienced an average of seven tornado events annually between 1953 and 2004.

Figure 5.4.3-7. Annual Average Number of Tornadoes in the U.S., 1953 to 2004

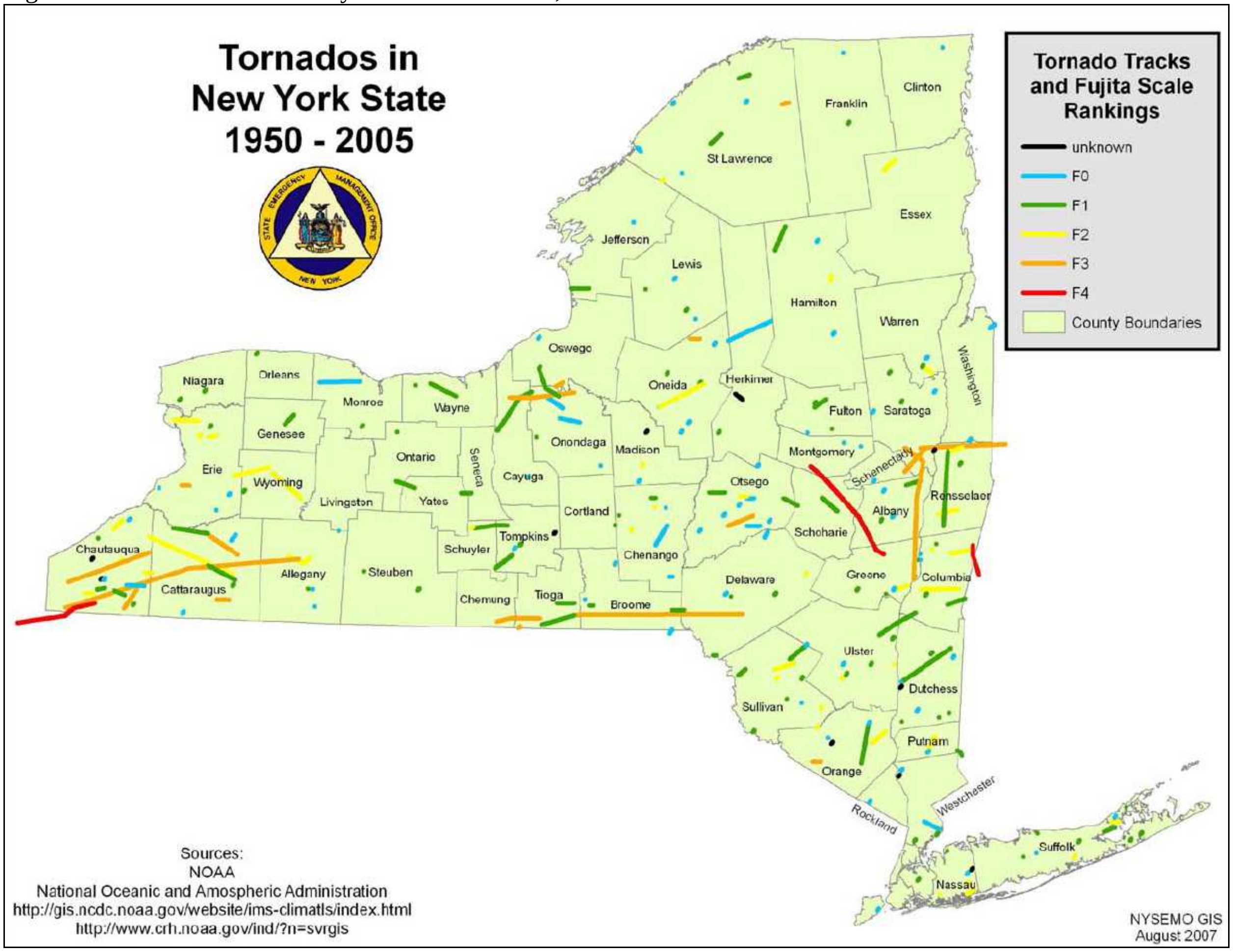



Source: NWS, 2010

Note: Between 1953 and 2004, New York State experienced an average of seven tornadoes each year.

New York State ranks 30th in the U.S. for frequency of tornadoes. When compared to other states on the frequency of tornadoes per square mile, the State ranks 35th (Pacific Disaster Center, 2006). New York State has a definite vulnerability to tornadoes and can occur, based on historical occurrences, in any part of the State. According to Figure 5.4.3-8, every county in New York State has experienced a tornado between 1950 and 2005 (Draft NYS HMP, 2011).

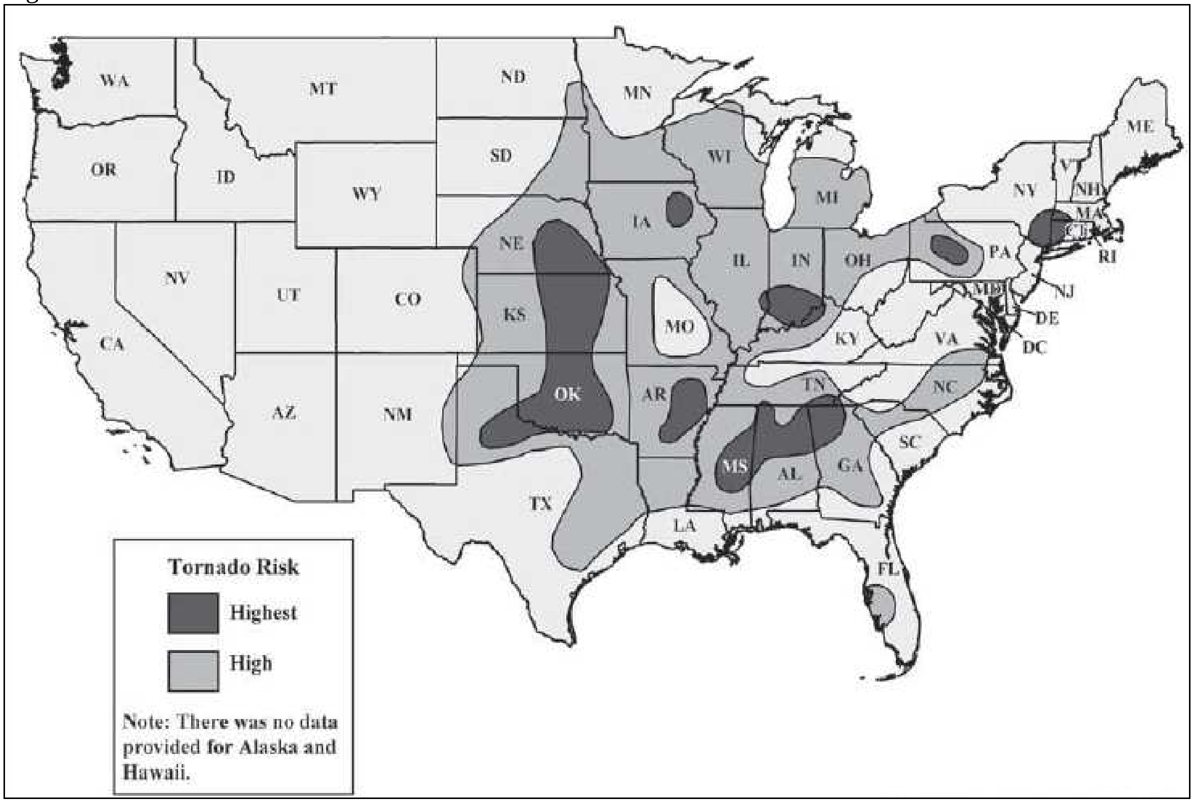
Figure 5.4.3-8. Tornado Activity in New York State, 1950-2005




Source: Draft NYS HMP, 2011

Figure 5.4.3-9 indicates that a majority of the State, with the exception of the southeastern section (Mid-Hudson Region), has an overall low risk of tornado activity. Tioga County is located in central New York State, which according to the figure, has a high risk of tornadoes. Details regarding historical tornado events are discussed in the next section (Previous Occurrences and Losses) of this profile.

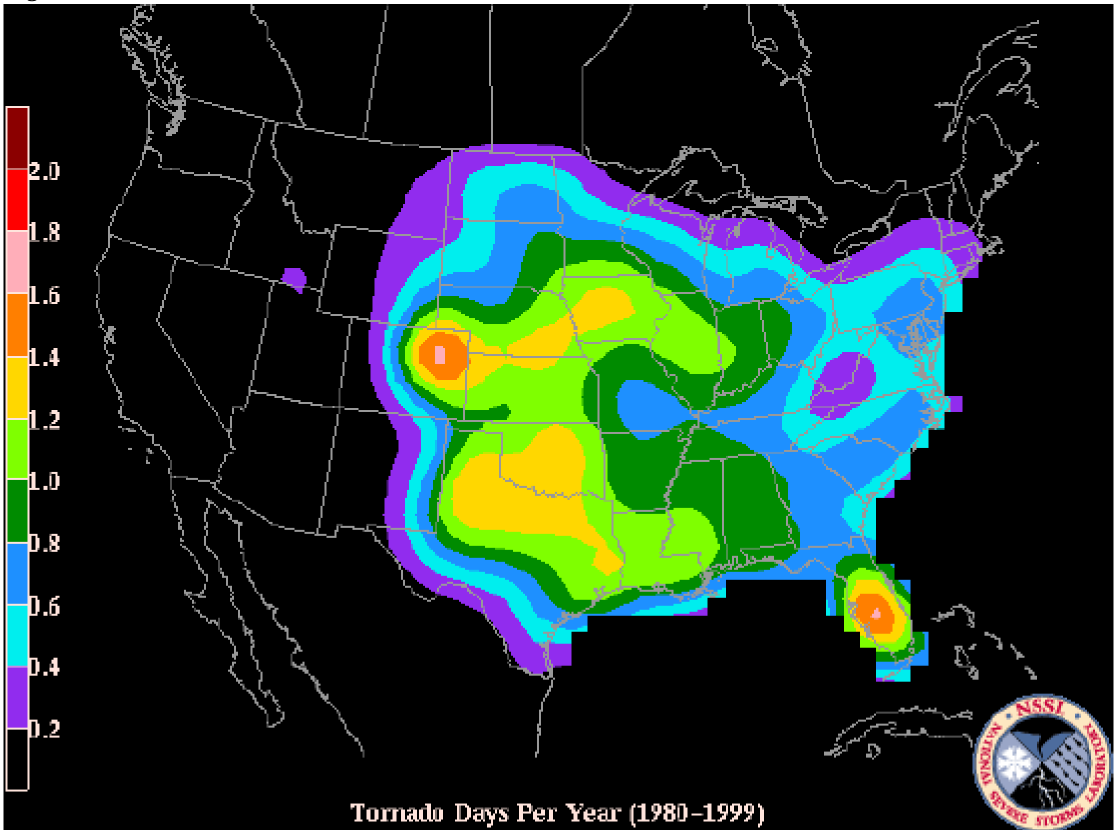
Figure 5.4.3-9. Tornado Risk in the U.S.




Source: Draft NYS HMP, 2011
Note: Tioga County is shown has having a high risk of tornado occurrences.

A study from NOAA's National Severe Storms Laboratory (NSSL) provided estimates of the long-term threat from tornadoes. The NSSL used historical data to estimate the daily probability of tornado occurrences across the U.S., no matter the magnitude of the tornado. Figure 5.4.3-10 shows the estimates prepared by the NSSL. In New York State, it is estimated that the probability of a tornado occurring is 0 and 0.6 days per year. In Tioga County, it is estimated that the probability of tornado occurring is 0.4 to 0.6 days per year (Draft NYS HMP, 2011).

Figure 5.4.3-10. Total Annual Threat of Tornado Events in the U.S., 1980-1999




Source: Draft NYS HMP, 2011; NSSL, 2003

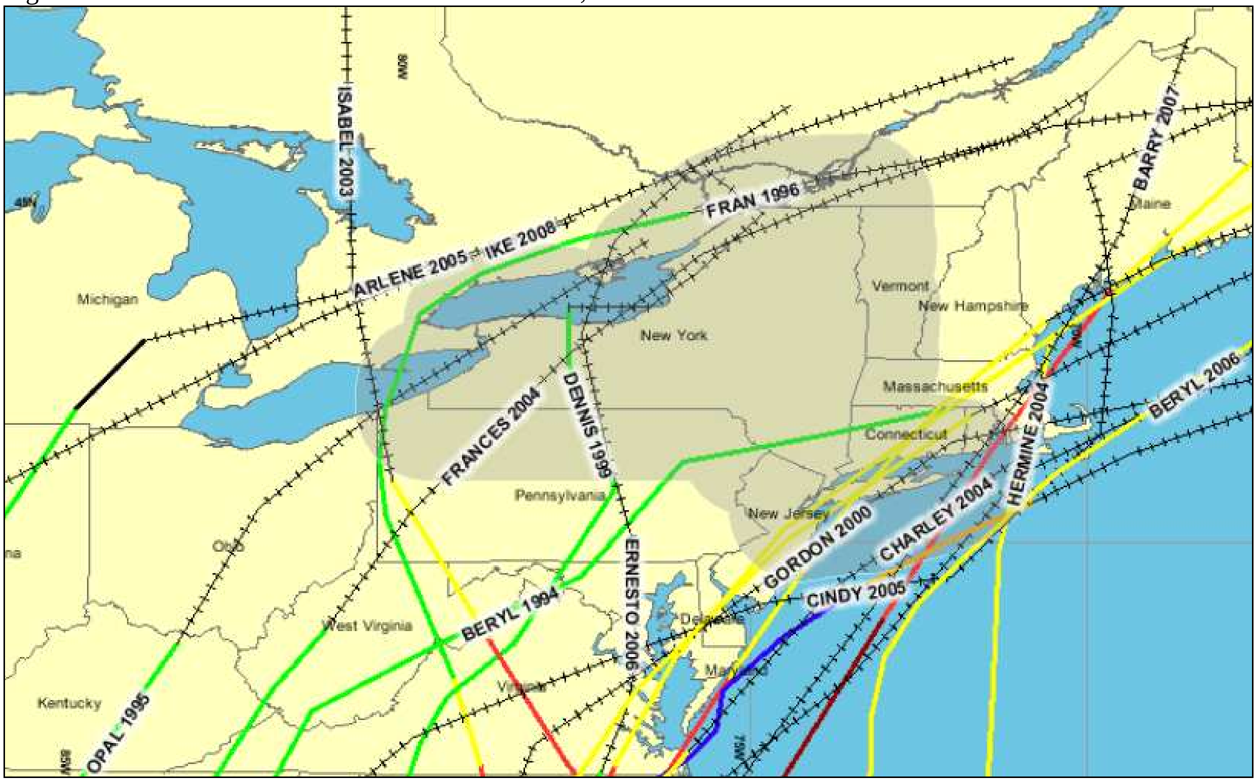
Note: The mean number of days per year with one or more events within 25 miles of a point is shown here. The fill interval for tornadoes is 0.2, with the purple starting at 0.2 days. For the nontornadic threats, the fill interval is 1, with the purple starting at 1. For the significant (violent), it's 5 days per century (millennium)

**Hurricanes/Tropical Storms**

Due to Tioga County's inland location, hurricanes do not appear to make direct landfall on the mitigation study area. However, the County has been known to experience the indirect landward effects, including high winds, heavy rains, and major flooding associated with hurricane and/or tropical storm events. Hurricanes and tropical storms can impact New York State from June to November, the official eastern U.S. hurricane season. However, late July to early October is the period hurricanes and tropical storms are most likely to impact New York State, due to the coolness of the North Atlantic Ocean waters (Draft NYS HMP, 2011).

From 1888 to 2005, 32 hurricanes and numerous tropical storms have crossed over New York State. Figure 5.4.3-11 illustrates the storm tracks for storms between 1990 and 2006 for the State. The vast majority of these storms have been over the eastern part of the State, specifically in the southeastern corner. This area includes the New York City metropolitan area and the mid and lower Hudson Valley areas. These areas comprise approximately 61-percent of New York State's population (Draft NYS HMP, 2011).

Figure 5.4.3-11. Hurricane Tracks in New York State, 1990 to 2006.




Source: Draft NYS HMP, 2011

Multiple sources have indicated that Tioga County has been impacted by many hurricanes, tropical storms and tropical depressions. The County has felt the direct and indirect landward effects associated with several hurricanes and tropical storms in recent history. These storms are based on the Historical Hurricane Tracker, which includes storms through 2010. More recently, the County felt the effects of Hurricane Irene and Tropical Storm Lee.

The Historical Hurricane Tracks tool is a public interactive mapping application that displays Atlantic Basin and East-Central Pacific Basin tropical cyclone data. This interactive tool tracks tropical cyclones from 1842 to 2010. Figure 5.4.3-12 displays tropical cyclone tracks for Tioga County; however, the associated names for some of these events are unknown. Between 1842 and 2010, Tioga County has experienced nine tropical cyclone events. These events occurred within 65 nautical miles of the County (NOAA, 2012).

Figure 5.4.3-12. Historical North Atlantic Tropical Cyclone Tracks (1842-2010)


Source: NOAA, 2012

## Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with severe storm events throughout New York State and Tioga County. With so many sources reviewed for the purpose of this HMP, loss and impact information for many events could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP.

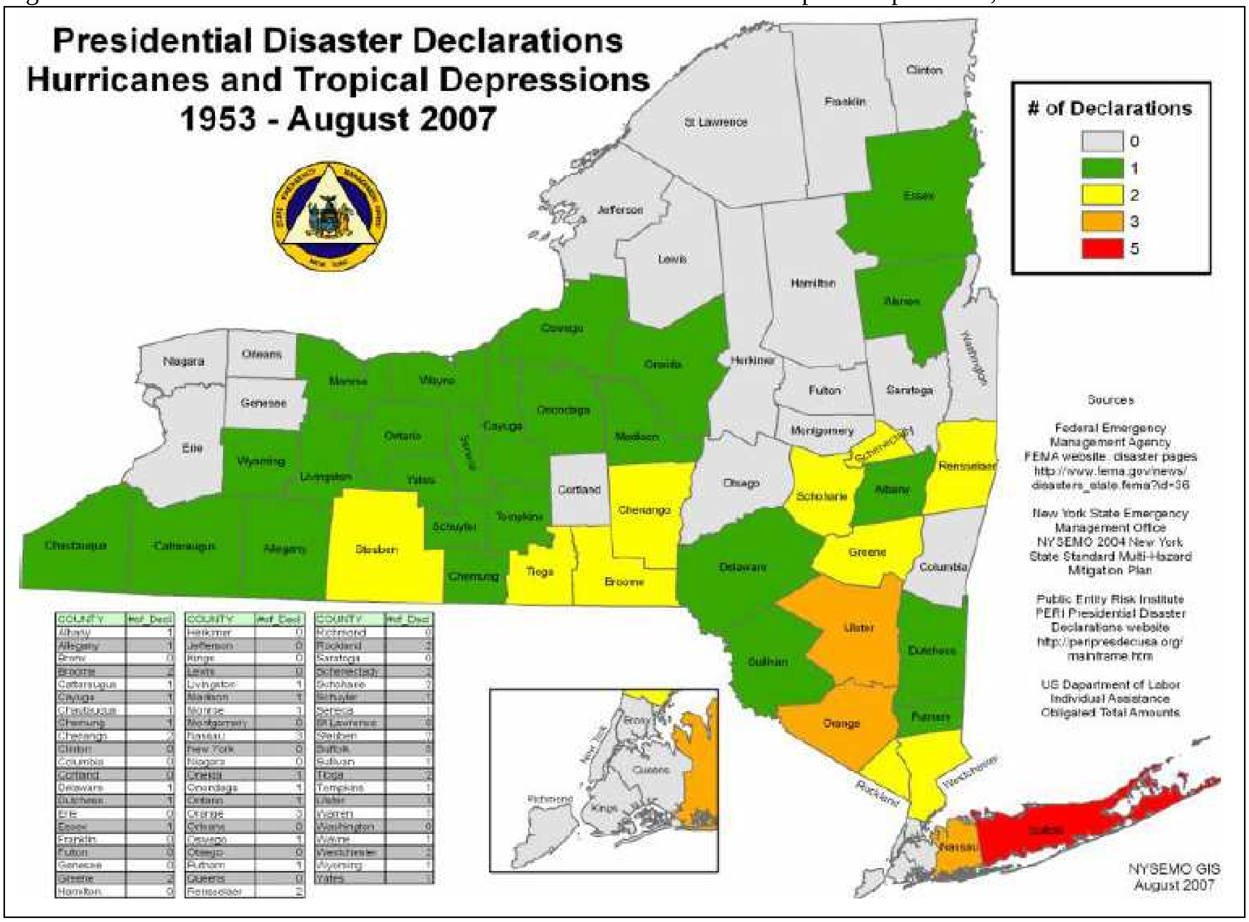
According to NOAA's NCDC storm events database, Tioga County experienced 80 severe storm events between 1950 and April 2012. These events include funnel clouds, hail, high wins, lightning, hurricane and tropical storms, precipitation, strong winds, thunderstorms and tornadoes. Total property damages, as a result of these severe storm events, were estimated at $171,000. This total also includes damages to other counties. According to the Hazard Research Lab at the University of South Carolina's Spatial Hazard Events and Losses Database for the U.S. (SHELDUS), between 1960 and 2010, 214 severe storm events occurred within the County. The database indicated that severe storm events and losses specifically associated with Tioga County and its municipalities totaled over $12.1 million in property damage and over $768,000 in crop damage. However, these numbers may vary due to the database identifying the location of the hazard event in various forms or throughout multiple counties or regions.

Between 1954 and 2012, FEMA declared that New York State experienced 51 severe storm-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types:

winter storms, severe storms, coastal storms, flooding, heavy rain, tropical storm, hurricane, high winds and tornado. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations. Of those events, the NYS HMP and other sources indicate that Tioga County has been declared as a disaster area as a result of 12 severe storm events (FEMA, 2012).

Figure 5.4.3-13 shows the FEMA disaster declarations (DR) for hurricanes and tropical depressions in New York State, from 1953 to August 2007. This figure indicates that Tioga County was included in two disaster declarations. Since the date of this figure, Tioga County has been included in one additional FEMA disaster declarations for hurricanes and tropical storms.

Figure 5.4.3-13. Presidential Disaster Declarations for Hurricanes and Tropical Depressions, 1953-2007




Source: Draft NYS HMP, 2011

Based on all sources researched, known severe storm events that have affected Tioga County and its municipalities are identified in Table 5.4.3-7. With severe storm documentation for New York State being so extensive, not all sources have been identified or researched. Therefore, Table 5.4.3-7 may not include all events that have occurred throughout the County and region.

Table 5.4.3-7. Severe Storm Events Between 1950 and 2012

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts | Source(s) |
|---|---|---|---|---|---|
| June 17, 1960 | TSTMs, High Wind, Hail, Heavy Rain | N/A | N/A | The County had over $260 K in property damage. | SHELDUS |
| July 4, 1963 | Wind | N/A | N/A | The County had over $80 K in property damage. | SHELDUS |
| 1972 | Tropical Storm Agnes | DR-338 | Yes | No reference and/or no damage reported. | FEMA |
| April 14, 1974 | Wind | N/A | N/A | The County had one injury reported and approximately $125 K in property damage. | SHELDUS |
| July 2-3, 1974 | TSTM | N/A | N/A | The County had over $294 K in property damage. | SHELDUS |
| September 22-28, 1975 | Severe Storms, Heavy Rain, Landslides, Flooding | DR-487 | Yes | The County had approximately $6.25 M in property damage. | SHELDUS, FEMA |
| July 11-12, 1976 | Severe Storms and Flooding | DR-515 | Yes | No reference and/or no damage reported. | FEMA |
| October 27-28, 1981 | Severe Storm / TSTM | N/A | N/A | The County had over $800 K in property damage from heavy rain. | SHELDUS |
| May 2, 1983 | Tornado (F3) | N/A | N/A | The County had approximately $2.5 M in property damage and one reported injury. | NOAA-NCDC |
| March 21-22, 1980 | TSTM / Wind | N/A | N/A | The County had over $80 K in property damage. | SHELDUS |
| August 27, 1988 | Tornado (F1) | N/A | N/A | The County had approximately $2.5 M in property damage from a tornado that struck between the Towns of Nichols and Owego (Apalachin). | NOAA-NCDC, SHELDUS |
| January 19-30, 1996 | Severe Storms and Flooding | DR-1096 | Yes | No reference and/or no damage reported. | FEMA |
| July 8, 1998 | Severe Storms and Flooding | DR-1233 | Yes | No reference and/or no damage reported. | FEMA, NOAA-NCDC |

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts | Source(s) |
|---|---|---|---|---|---|
| May 31, 1998 | Severe Storm | N/A | N/A | Severe thunderstorms ripped through the County. The series of storms downed trees and power lines throughout the County, with isolated roof damage to homes west of the Town of Owego. Golf ball sized hail was reported in the Town of Newark Valley. The hail damaged cars and crops; with hundreds of acres of crops at local fruit stands severely damaged. The County had approximately $50 K in property damage and $30 K in crop damage.<br><br>The storms also caused tornadoes in central NYS. The most devastating tornado cut a discontinuous 60-mile track from southeastern Tioga County across southern Broome County and into Delaware County where it finally lifted back into the cloud base. This tornado alone damaged or destroyed more than 30 homes and injured nearly 20 people. | NOAA-NCDC |
| September 27, 1998 | Severe Storms | N/A | N/A | Severe thunderstorms that produced wind damage in Tioga County. There were isolated reports of wind damage in the Village of Waverly and in the Town of Nichols. Most of the damage was downed trees and power lines. The County had approximately $35 K in property damage. | NOAA-NCDC |
| May 3 – August 12, 2000 | Severe Storms | DR-1335 | Yes | 5/18 - TSTM winds produced wind damage to the County<br>6/11 - Wind damage was reported throughout the County.<br>6/29 – One- inch diameter hail was reported in the Town of Candor, with some accumulation noted. Many trees and wires were down with 100 residents left without power; a rotating wall cloud was reported over the Town of Owego.<br>8/9 - TSTM winds brought down numerous trees and power lines. Brown Road, West Creek Road, and Wilson Creek Road were blocked by fallen trees and limbs. | NOAA-NCDC |
| December 12, 2000 | Wind | N/A | N/A | The County had over $64 K in property damage. | SHELDUS |
| May 31, 2002 | Tornado (F1) | N/A | N/A | The tornado first touched down about a mile and a half northeast of the Village of Owego, along Carmichael Road. As the tornado passed over a ridge toward Beecher Hill Road, it caused extensive damage. There was major tree damage, two mobile homes were completely destroyed, and a house experienced significant damage. The tornado moved east and crossed Lisle Road causing significant tree damage. It continued east crossing Gaskill Road, destroying a barn and shed. Trees were uprooted and debris was blown over a | NOAA-NCDC, SHELDUS |

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts | Source(s) |
|---|---|---|---|---|---|
| | | | | quarter mile away. The tornado made one last final touchdown in the area of Ford Road, Foster Road and Whittemore Road. In this area, a mobile home was destroyed and there was significant tree damage. Overall, the tornado damaged between 30 and 50 homes and destroyed three mobile homes. Many barns were damaged. There were seven injuries and $600 K in property damage. | |
| July 21, 2003 | Severe Storm | N/A | N/A | Thunderstorm winds downed trees and wires. Roads were blocked off in the Town of Nichols (Lounsberry). Trees fell on cars and trucks in the Town of Owego. The County had approximately $50 K in property damage. | NOAA-NCDC |
| September 19, 2003 | Wind | N/A | N/A | The County had approximately $50 K in property damage. | SHELDUS |
| October 15, 2003 | Wind | N/A | N/A | The County had over $58 K in property damage. | SHELDUS |
| November 13, 2003 | Wind | N/A | N/A | The County had over $52 K in property damage. | SHELDUS |
| September 16-18, 2004 | Severe Storm (Tropical Storm Ivan) | DR-1565 | Yes | No reference and/or no damage reported. | FEMA |
| April 2-4, 2005 | Severe Storms and Flooding | DR-1589 | Yes | No reference and/or no damage reported. | FEMA |
| June 6, 2005 | Severe Storm | N/A | N/A | TSTM winds downed numerous trees and wires. The towns affected by this storm were the Towns of Spencer, Barton, Tioga, Candor, Newark Valley, and Owego. The County had approximately $50 K in property damage. | NOAA-NCDC, NWS |
| June 26 – July 10, 2006 | Severe Storm and Flooding | DR-1650 | Yes | 7/10 - Trees down on some wires in the County | FEMA, NOAA-NCDC, SHELDUS |
| November 16-17, 2006 | Severe Storm and Flooding | DR-1670 | Yes | A series of storms produced squall line TSTMS with heavy rainfall across parts of NYS. The line of TSTMs produced 45 to 74 mph winds across central NYS. Many hillsides and creeks were flooded, causing mudslides and debris flows. In Tioga County, the Town of Owego experienced heavy rainfall and flash flooding. There were reports of downed trees in the County. | FEMA, NOAA-NCDC, SHELDUS |

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts | Source(s) |
|---|---|---|---|---|---|
| May 16, 2009 | Tornado (F0) | N/A | N/A | A series of showers and TSTMs developed across NYS. Some of the TSTMs produced tornadoes, wind damage and large hail. In Tioga County, the Towns of Owego and West Newark felt the effects of the storms. The County had approximately $10 K in property damage. | SHELDUS, NOAA-NCDC |
| April 26 – May 8, 2011 | Severe Storm, Flooding, Straight-Line Winds | DR-1993 | Yes | No reference and/or no damage reported. | FEMA, NOAA-NCDC |
| May 26, 2011 | Severe Storms | N/A | N/A | A storm system brought rain and TSTMs to the area. There were many reports of large hail and damaging winds across central NYS. In Tioga County, the storms downed trees and wires in the Town of Owego. Route 17C was closed. There were numerous power outages in the County. The County had approximately $45 K in property damage. | NOAA-NCDC |
| September 7 -10, 2011 | Remnants of Tropical Storm Lee | EM-3341 / DR-4031 | Yes | No reference and/or no damage reported. | FEMA, NOAA-NCDC |

Sources: FEMA, NOAA-NCDC, NWS, SHELDUS
Note: 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 inflation.

DR Federal Disaster Declaration
EM Federal Emergency Declaration
FEMA Federal Emergency Management Agency
IA Individual Assistance
K Thousand ($)
M Million ($)
Mph Miles Per Hour
NCDC National Climate Data Center
NOAA National Oceanic Atmospheric Administration
NYS New York State
NWS National Weather Service
PA Public Assistance
SHELDUS Spatial Hazard Events and Losses Database for the U.S.
TSTM Thunderstorms

## Probability of Future Events

Predicting future severe storm events in a constantly changing climate has proven to be a difficult task. Predicting extremes in New York State is particularly difficult because of the region's geographic location. It is positioned roughly halfway between the equator and the North Pole and is exposed to both cold and dry airstreams from the south. The interaction between these opposing air masses often leads to turbulent weather across the region (Keim, 1997).

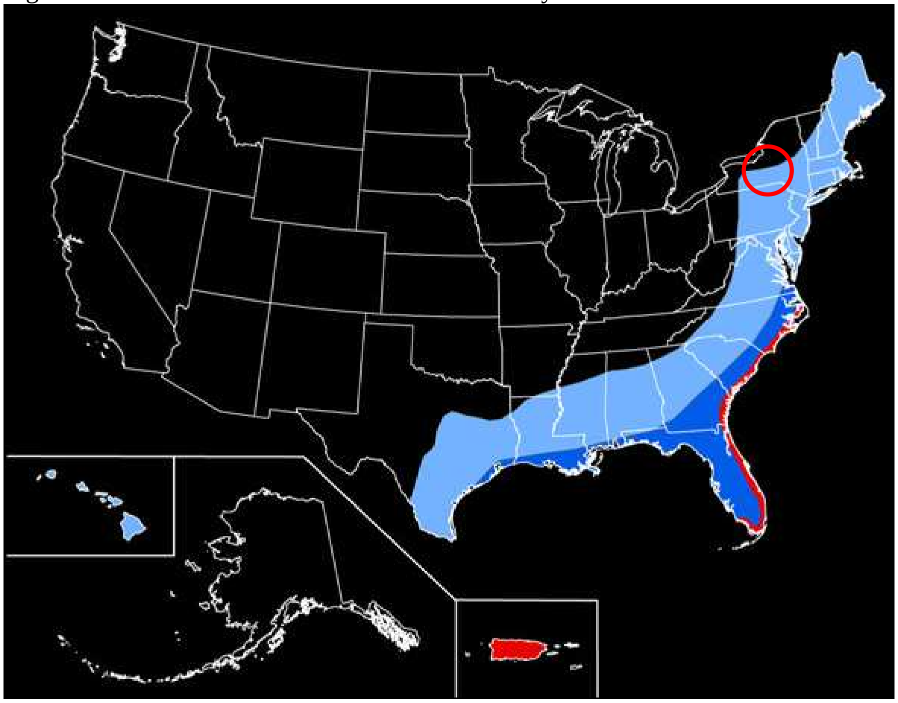
In Section 5.3, the identified hazards of concern for Tioga County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for ranking hazards. Based on historical records and input from the Planning Committee, the probability of occurrence for severe storms in the County is considered 'Frequent'' (likely to occur more than once every 25 years, as presented in Table 5.3-3); however, impacts only related to severe storms, excluding those associated with hurricanes, tropical storms, Nor'easters and flooding, are expected to be minimal.

It is estimated that Tioga County will continue to experience direct and indirect impacts of severe storms annually that may induce secondary hazards such as flooding, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents and inconveniences.

### Hurricanes

Figure 5.4.3-14 illustrates the number of hurricanes expected to occur during a 100-year period. According to this map, portions of New York State, including Tioga County, can expect between 20 and 40 hurricanes during a 100-year return period.

Figure 5.4.3-14. Number of Hurricanes for a 100-year Return Period



Source: USGS, 2005

Note: The number of hurricanes expected to occur during a 100-year MRP based on historical data—light blue area, 20 to 40; dark blue area, 40 to 60; red area, more than 60. Map not to scale.

**Nor'Easters**

Analysis of Nor'Easter frequency by researchers reveals that fewer Nor'Easters occurred during the 1980s. However, the frequency of major Nor'Easters (class 4 and 5 on the Dolan-Davis Scale) has increased in recent years. In the period of 1987 to 1993, at least one class 4 or 5 storm has occurred each year along the Atlantic coast, a situation duplicated only once in the last 50 years (North Carolina Department of Public Safety, 2009).

According to the Cape Cod Commission's Emergency Preparedness Handbook, unlike the relatively infrequent hurricane, the northeastern U.S. generally experiences at least one or two Nor'Easter events each year with varying degrees of severity. These storms have the potential to inflict more damage than many hurricanes because high winds can last from 12 hours to three days, while the duration of hurricanes ranges from six to 12 hours (Cape Cod Commission, 2010). Infrastructure, including critical facilities, may be impacted by these events, and power outages and transportation disruptions (for example: snow, heavy rain and/or debris impacted roads, as well as hazards to navigation and aviation) are often associated with Nor'Easters and other winter storms (Northeast States Emergency Consortium [NESEC], Date Unknown). All areas of Tioga County are potentially at risk for property damage and loss of life due to Nor'Easters; therefore, having a moderate to high probability for Nor'Easters to occur.

**The Role of Global Climate Change on Future Probability**

Climate change is beginning to affect both people and resources in New York State, and these impacts are projected to continue growing. Impacts related to increasing temperatures and sea level rise are already being felt in the State. ClimAID: the Integrated Assessment for Effective Climate Change in New York State (ClimAID) was undertaken to provide decision-makers with information on the State's vulnerability to climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge (New York State Energy Research and Development Authority [NYSERDA], 2011).

Each region in New York State, as defined by ClimAID, has attributes that will be affected by climate change. Tioga County is part of Region 3, Southern Tier. Some of the issues in this region, affected by climate change, include: dairy dominates the agricultural economy and milk production losses are projected, Susquehanna River flooding increases, and this region is one of the first parts of the State hti by invasive insects, weeds and other pests moving north (NYSERDA, 2011).

Temperatures are expected to increase throughout the state, by 1.5 to 3ºF by the 2020s, 3.5 to 5.5ºF by the 2050s and 4.5 to 8.5ºF by the 2080s. The lower ends of these ranges are for lower greenhouse gas emissions scenarios and the higher ends for higher emissions scenarios. Annual average precipitation is projected to increase by up to five-percent by the 2020s, up to 10-percent by the 2050s and up to 15-percent by the 2080s. During the winter months is when this additional precipitation will most likely occur, in the form of rain, and with the possibility of slightly reduced precipitation projected for the late summer and early fall. Table 5.4.3-8 displays the projected seasonal precipitation change for the Southern Tier ClimAID Region (NYSERDA, 2011).

Table 5.4.3-8. Projected Seasonal Precipitation Change in Region 3, 2050s (% change)

| Winter | Spring | Summer | Fall |
|---|---|---|---|
| +5 to +15 | 0 to +15 | -10 to +10 | -5 to +10 |

Source: NYSERDA, 2011

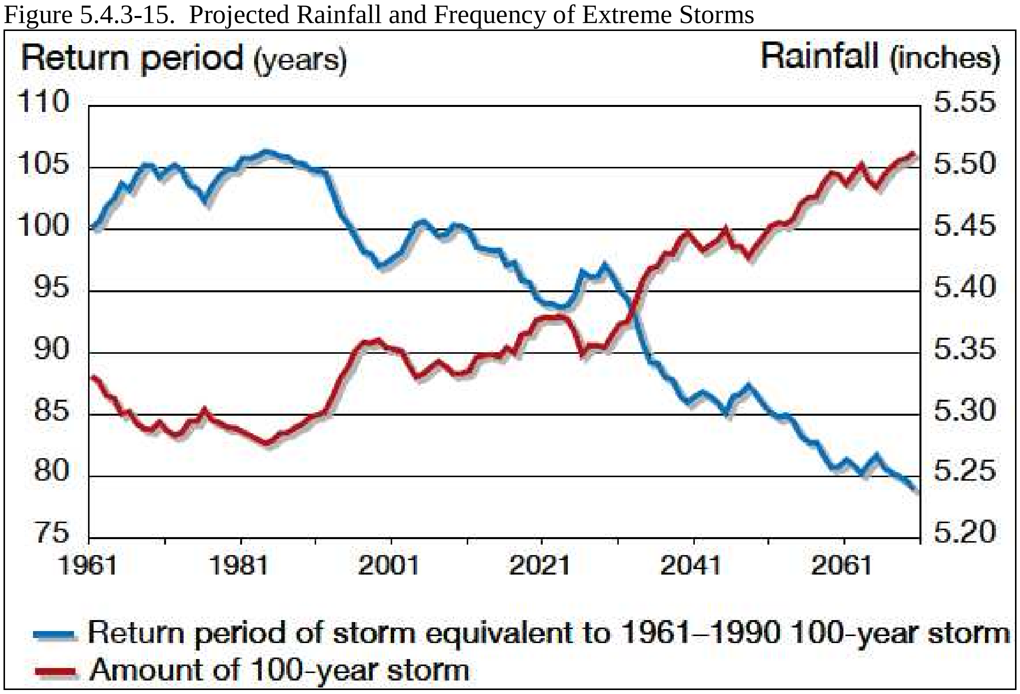
The projected increase in precipitation is expected to fall in heavy downpours and less in light rains. The increase in heavy downpours has the potential to affect drinking water; heighten the risk of riverine flooding; flood key rail lines, roadways and transportation hugs; and increase delays and hazards related to extreme weather events (NYSERDA, 2011).

Increasing air temperatures intensify the water cycle by increasing evaporation and precipitation. This can cause an increase in rain totals during events with longer dry periods in between those events. These changes can have a variety of effects on the State's water resources (NYSERDA, 2011).

Over the past 50 years, heavy downpours have increased and this trend is projected to continue. This can cause an increase in localized flash flooding in urban areas and hilly regions. Flooding has the potential to increase pollutants in the water supply and inundate wastewater treatment plants and other vulnerable facilities located within floodplains. Less frequent rainfall during the summer months may impact the ability of water supply systems. Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent wastewater treatment plants (NYSERDA, 2011).

Figure 5.4.3-15 displays the project rainfall and frequency of extreme storms in New York State. The amount of rain fall in a 100-year event is projected to increase, while the number of years between such storms (return period) is projected to decrease. Rainstorms will become more severe and more frequent (NYSERDA, 2011).

Figure 5.4.3-15. Projected Rainfall and Frequency of Extreme Storms




Source: NYSERDA, 2011

Total precipitation amounts have slightly increased in the Northeast U.S., by approximately 3.3 inches over the last 100 years. There has also been an increase in the number of two-inch rainfall events over a 48-hour period since the 1950s (a 67-percent increase). The number and intensity of extreme precipitation events are increasing in New York State as well. More rain heightens the danger of localized flash flooding, streambank erosion and storm damage (DeGaetano et al [Cornell University], 2010).

## VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For severe storms, the entire Tioga County has been identified as the hazard area. Therefore, all assets in the County (population, structures, critical facilities and lifelines), as described in the County section, are vulnerable. The following text evaluates and estimates the potential impact of severe storms on the County including:

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

### Overview of Vulnerability

The high winds and air speeds of a hurricane or any severe storm often 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 impacted 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 severe storm evaluates available data for a range of storms included in this hazard category.

Due to the County's inland location, losses from wind are primarily associated with severe thunderstorm or tropical depression/storm-related winds and rain (see flooding discussion in Section 5.4.1 Flood). Secondary flooding associated with the torrential downpours during severe storms is also a primary concern in the County. The County has experienced flooding in association with numerous severe storms in the past.

The entire inventory of the County is at risk of being damaged or lost due to impacts of severe wind. Certain areas, infrastructure, and types of building are at greater risk than others due to proximity to falling hazards and/or their manner of construction.

The entire inventory of the County is at risk of being damaged or lost due to impacts of severe storms (severe wind). Certain areas, infrastructure, and types of building are at greater risk than others due to proximity to falling hazards and manner of construction. Potential losses associated with high wind events were calculated for Tioga County for two probabilistic hurricane events, the 100-year and 500-year MRP wind events. The impacts on population, existing structures and critical facilities on the County are presented below, following a summary of the data and methodology used.

### Data and Methodology

After reviewing historic data, the HAZUS-MH methodology and model were used to analyze the severe storm hazard for Tioga County. Data used to assess this hazard include data available in the HAZUS-MH 2.0 hurricane model, professional knowledge, information provided by the Steering and Planning Committees and input from public citizens.

A probabilistic scenario was run for Tioga County for annualized losses and the 100- and 500-year MRPs were examined for the wind/severe storm hazard. Figures 5.4.3-1 and 5.4.3-2, earlier in this section, show the HAZUS-MH maximum peak gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP hurricane events. The estimated hurricane track for the 100- and 500-year events is also shown.

HAZUS-MH contains data on historic hurricane events and wind speeds. It also includes surface roughness and vegetation (tree coverage) maps for the area. Surface roughness and vegetation data support the modeling of wind force across various types of land surfaces. Hurricane and inventory data available in HAZUS-MH were used to evaluate potential losses from the 100- and 500-year MRP events (severe wind impacts). Other than data for critical facilities, the default data in HAZUS-MH 2.0 was the best available for use in this evaluation.

### Impact on Life, Health and Safety

The impact of a severe storm on life, health and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time was provided to residents. It is assumed that the entire County's population (U.S. Census 2010 population of 51,125 people) is exposed to this storm 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. HAZUS-MH estimates there will be zero people displaced and zero people that may require temporary shelter due to a 100-year and 500-year MRP event. Please refer to Section 4 for a list of shelters in Tioga County.

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 which may not be available due to isolation during a storm event.

### Impact on General Building Stock

After considering the population exposed to the severe storm hazard, the general building stock replacement value exposed to and damaged by 100- and 500-year MRP events was examined. Wind-only impacts from a severe storm are reported based on the probabilistic hurricane runs in HAZUS-MH 2.0. 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 5.1).

It is assumed that the entire County's general building stock is exposed to the severe storm wind hazard (greater than $3.23B structure only). Expected building damage was evaluated by HAZUS across the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 5.4.3-9 summarizes the definition of the damage categories.

Table 5.4.3-9. 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**<br>Little of 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**<br>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**<br>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 |
| **Severe Damage**<br>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**<br>Complete roof failure and/or failure of wall frame. Loss of more than 50% of roof sheathing. | Typically > 50% | > 50% | > 25% | Typically > 20 Impacts | Yes | Yes |

Source: HAZUS-MH Hurricane Technical Manual

As noted earlier in the profile, HAZUS estimates the 100-year MRP wind speeds for Tioga County to be zero<50 miles per hour (mph) associated with this event). This wind speed is not fast enough to be considered a hurricane. For the 100-year MRP event, HAZUS-MH 2.0 estimates $0 in building damages across the County with 100% of the buildings experiencing very minor to zero damage. Residential buildings comprise the majority of the building inventory and are estimated to experience the majority of the damage (wood and masonry).

HAZUS estimates the 500-year MRP wind speeds for Tioga County to range from 5459 to 6563 mph. This wind speed is not fast enough to be considered a hurricane; these wind speeds are characteristic of a tropical storm. HAZUS estimates $795,000 in damages to the general building stock (structure only). This is 0.02-percent of the County's building inventory. The residential buildings are estimated to experience the majority of the damage (wood and masonry). Table 5.4.3-10 summarizes the building value (structure only) damage estimated for the 100- and 500-year MRP wind-only events by occupancy class.

Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings in general, regardless of their occupancy class, tend to 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 dollar damage reflects the overall impact to buildings at an aggregate level.

Of the nearly $795,000 in total residential replacement value (structure) for the entire County, an estimated $0 in residential building damage can be anticipated for the 100-year event and $753,000 in residential building damage can be anticipated for the 500-year event. Residential building damage accounts for 96-percent of the 500-year wind-only event. This illustrates residential structures are the most vulnerable to the wind hazard. Figure 5.4.3-16 illustrates the density of damage estimated for residential structures for the 500-year MRP wind event for Tioga County as a whole.

Table 5.4.3-10. Estimated Building Replacement Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Hurricane-Related Winds for All Occupancy Classes

| Municipality | Total Building Damage | | | | Residential Buildings | | Commercial Buildings | | Industrial Buildings | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 Year | % of GBS RCV Total | 500 Year | % of GBS RCV Total | 100 Year | 500 Year | 100 Year | 500 Year | 100 Year | 500 Year |
| Barton (T) | $0 | NA | $24,791 | 0.013.12% | $0 | $10,178 | $0 | $14,613 | $0 | $0 |
| Berkshire (T) | $0 | NA | $29,051 | 0.043.65% | $0 | $27,945 | $0 | $593 | $0 | $147 |
| Candor (T) | $0 | NA | $49,549 | 0.026.23% | $0 | $49,502 | $0 | $47 | $0 | $0 |
| Candor (V) | $0 | NA | $10,506 | 0.021.32% | $0 | $10,497 | $0 | $9 | $0 | $0 |
| Newark Valley (T) | $0 | NA | $54,725 | 0.046.88% | $0 | $52,798 | $0 | $1,315 | $0 | $223 |
| Newark Valley (V) | $0 | NA | $20,288 | 0.032.55% | $0 | $18,954 | $0 | $700 | $0 | $55 |
| Nichols (T) | $0 | NA | $22,771 | 0.022.86% | $0 | $22,146 | $0 | $446 | $0 | $31 |
| Nichols (V) | $0 | NA | $4,879 | 0.0161% | $0 | $4,706 | $0 | $148 | $0 | $0 |
| Owego (T) | $0 | NA | $468,003 | 0.0458.86% | $0 | $447,150 | $0 | $10,642 | $0 | $7,347 |
| Owego (V) | $0 | NA | $38,990 | 0.014.90% | $0 | $38,990 | $0 | $0 | $0 | $0 |
| Richford (T) | $0 | NA | $14,752 | 0.031.86% | $0 | $13,824 | $0 | $550 | $0 | $158 |
| Spencer (T) | $0 | NA | $8,072 | 0.011.02% | $0 | $8,072 | $0 | $0 | $0 | $0 |
| Spencer (V) | $0 | NA | $2,717 | 0.0134% | $0 | $2,717 | $0 | $0 | $0 | $0 |
| Tioga (T) | $0 | NA | $43,565 | 0.025.48% | $0 | $43,171 | $0 | $164 | $0 | $71 |
| Waverly (V) | $0 | NA | $2,490 | 0.0031% | $0 | $2,490 | $0 | $0 | $0 | $0 |
| **Tioga County** | **$0** | **NA** | **$795,149** | **0.02**3.12% | **$0** | **$753,140** | **$0** | **$29,227** | **$0** | **$8,032** |

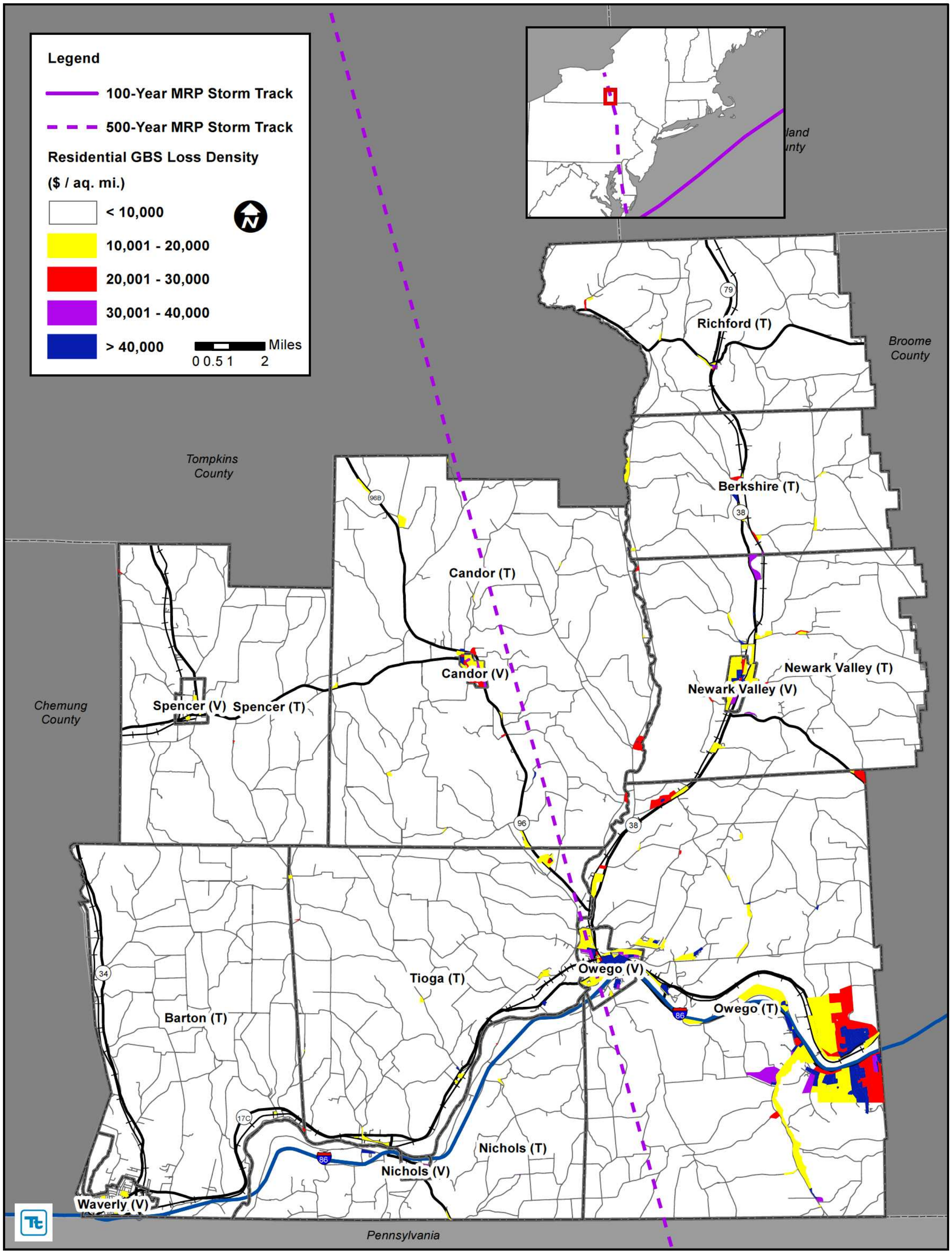
| Municipality | Agriculture Buildings | | Religious Buildings | | Government Buildings | | Education Buildings | |
|---|---|---|---|---|---|---|---|---|
| | 100 Year | 500 Year | 100 Year | 500 Year | 100 Year | 500 Year | 100 Year | 500 Year |
| Barton (T) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Berkshire (T) | $0 | $0 | $0 | $209 | $0 | $87 | $0 | $70 |
| Candor (T) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Candor (V) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Newark Valley (T) | $0 | $0 | $0 | $236 | $0 | $0 | $0 | $153 |
| Newark Valley (V) | $0 | $0 | $0 | $273 | $0 | $29 | $0 | $277 |

| Municipality | Agriculture Buildings | | Religious Buildings | | Government Buildings | | Education Buildings | |
|---|---|---|---|---|---|---|---|---|
| | 100 Year | 500 Year | 100 Year | 500 Year | 100 Year | 500 Year | 100 Year | 500 Year |
| Nichols (T) | $0 | $0 | $0 | $148 | $0 | $0 | $0 | $0 |
| Nichols (V) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $25 |
| Owego (T) | $0 | $23 | $0 | $1,500 | $0 | $628 | $0 | $713 |
| Owego (V) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Richford (T) | $0 | $0 | $0 | $11 | $0 | $203 | $0 | $6 |
| Spencer (T) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Spencer (V) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Tioga (T) | $0 | $0 | $0 | $109 | $0 | $0 | $0 | $50 |
| Waverly (V) | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Tioga County** | **$0** | **$23** | **$0** | **$2,486** | **$0** | **$947** | **$0** | **$1,294** |

Source: HAZUS-MH 2.0

Note (1): The valuation of general building stock and loss estimates are based on the default general building stock database provided in HAZUS-MH 2.0.

Figure 5.4.3-16. Density of Losses for Residential Structures (Structure Only) for Tioga County 500-Year MRP Wind Event




Source: HAZUS-MH 2.0

Annualized losses were also examined for Tioga County. A total of $13,481 is estimated as the annualized loss for the entire County; see Table 5.4.3-11. Please note that annualized loss does not predict what losses will occur in any particular year.

Table 5.4.3-11. Summary of Estimated Annualized Wind General Building Stock Losses for Tioga County

| Municipality | Total (Buildings + Contents) | Buildings | Contents |
|---|---|---|---|
| Barton (T) | $856 | $656 | $200 |
| Berkshire (T) | $282 | $221 | $61 |
| Candor (T) | $933 | $698 | $235 |
| Candor (V) | $209 | $163 | $46 |
| Newark Valley (T) | $551 | $433 | $118 |
| Newark Valley (V) | $198 | $154 | $44 |
| Nichols (T) | $628 | $469 | $159 |
| Nichols (V) | $184 | $145 | $39 |
| Owego (T) | $5,968 | $4,280 | $1,688 |
| Owego (V) | $826 | $671 | $155 |
| Richford (T) | $152 | $114 | $38 |
| Spencer (T) | $501 | $368 | $133 |
| Spencer (V) | $186 | $138 | $48 |
| Tioga (T) | $1,184 | $895 | $289 |
| Waverly (V) | $823 | $679 | $144 |
| **Tioga County** | **$13,481** | **$10,084** | **$3,397** |

Source: HAZUS-MH 2.0

## Impact on Critical Facilities

HAZUS-MH estimates the probability that critical facilities (i.e., medical facilities, fire/EMS, police, EOC, 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 does not estimate any damage or loss of use for critical facilities as a result of a 100-year or 500-year MRP event.

At this time, HAZUS-MH 2.0 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, falling debris etc. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs.

Utility structures could suffer damage associated with falling tree limbs or other debris. Such impacts can result in the loss of power, which can impact business operations and can impact 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 impact the economy, including: loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss and rental loss due to the repair/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 the estimated costs to repair or replace the damage caused to the building. This is 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 approximately $0 in business interruption losses for Tioga County as a result of the 100-year MRP wind-only event (relocation cost for the residential occupancy class). It is clear there are minimal business interruption costs as a result of the 100-year wind event.

For the 500-year MRP wind only event, HAZUS-MH estimates $0 in business interruption losses for Tioga County.

HAZUS-MH 2.0 also estimates the amount of debris that may be produced a result of the 100- and 500-year MRP wind events. Table 5.4.3-12 estimates the debris produced. Because the estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur.

Table 5.4.3-12. Debris Production for 100- and 500-Year MRP Hurricane-Related Winds

| Municipality | Brick and Wood (tons) | | Concrete and Steel (tons) | | Tree (tons) | |
|---|---|---|---|---|---|---|
| | 100-Year | 500-Year | 100-Year | 500-Year | 100-Year | 500-Year |
| Barton (T) | 0 | 0 | 0 | 0 | 0 | 514 |
| Berkshire (T) | 0 | 0 | 0 | 0 | 0 | 752 |
| Candor (T) | 0 | 0 | 0 | 0 | 0 | 2,341 |
| Candor (V) | 0 | 0 | 0 | 0 | 0 | 11 |
| Newark Valley (T) | 0 | 0 | 0 | 0 | 0 | 1100 |
| Newark Valley (V) | 0 | 0 | 0 | 0 | 0 | 26 |
| Nichols (T) | 0 | 0 | 0 | 0 | 0 | 958 |
| Nichols (V) | 0 | 0 | 0 | 0 | 0 | 13 |
| Owego (T) | 0 | 0 | 0 | 0 | 0 | 2,841 |
| Owego (V) | 0 | 0 | 0 | 0 | 0 | 55 |
| Richford (T) | 0 | 0 | 0 | 0 | 0 | 864 |
| Spencer (T) | 0 | 0 | 0 | 0 | 0 | 993 |
| Spencer (V) | 0 | 0 | 0 | 0 | 0 | 5 |
| Tioga (T) | 0 | 0 | 0 | 0 | 0 | 1,562 |
| Waverly (V) | 0 | 0 | 0 | 0 | 0 | 23 |
| **Tioga County** | **0** | **0** | **0** | **0** | **0** | **12,058** |

Source: HAZUS-MH 2.0

It is estimated that the impact to the economy, as a result of a severe storm event, would be considered "low" in accordance with the risk ranking shown in Table 5.3-X.

### Future Growth and Development

As discussed in Sections 4 and 9, areas targeted for future growth and development have been identified across the County. Any areas of growth could be potentially impacted by the severe storm hazard because the entire planning area is exposed and vulnerable. Please refer to the specific areas of development indicated in tabular form (subsection B) and/or on the hazard maps (subsection I) included in the jurisdictional annexes in Volume II, Section 9 of this plan.

### Additional Data and Next Steps

Over time, Tioga County will 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, specific building information such as first floor elevation, type of construction, foundation type and details on protective features (for example, hurricane straps). In addition, information on particular buildings or infrastructure age or year built would be helpful in future analysis of this hazard.

### Overall Vulnerability Assessment

Tioga County is highly vulnerable to severe storm events which can cause significant impacts and losses to the area's structures, facilities, utilities, and population. Existing and future mitigation efforts should continue to be developed and employed that will enable the study area to be prepared for these events when they occur. The overall hazard ranking determined by the Planning Committee for this hazard is "medium" with a "frequent" probability of occurrence (see Tables 5.3-3 through 5.3-6 in Section 5.3).