# 5.4.5 Severe Storm

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

## 5.4.5.1 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 Putnam County.

### Description

For the purpose of this HMP and as deemed appropriated by Putnam County, the severe storm hazard includes hailstorms, windstorms, lightning, thunderstorms, tornadoes, and tropical cyclones (which include tropical depressions, tropical storms, and hurricanes), 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 5.4.6 (Severe Winter Storms).

#### Hailstorms

Hail forms inside a thunderstorm where there are strong updrafts of warm air and downdrafts of cold water. If a water droplet is picked up by the updrafts, it can be carried well above the freezing level. Water droplets freeze when temperatures reach 32°F or colder. As the frozen droplet begins to fall, it may thaw as it moves into warmer air toward the bottom of the thunderstorm. However, the droplet may be picked up again by another updraft and carried back into the cold air and re-freeze. With each trip above and below the freezing level, the frozen droplet adds another layer of ice. The frozen droplet, with many layers of ice, falls to the ground as hail. Most hail is small and typically less than two inches in diameter (NWS 2010). Figure 5.4.5-1 illustrates the process that occurs in hail formulation.

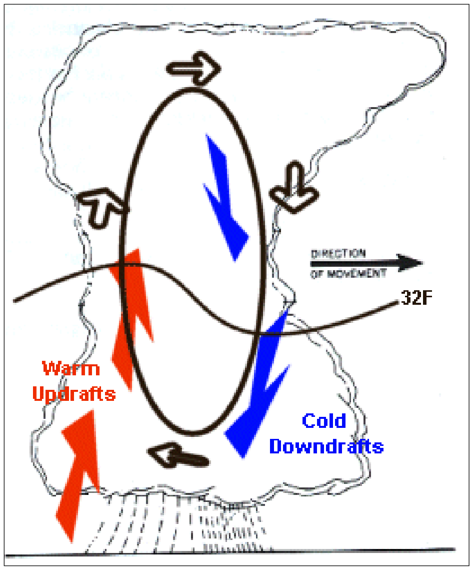
The size of hailstones is a direct function of the size and severity of the storm. The size varies and is related to the severity and size of the thunderstorm that produced it. The higher the temperatures at the earth's surface, the greater the strength of the updrafts, and the greater the amount of time the hailstones are suspended, giving them more time to increase in size. Damage to crops and vehicles are typically the most significant impacts of hailstorms. However, hail is considered a low risk hazard to New York State.

#### High Winds / Windstorms

High winds, other than tornadoes, are experienced in all parts of the U.S. 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. It is rough horizontal movement of air caused by uneven heating of the earth's surface. Wind occurs at all scales, from local breezes lasting a few minutes to global winds resulting from solar heating of the earth. Effects from high winds can include downed trees and power lines, and damages to roofs, windows, etc. (Ilicak 2005). The following table provides the descriptions of winds used by the 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. Winds vary from zero at ground level to 200 miles per hour (mph) in the upper atmospheric jet stream at six to eight miles above the earth's surface (FEMA 1997).

### Figure 5.4.5-1. Hail Formation




*Source: NOAA 2012*
*°F degrees Fahrenheit*

### Table 5.4.5-1. NWS Wind Descriptions

| Descriptive Term | Sustained Wind Speed (mph) |
|---|---|
| Strong, dangerous, or damaging | ≥40 |
| Very Windy | 30-40 |
| Windy | 20-30 |
| Breezy, brisk, or blustery | 15-25 |
| None | 5-15 or 10-20 |
| Light or light and variable wind | 0-5 |

*Source: NWS 2010*
*mph miles per hour*

A type of windstorm that is experienced often during rapidly moving thunderstorms is a derecho. A derecho is a long-lived windstorm that is associated with a rapidly moving squall line of thunderstorms. It produces straight-line winds gusts of at least 58 mph and often has isolated gusts exceeding 75 mph. This means that 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 U.S., though, on occasion, can persist into the mid-Atlantic and northeast U.S. (ONJSC Rutgers University 2013a).

High wind storms cause disruptions to power and have the potential to damage structures in the State. High winds storms also have the potential to knock down tree limbs which subsequently damage power and other utility lines thus contributing to widespread power outages. High wind storms are often accompanied by other events such as thunderstorms, or part of hurricane and tropical storms. The worst case scenario for a high wind event includes widespread power outages to populated cities and municipalities.

### Tornadoes

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 one mile in width and 50 miles in length. 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).

Tornado watches and warning are issued by the local NWS office. A tornado watch is released when tornadoes are possible in an area. A tornado warning means a tornado has been sighted or indicated by weather radar. The current average lead time for tornado warnings is 13 minutes; however, warning times for New York State may be shorter due to the fact that the State experiences smaller tornadoes that are difficult to warn for. Occasionally, tornadoes develop so rapidly, that little, if any, advance warning is possible (NOAA 2013; FEMA, 2013).

### Thunderstorms

A thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS 2009d). 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 have the potential to become dangerous due to their ability in generating tornadoes, hailstorms, strong winds, flash flooding, and lightning. The NWS considers a thunderstorm severe only if it produces damaging wind gusts of 58 mph or higher or large hail one-inch (quarter size) in diameter or larger or tornadoes (NWS 2010).

The rising air in a thunderstorm cloud causes various types of frozen precipitation to form within the cloud, which includes very small ice crystals and larger pellets of snow and ice. The smaller ice crystals are carried upward toward the top of the clouds by the rising air while the heavier and denser pellets are either suspended by the rising air or start falling towards the ground. Collisions occur between the ice crystals and the pellets, and these collisions serve as the charging mechanism of the thunderstorm. The small ice crystals become positively charged while the pellets become negatively charged, resulting in the top of the cloud becomes positively charged and the middle to lower part of the storm becomes negatively charged. At the same time, the ground below the cloud becomes charged oppositely. When the charge difference between the ground and the cloud becomes too large, a small amount of charge starts moving toward the ground. When it nears the ground, an upward leader of opposite charge connects with the step leader. At the instant this connection is made, a powerful discharge occurs between the cloud and ground. The discharge is seen as a bright, visible flash of lightning (NOAA Date Unknown). Thunder is the sound caused by rapidly expanding gases in a lightning discharge (NWS 2009c).

Meteorologists can often predict the likelihood of a severe thunderstorm. This can give several days warning. However, meteorologists cannot predict the exact time of onset, specific location, or the severity of the storm. Some storms may come on more quickly and have only a few hours of warning time.

The most common problems associated with severe storms are immobility and loss of utilities. Fatalities are uncommon, but can occur due to lightning strikes. Roads may become impassable due to flooding, downed trees, or a landslide. Power lines may be downed due to high winds, and services such as water or phone may be disrupted. Lightning can cause severe damage and injury. Wind storms can be a frequent problem and have caused damage to utilities. Wind storms, as mentioned previously, may occur as part of thunderstorms or independently. The predicted wind speed given in wind warnings issued by the NWS is for a one-minute average; gusts may be 25 to 30% higher.

In the U.S., an average of 300 people are injured and 80 people are killed by lightning each year. Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes. An estimated 100,000 thunderstorms occur each year in the U.S., with approximately 10% of them classified as severe. During the warm season, thunderstorms are responsible for most of the rainfall.

### Hurricanes and Tropical Storms

A tropical cyclone develops in the tropics. It is an organized rotating weather system and begins as a tropical depression with sustained winds below 38 mph. These storms can then potentially develop into a tropical storm (sustained winds of 39 to 73 mph) or a hurricane (winds of 74 mph or higher). Tropical cyclones contain a warm core of low barometric pressure and can produce heavy rainfall, powerful winds, and storm surge. Tropical cyclones are less dangerous than hurricanes, tropical storms and depressions; however, they cause heavy rains, coastal flooding, and severe weather (NYS DHSES 2014).

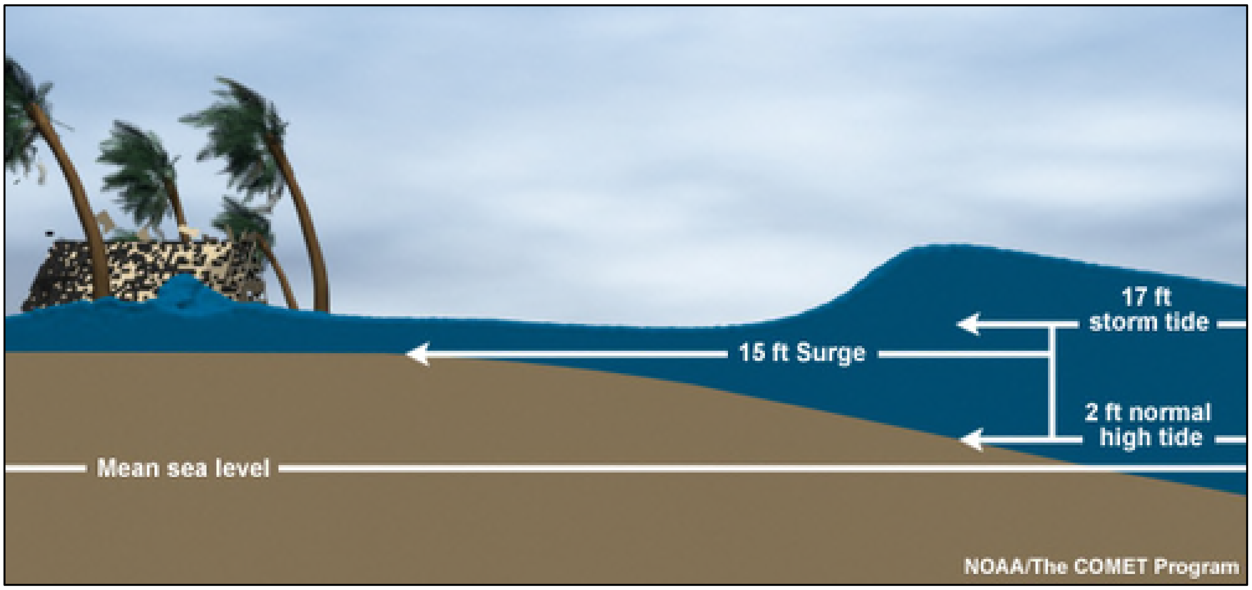
A tropical depression is an organized system of clouds and thunderstorms with a defined surface circulation and maximum sustained winds of less than 38 mph. It has no "eye" (the calm area in the center of the storm) and does not typically have the organization or the spiral shape of more powerful storms (Emanuel, Date Unknown; Miami Museum of Science, 2000).A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds and heavy rain (winds are at a lower speed than hurricane-force winds, thus gaining its status as tropical storm versus hurricane). Tropical storms strengthen when water evaporated from the ocean is released as the saturated air rises, resulting in condensation of water vapor contained in the moist air. They are fueled by a different heat mechanism than other cyclonic windstorms such as Nor'Easters and polar lows.

A hurricane is a tropical storm that attains hurricane status when its wind speed reaches 74 or more miles an hour. Tropical systems may develop in the Atlantic between the Lesser Antilles and the African coast, or may develop in the warm tropical waters of the Caribbean and Gulf of Mexico. These storms may move up the Atlantic coast of the United States and impact the eastern seaboard, or move into the United States through the states along the Gulf Coast, bringing wind and rain as far north as New England before moving offshore and heading east. The Atlantic hurricane season runs from June 1$^{st}$ through November 30$^{th}$, with the peak of the season from mid-August to late October.

One of the greatest hazards posed by a hurricane is its storm surge. Storm surges inundate coastal floodplains by dune overwash, tidal elevation rise in inland bays and harbors, and backwater flooding through coastal river mouths. Strong winds can increase in tide levels and water-surface elevations. Storm systems generate large waves that run up and flood coastal beaches. The combined effects create storm surges that affect the beach, dunes, and adjacent low-lying floodplains. Shallow, offshore depths can cause storm-driven waves and tides to pile up against the shoreline and inside bays. In Putnam County, storm surges impacts the communities of Cold Spring and Philipstown and will be exacerbated by rising sea levels (discussed further in the Climate Change Impacts section of this profile).

Based on an area's topography, a storm surge may inundate only a small area (along sections of the northeast or southeast coasts) or storm surge may inundate coastal lands for a mile or more inland from the shoreline. Figure 5.4.5-2 depicts storm surge.

**Figure 5.4.5-2. Storm Surge**




*Source: NHC, 2010*

## Extent

### Hailstorms

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. Table 5.4.5-2 shows the different types of hail and the comparison to real-world objects.

**Table 5.4.5-2. 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 |

**Table 5.4.5-2. Hail Size**

| Description | Diameter (in inches) |
|---|---|
| Grapefruit | 4.00 |
| Softball | 4.50 |

*Source: NYS DHSES, 2014*

## Tornado

Damage caused by a tornado is a result of the high wind velocity and wind-blown debris. The magnitude or severity of a tornado was originally categorized using the Fujita Scale (F-Scale) which was introduced in 1971. 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 5.4.5-3 explains each of the six F-Scale categories.

**Table 5.4.5-3. 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. |
| 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; NYS DHSES 2014*

Although the F-Scale has been in use for over 40 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 (NWS, 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 (NWS, 2008). Table 5.4.5-4 displays the EF Scale and each of its six categories.

**Table 5.4.5-4. Enhanced Fujita Damage Scale**

| EF-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 5.4.5-5 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 5.4.5-5. EF Scale Damage Indicators**

| DI Number | Damage Indicator | Building Use |
|---|---|---|
| 1 | Small barns or farm outbuildings (SBO) | Residential |
| 2 | One to two Family Residences (FR12) | |
| 3 | Manufactured Home – Single Wide (MHSW) | |
| 4 | Manufactured Home – Single Double (MHDW) | |
| 5 | Apartments, Condos, Townhouses (three stories or less) (ACT) | |
| 6 | Motel (M) | Commercial and Retail Structures |
| 7 | Masonry Apartment or Motel Building (MAM) | |
| 8 | Small Retail Building (fast food restaurant) (SRB) | |
| 9 | Small Professional Building (e.g. doctor's office, branch bank) (SPB) | |
| 10 | Strip Mall (SM) | |
| 11 | Large Shopping Mall (LSM) | |

**Table 5.4.5-5. EF Scale Damage Indicators**

| DI Number | Damage Indicator | Building Use |
|---|---|---|
| 12 | Large, Isolated Retail Building (e.g. K-Mart, Wal-Mart) (LIRB) | |
| 13 | Automobile Showroom (ASR) | |
| 14 | Automobile Service Building (ASB) | |
| 15 | Elementary School (single story; interior or exterior hallways) (ES) | Schools |
| 16 | Junior or Senior High School (JHSH) | |
| 17 | Low-Rise Building (1-4 stories) (LRB) | Professional Buildings |
| 18 | Mid-Rise Building (5-20 stories) (MRB) | |
| 19 | High-Rise Building (more than 20 stories) (HRB) | |
| 20 | Institutional Building (e.g. hospital, government, or university) (IB) | |
| 21 | Metal Building Systems (MBS) | Metal Buildings and Canopies |
| 22 | Service Station Canopy (SSC) | |
| 23 | Warehouse Building (tilt-up walls or heavy timber construction) (WHB) | |
| 24 | Transmission Line Towers (TLT) | Towers/Poles |
| 25 | Free-Standing Towers (FST) | |
| 26 | Free-Standing Light Poles, Luminary Poles, Flag Poles (FSP) | |
| 27 | Trees: Hardwood (TH) | Vegetation |
| 28 | Trees: Softwoods (TS) | |

*Source: SPC, Date Unknown; NYS DHSES 2014*

### Hurricanes and Tropical Storms

The term used to identify a tropical cyclone is based on the strength of its winds. Hurricanes are further categorized. The extent of a hurricane is categorized by the Saffir-Simpson Hurricane Scale. The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 rating based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. Category 1 and 2 storms are still dangerous and require preventative measures (NHC, 2013). Table 5.4.5-6 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes land fall.

**Table 5.4.5-6. The Saffir-Simpson Scale**

| Category | Wind Speed (mph) | Storm Surge (feet) | Expected Damage |
|---|---|---|---|
| 1 | 74-95 mph | 3 to 5 feet | Very dangerous winds will produce some damage: Homes with well-constructed frames could have damage to roof, shingles, vinyl siding, and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days. |
| 2 | 96-110 mph | 6 to 8 feet | Extremely dangerous winds will cause extensive damage: Homes with well-constructed frames could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks. |
| 3 (major) | 111-129 mph | 9 to 12 feet | Devastating damage will occur: Homes with well-built frames may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes. |

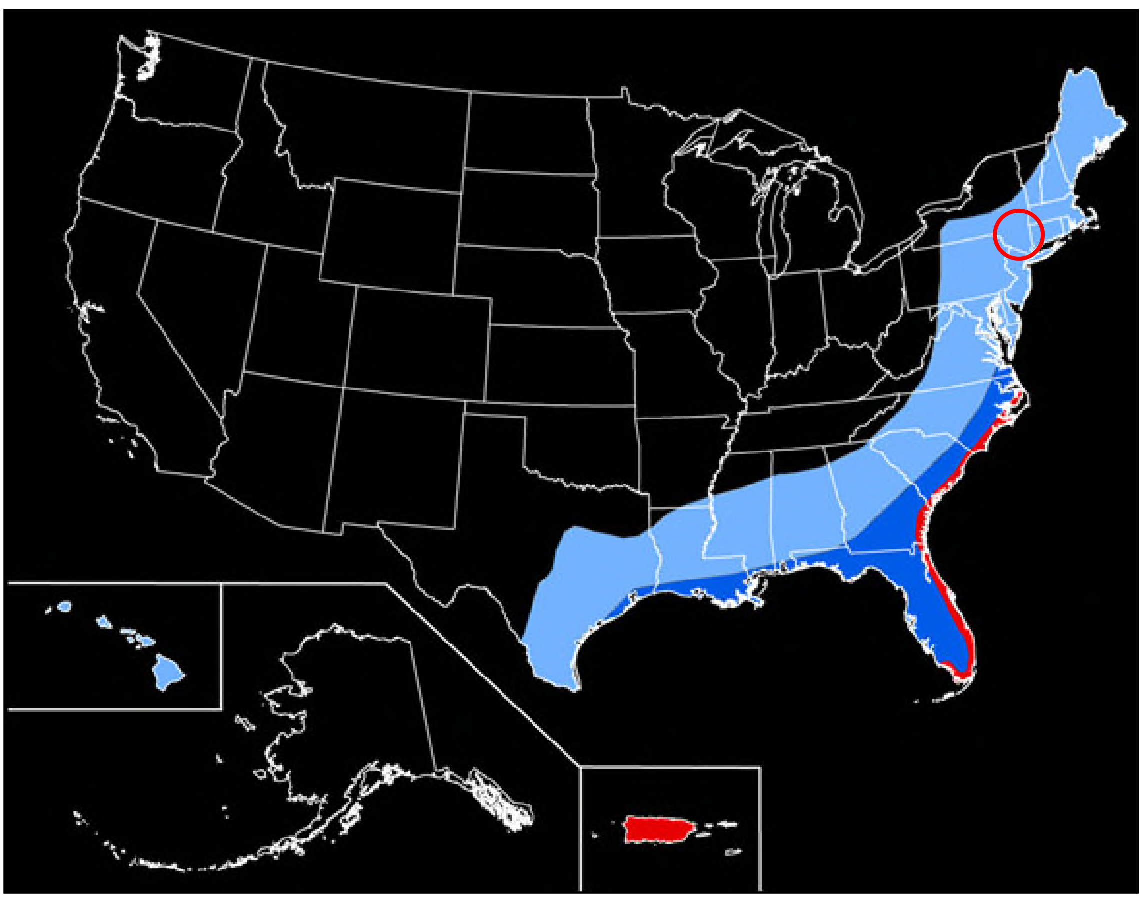
**Table 5.4.5-6. The Saffir-Simpson Scale**

| Category | Wind Speed (mph) | Storm Surge (feet) | Expected Damage |
|---|---|---|---|
| 4 (major) | 130-156 mph | 13 to 18 feet | Catastrophic damage will occur: Homes with well-built frames can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months. |
| 5 (major) | >157 mph | 19+ feet | Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months. |

*Source: NHC, 2013; NASA 2003*
*mph = Miles per hour*
*> = Greater than*

Figure 5.4.5-3 illustrates the number of hurricanes expected to occur during a 100-year period. According to this map, portions of New York State, including Putnam County, can expect between 20 and 40 hurricanes during a 100-year return period.

**Figure 5.4.5-3. Number of Hurricanes for a 100-year Return Period**



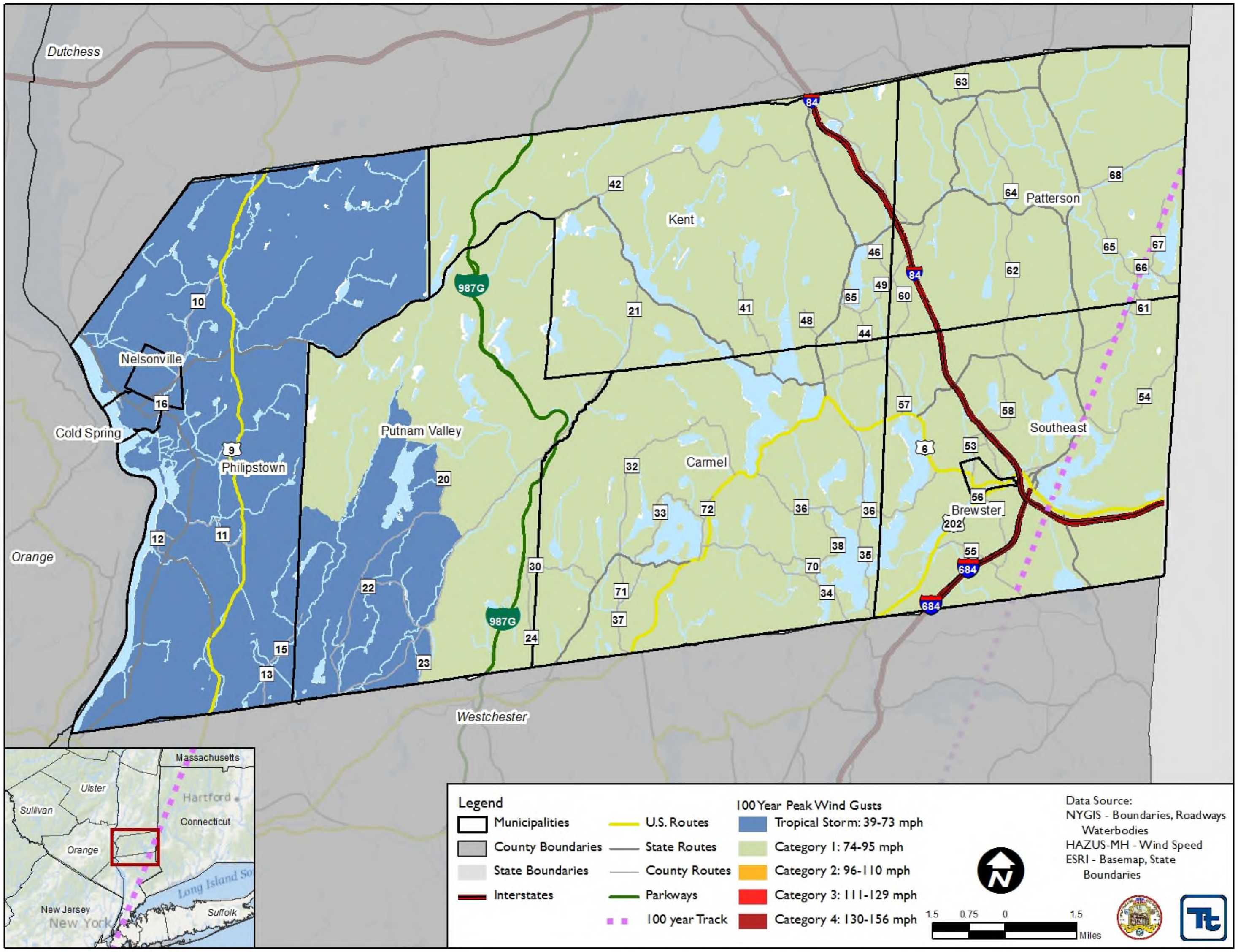
*Source: USGS, 2005*
*Note: The number of hurricanes expected to occur during a 100-year MRP based on historical data—light blue area, 20 to 40; dark blue area, 40 to 60; red area, more than 60. Map not to scale.*

## 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). 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).

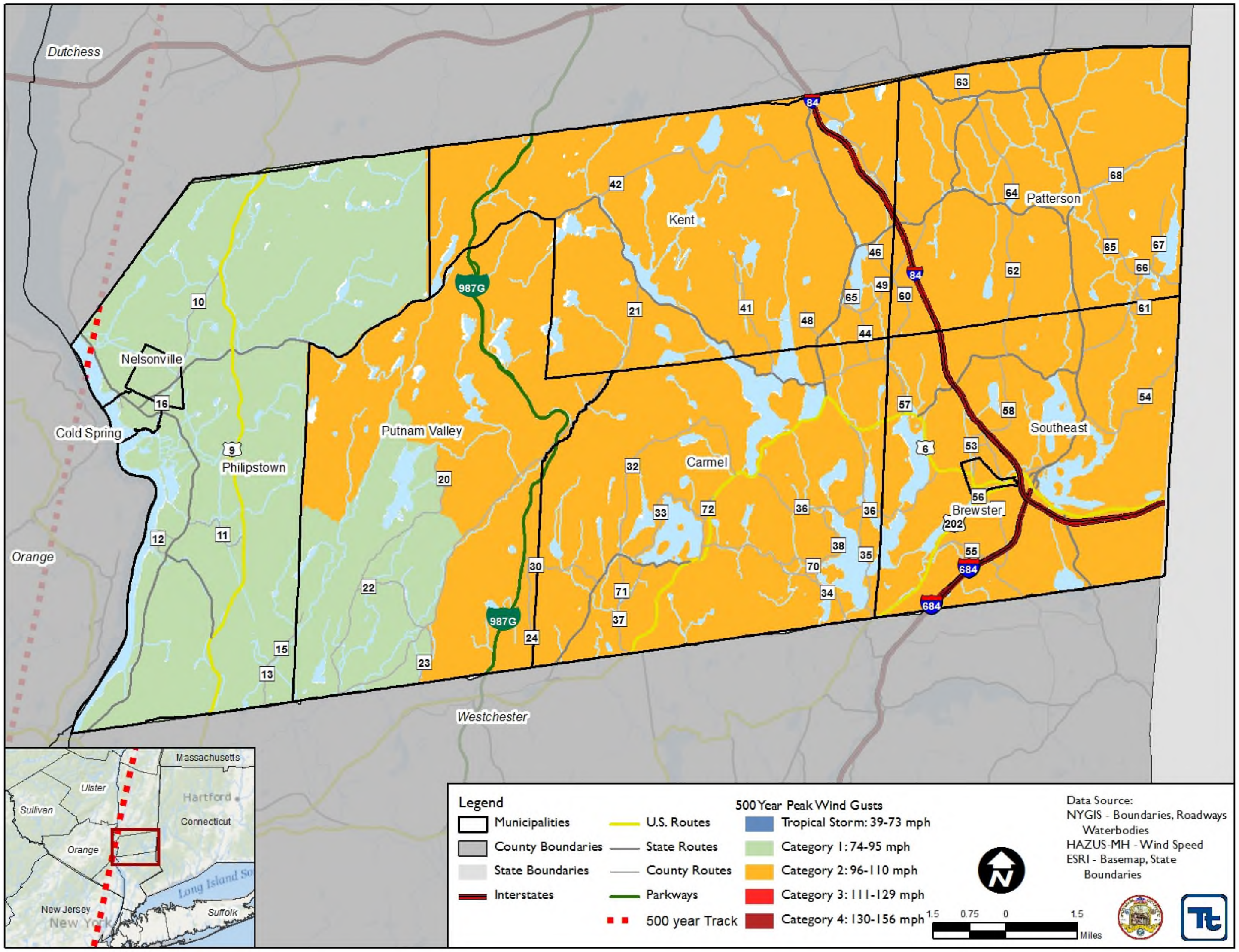
Figures 5.4.5-4 and 5.4.5-5 show the estimated maximum 3-second gust wind speeds that can be anticipated in the county associated with the 100- and 500-year MRP HAZUS-MH model runs, respectively. The estimated hurricane track for the 100- and 500-year event is also shown. For the 100-year MRP event, the maximum 3-second wind speeds range from 101 to 109 miles per hour (mph), characteristic of a Category 2 hurricane. For the 500-year MRP event, the maximum 3-second gust wind speeds for the county range from 119 to 132 mph, characteristic of a Category 3 hurricane. 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 5.4.5-4. Wind Speeds and Storm Track for the 100-Year Mean Return Period Event in Putnam County**




*Source: HAZUS-MH 2.1*
*Note: Peak gust wind speeds range from 69 to 82 miles per hour across the County.*

**Figure 5.4.5-5. Wind Speeds and Storm Track for the 500-Year Mean Return Period Event in Putnam County**




*Source: HAZUS-MH 2.1*
*Note: Peak gust wind speeds range from 88 to 94 miles per hour across the County.*

## Location

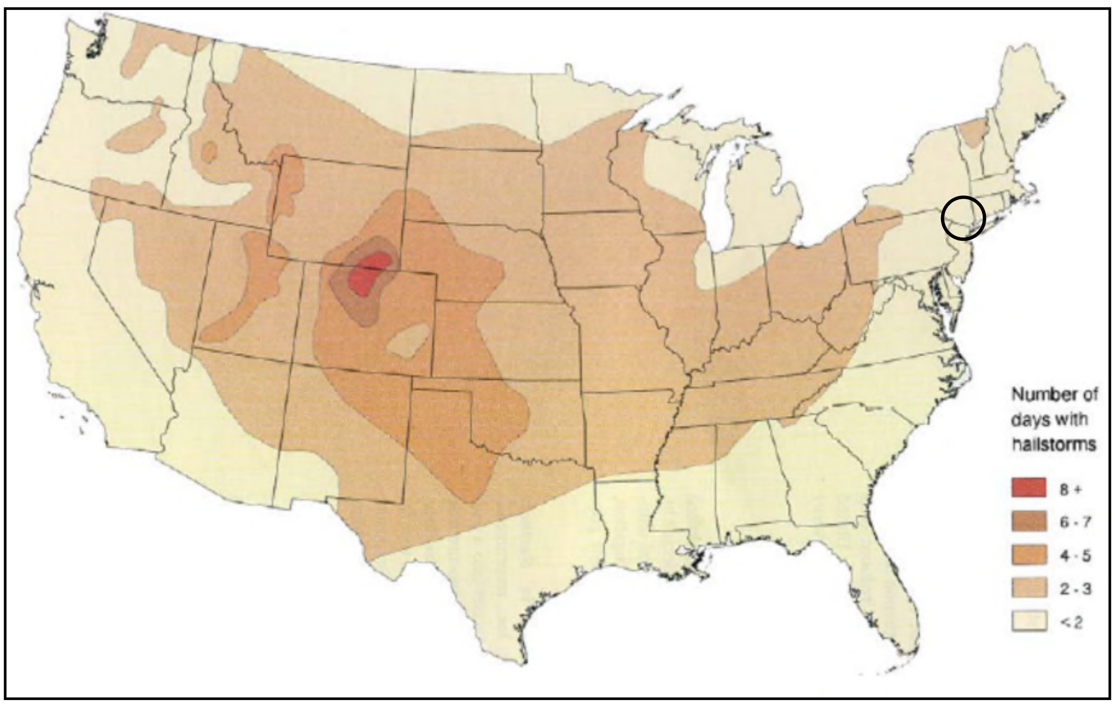
Severe storms are a common natural hazard in New York State because the State exhibits a unique blend of weather (geographically and meteorological) features that influence the potential for severe storms and associated flooding. Factors include temperature, which is affected by latitude, elevation, 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 (NYS DHSES, 2014).

### Hailstorms

Hailstorm events are more frequent in the southern and central plain states in the U.S. because the climate in this part of the country produces violent thunderstorms. However, hailstorms have been observed in almost every location where thunderstorms occur (Federal Alliance for Safe Homes, Inc., 2013). In New York State, hailstorms can occur anywhere within the State either independently or during a tornado, thunderstorm, or lightning event.

Hailstorms are more frequent in the southern and central plain states, where the climate produces violent thunderstorms. Figure 5.4.5-6 illustrates that Putnam County and most of New York State experience less than two hailstorms per year.

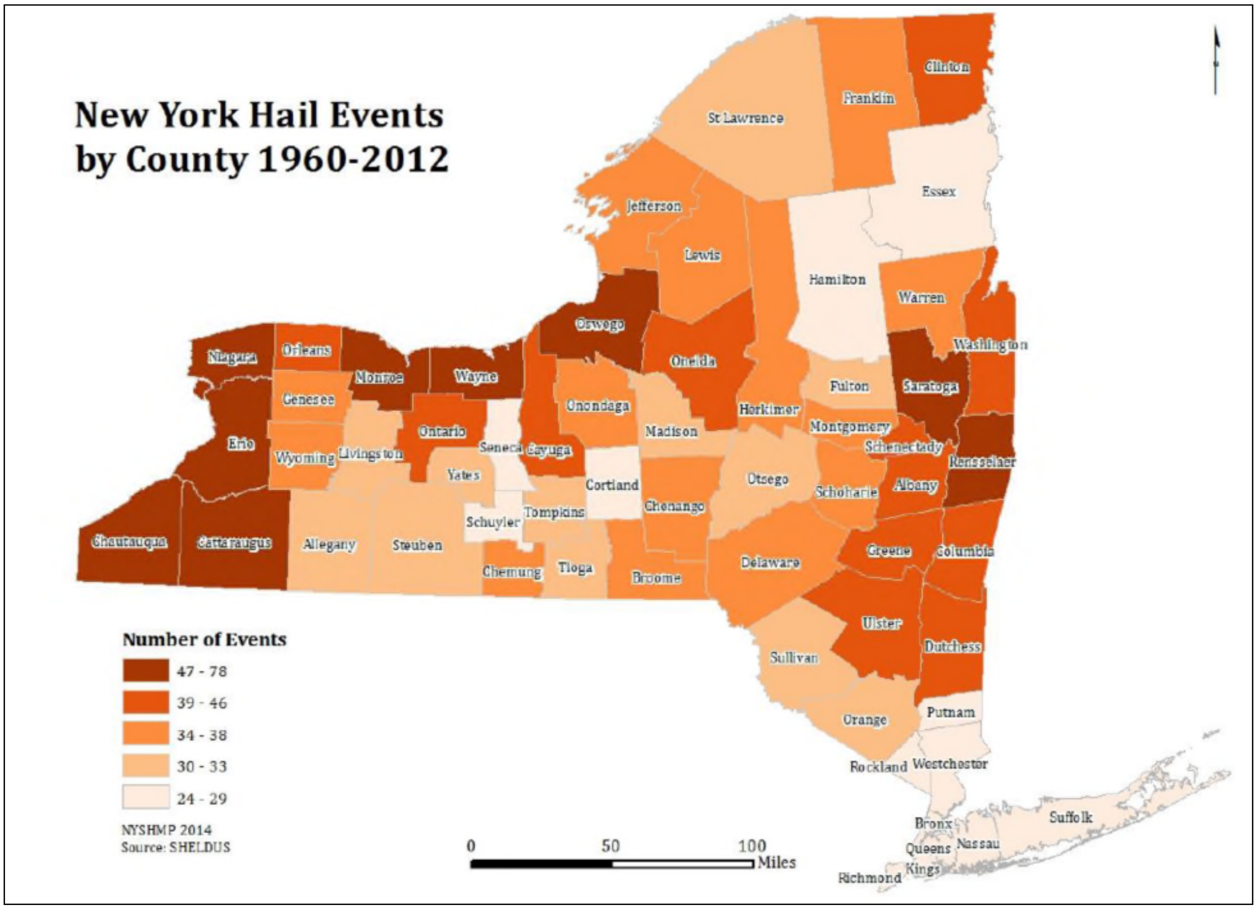
**Figure 5.4.5-6. Number of Days With Hailstorms Annually in the U.S.**




*Source: NVRC, 2006*
*Note: The black oval indicates the approximate location of Putnam County.*

Figure 5.4.5-7 shows the number of hail events from 1960 to 2012 across New York State. The figure indicates that Putnam County experienced between 24 and 29 events during this timeframe (NYS DHSES, 2014).

**Figure 5.4.5-7. New York Hail Events by County, 1960 to 2012**



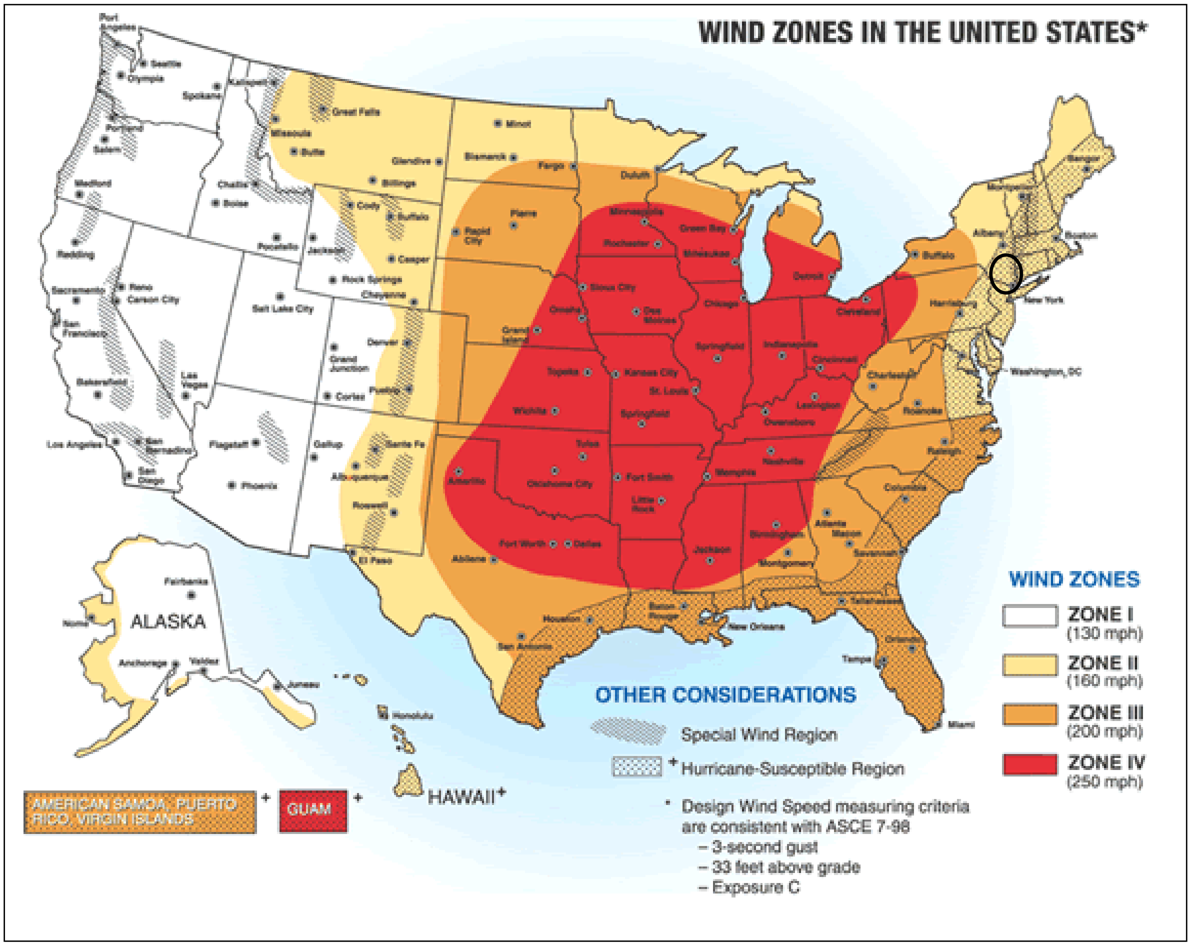

*Source: NYS DHSES, 2014*

## High Winds / Windstorms

New York State, including Putnam County, is located in a region highly susceptible to high wind events which include tornadoes and straight-line winds. They can cause significant damage to communities and infrastructure across the State (NYS DHSES 2014).

Figure 5.4.5-8 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). Putnam County is located in Wind Zone II with speeds up to 200 miles per hour. The County is also located within the hurricane susceptible region (FEMA, 2012).

## Figure 5.4.5-8. Wind Zones in the U.S.




*Source:* *FEMA, 2012*
*Note:* *The black circle indicates the approximate location of Putnam County.*

## Table 5.4.5-7. 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. |
| Hurricane Susceptible | Southern US coastline from Gulf Coast of Texas eastward to include entire state of Florida. |

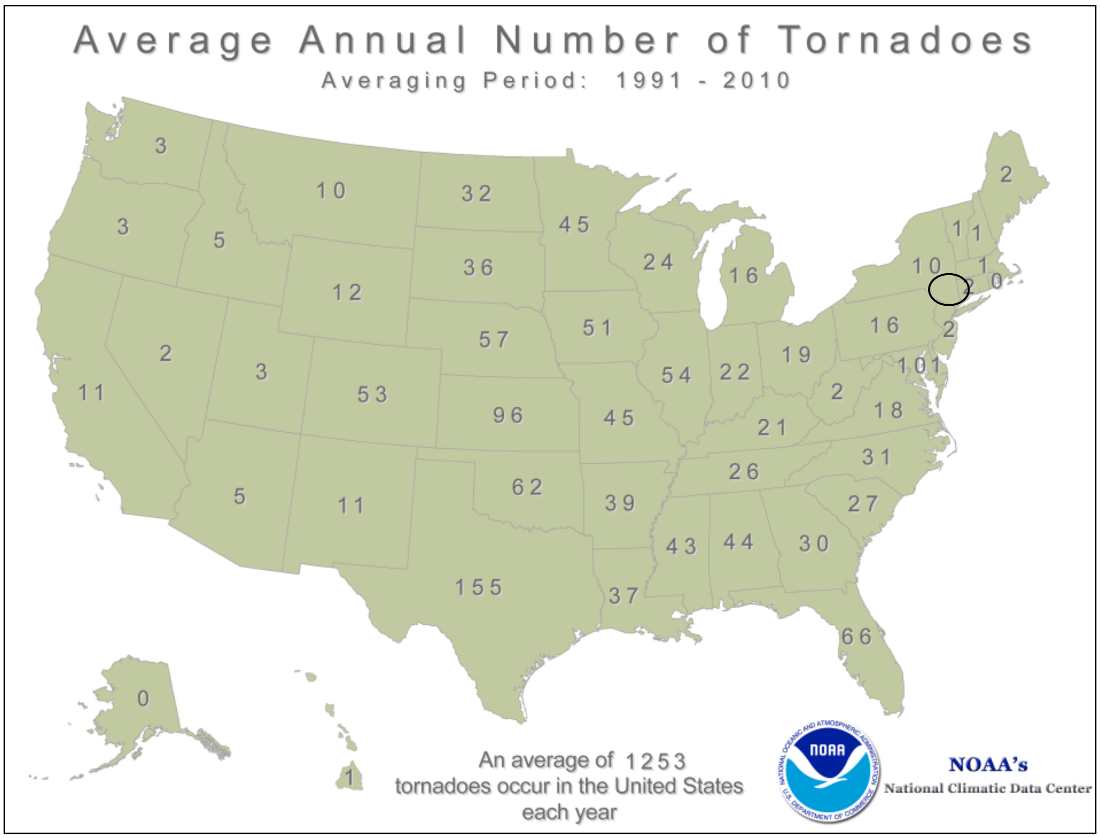
| Wind Zones | Areas Affected |
|---|---|
| Region | East Coastline from Maine to Florida, including all of Massachusetts, Connecticut, Rhode Island, Delaware, and Washington DC. All of Hawaii, Guam, American Samoa, Puerto Rico and Virgin Islands. |

*Source: NYS DHSES, 2014*

## Tornado

The U.S. experiences more tornadoes than any other country. In a typical year, an average of 1,253 tornadoes occur in 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 5.4.5-9 shows the annual average number of tornadoes between 1991 and 2010 (NWS, 2011). New York State experienced an average of 10 tornado events annually between 1991 and 2010.

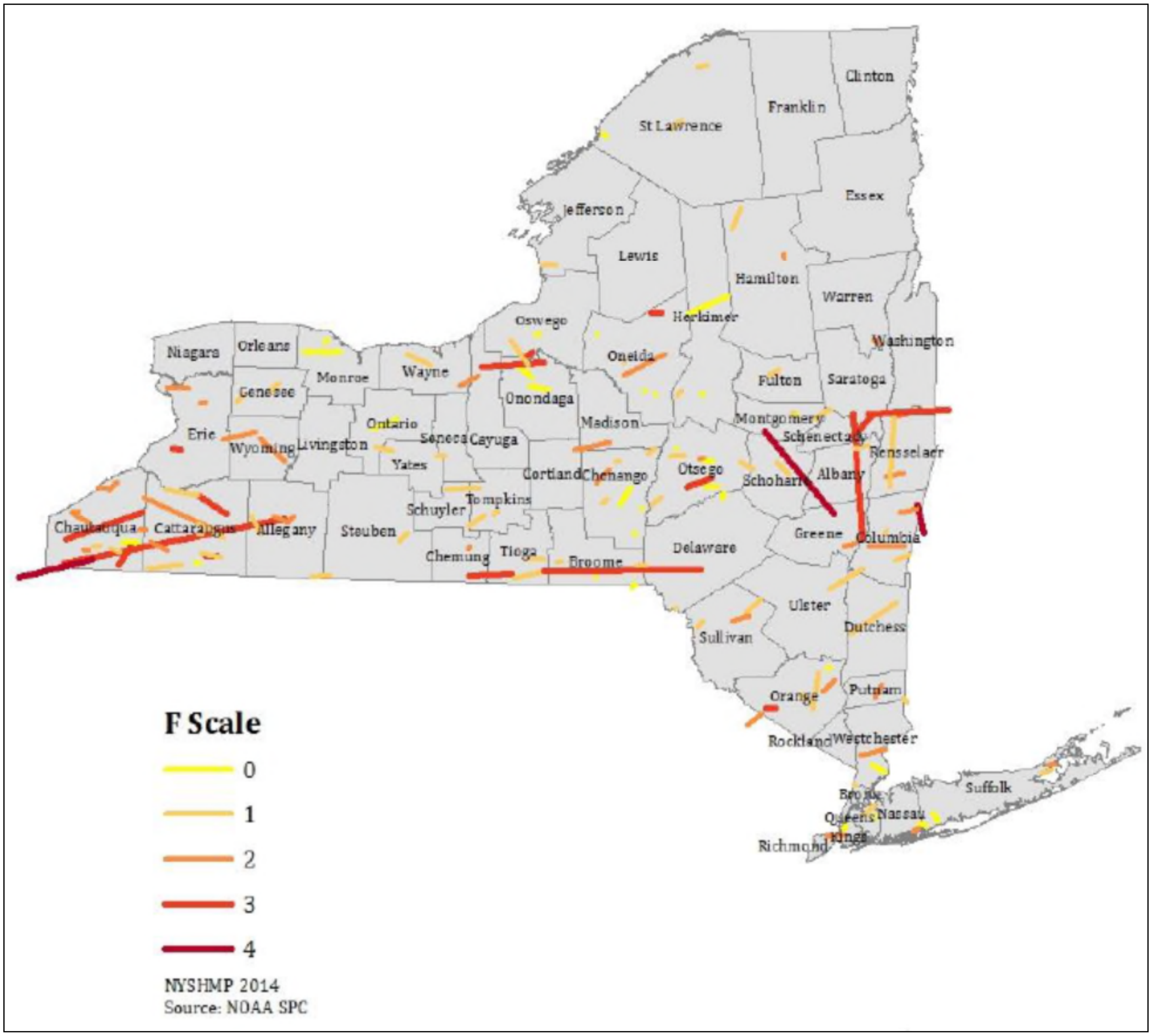
**Figure 5.4.5-9. Annual Average Number of Tornadoes in the U.S., 1991-2010**




*Source: NCDC, 2013*
*Note: Between 1991 and 2010, New York State experienced an average of 10 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 (The Disaster Center, Date Unknown). New York State has a definite vulnerability to tornadoes and can occur, based on historical occurrences, in any part of the State. Figure 5.4.5-10 shows historical straight-path tornado tracks for New York State between 1960 and 2012. The figure indicates that Putnam County has experienced F0 and F2 tornadoes (NYS DHSES, 2014).

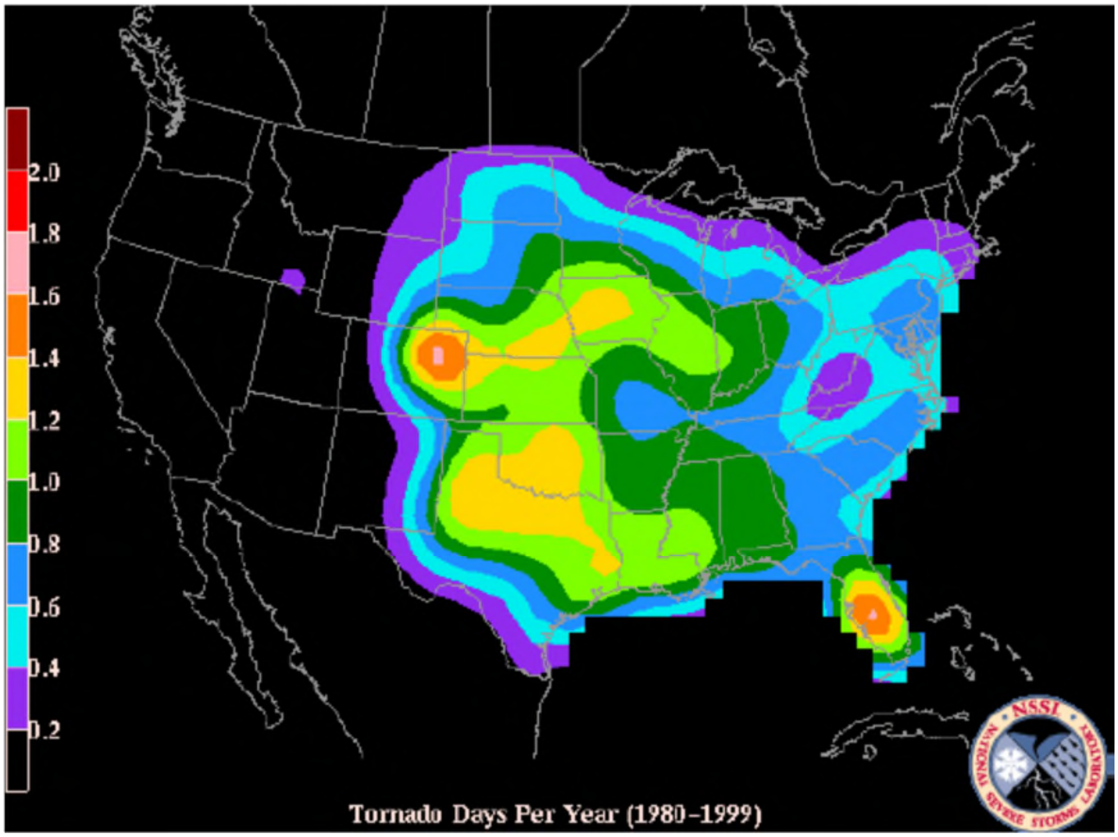
**Figure 5.4.5-10. Historical Tornado Tracks in New York State, 1960-2012**




*Source: NYS DHSES, 2014*

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 5.4.5-11 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 Putnam County, it is estimated that the probability of tornado occurring is 0.4 to 0.6 days per year (NSSL, 2003).

**Figure 5.4.5-11. Total Annual Threat of Tornado Events in the U.S., 1980-1999**



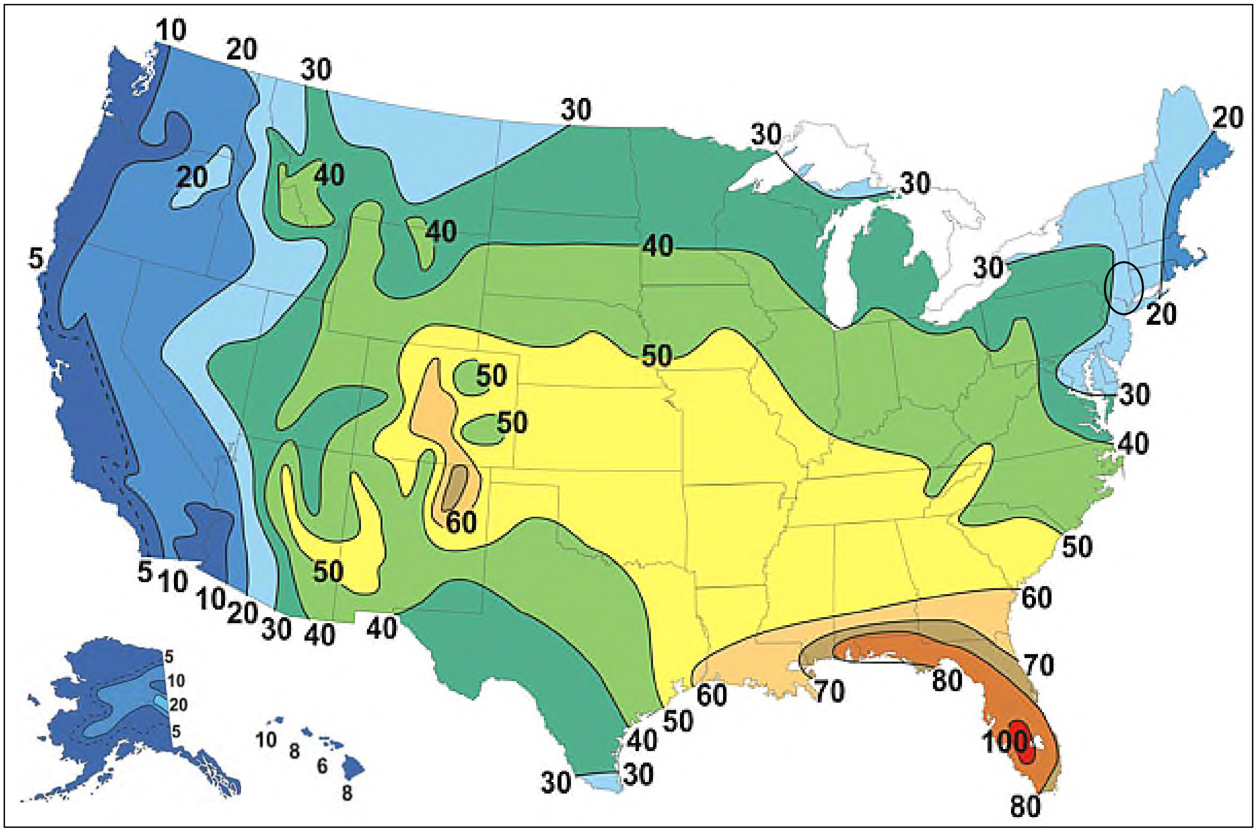

*Source: NSSL, 2003*

*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)*

## Thunderstorms

Thunderstorms affect relatively small localized areas, rather than large regions much like winter storms, and hurricane events (NWS, 2010). 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 5.4.5-12 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 Putnam County experiences between 20 and 30 thunderstorm days each year.

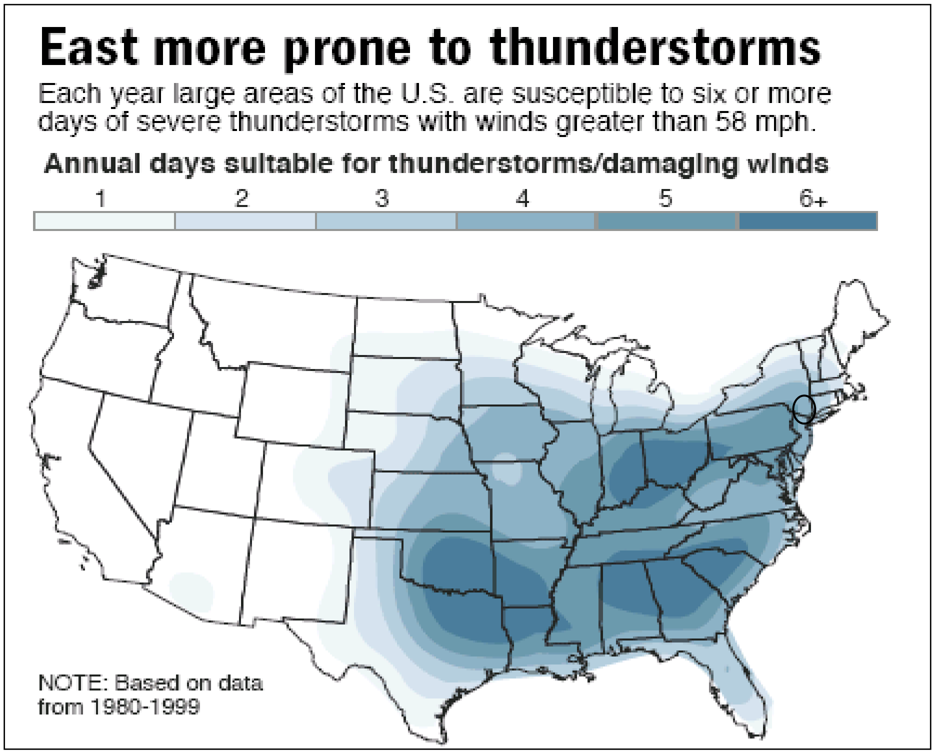
**Figure 5.4.5-12. Annual Average Number of Thunderstorm Days in the U.S.**




*Source: NWS, 2010*
*Note: The black oval indicates the approximate location of Putnam 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. As prepared by the NWS, Figure 5.4.5-13 identifies those areas, particularly within the eastern U.S. that are more prone to thunderstorms, which includes New York State and Putnam County.

**Figure 5.4.5-13. Annual Days Suitable for Thunderstorms/Damaging Winds**




*Source: NBCNews.com, 2007*
*Note: The black oval indicates the approximate location of Putnam County.*

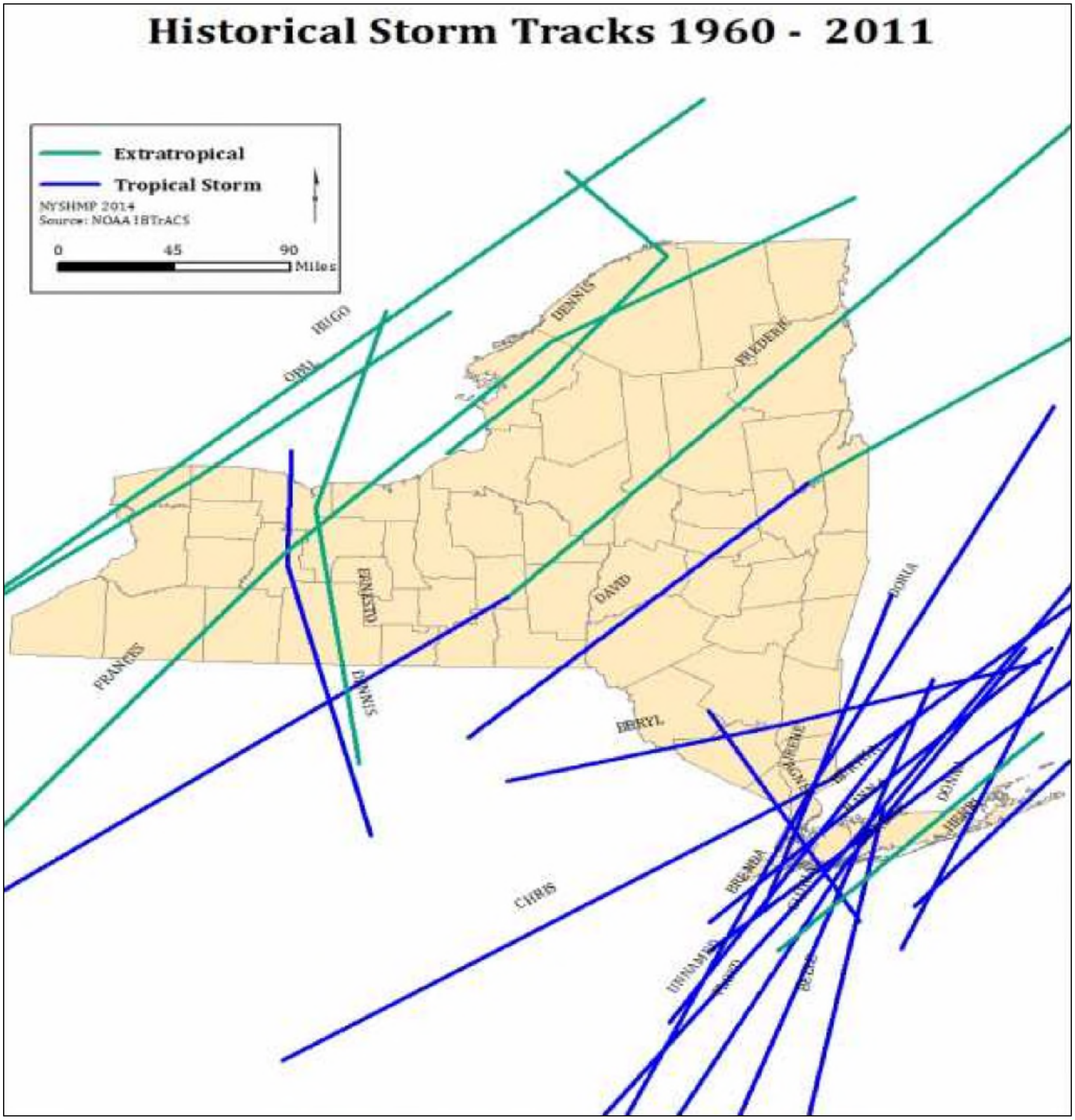
## Hurricanes and Tropical Storms

Hurricane risk in the U.S. extends along the entire east coast, from Maine to Florida, the Gulf Coast, and Hawaii. Hurricane and tropical storms are the two major types of storms that generally impact New York State's marine coastline and adjacent inland areas (NYS DHSES 2014).

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 (NYS DHSES, 2014).

Figure 5.4.5-14 from the NYS HMP, illustrates the storm tracks for storms between 1960 and 2011 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 (NYS DHSES, 2014).

**Figure 5.4.5-14. Hurricane Tracks in New York State, 1960 to 2011.**

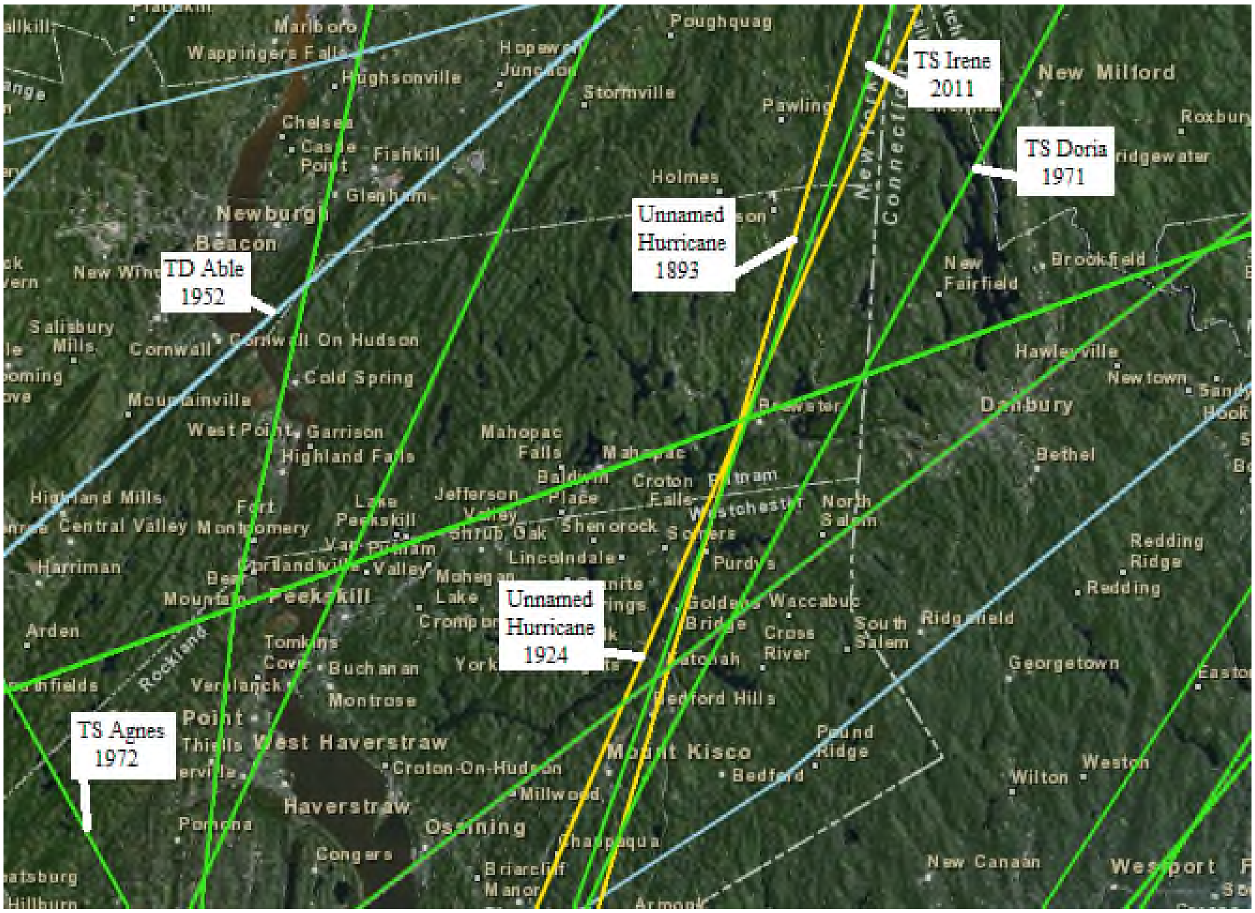



*Source: NYS DHSES, 2014*

Multiple sources have indicated that Putnam County has been impacted by hurricanes, tropical storms and tropical depressions. The County has felt the direct and indirect coastal and 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 2012. More recently, the County felt the effects of Hurricane Irene and Tropical Storm Lee. In 2012, Hurricane Sandy caused power outages, school and business closings, flooding, fuel shortages, and downed utility poles and trees.

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 2012. Figure 5.4.5-15 displays tropical cyclone tracks for Putnam County; however, the associated names for some of these events are unknown. Between 1842 and 2012, Putnam County has experienced 31 tropical cyclone occurrences within 65 nautical miles of the County (NOAA, 2014).

**Figure 5.4.5-15. Historical North Atlantic Tropical Cyclone Tracks (1842-2012)**




*Source: NOAA, 2014*

## Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with hurricane events throughout New York State and Putnam 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.

The NYS HMP indicated that Putnam County has experienced 27 hailstorm events between 1960 and 2012. Those events caused 1 injury and over $60,000 in property damage and over $6,400 in crop damage. Between 1960 and 2012, the County experienced 87 high wind events that caused 13 injuries, over $5.7 million property damage and over $17,600 in crop damage. Between 1960 and 2012, the County experienced 8 hurricane events that caused 2 injuries, over $5.8 million property damage and over $4 million in crop damage. Of those

122 events, at least[1] 22 of them have occurred between 2010 and 2012 (no fatalities or injuries, $113,750 in property damage) (NYS DHSES, 2014).

Between 1954 and 2014, 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: severe storms, 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 Putnam County has been declared as a disaster area as a result of eight severe storm events (FEMA, 2014).

For this 2014 Plan, known severe storm events that have impacted Putnam County between 2005 and 2013 are identified in Table 5.4.5-8. With severe storm documentation for New York State and Putnam County being so extensive, not all sources have been identified or researched. Only events that caused fatalities, injuries, or recorded damages are included. Therefore, Table 5.4.5-8 may not include all events that have occurred in the County. Please note Nor'Easter hazard events will be addressed specifically in Section 5.4.6 (Severe Winter Storm).

[1] Hurricane figures for 2010-2012 specifically are not reflected in the NYS HMP.

**Table 5.4.5-8. Severe Storm Events between 1950 and 2014**

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts |
|---|---|---|---|---|
| August 9, 1968 | Tornado | N/A | N/A | An F1 tornado caused $25,000 in damages. |
| July 29, 1971 | Tornado | N/A | N/A | An F2 tornado caused $250,000 in damages over 4.5 miles. |
| September 11-14, 1971 | Severe Storms and Flooding (Tropical Storm Doria) | DR-311 | Yes | Doria brought heavy rain to the New York City and southeastern portion of the State. Four-day precipitation totals ranged from 4.5 to seven inches. Flooding was widespread in the area of heaviest rainfall. Heavy property damage was experienced in Westchester County, eastern Orange County, and the Catskill-Hudson sector of the mid-Hudson Valley. Locally severe damage from road washouts and deposition of mud, rocks, and debris occurred near the slopes of Mt. Beacon in Dutchess County. This storm caused seven deaths and $147.6 million in damage throughout its path. New York State experienced approximately $7.4 million in total eligible damages. Damage estimates in Putnam County were not available. |
| September 25-27, 1975 | Severe Storms, Heavy Rain, Landslides, Flooding (Hurricane Eloise) | DR-487 | Yes | A week long rainfall event resulted in considerable flooding in the area. Hardest hit counties included: Broome, Cayuga, Chemung, Chenango, Madison, Onondaga, Oswego, and Tioga. Rainfall totals ranged from four to seven inches, with totals over 10 inches in southeastern New York State (including Putnam County). New York State experienced approximately $25 million in property damages and two fatalities. Damage estimates in Putnam County were not available. |
| July 10, 1989 | Tornado | N/A | N/A | An F2 tornado injured 2 people and caused $25 M in damages over 1/2 mile. 50 housing units in the King's Grant townhouse complex in Carmel were severely damaged. The tornado then damaged 6-12 residences in Brewster Heights. |
| June 29, 1990 | Tornado | N/A | N/A | $25,000 in property damages over 1/2 mile. |
| September 3, 1993 | Lightning; TSTM Wind | N/A | N/A | Numerous trees and power lines were downed during the event. These storms also produced torrential rains and frequent cloud to ground lightning. One strike started a fire at a high school. |
| September 22, 1994 | High Wind | N/A | N/A | These winds downed several trees and ripped off hundreds of branches which in turn downed power lines. Nearly 18,000 homes lost power for several hours. |
| November 7, 1994 | High Wind | N/A | N/A | Numerous branches and some power lines were blown down. At some locations the winds were strong enough to down a couple of trees. |
| May 24, 1995 | TSTM Wind | N/A | N/A | A line of thunderstorms moving across the region generated damaging winds. Numerous trees and power lines were downed. In Middle Hope a woman was killed and her daughter injured when a 50- by 25-foot section of a roof landed on their Jeep Cherokee after being ripped off a nearby condominium. In Scotchtown, high winds also ripped the roof off a house, but no injuries were reported. |

**Table 5.4.5-8. Severe Storm Events between 1950 and 2014**

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts |
|---|---|---|---|---|
| August 31, 1995 | TSTM Wind | N/A | N/A | A severe thunderstorm moving through the county downed several trees and power lines. |
| January 19-20, 1996 | Severe Storms, Flooding | DR-1095 | Yes | The storm brought heavy rains and caused significant snowmelt. Street and poor drainage flooding became a major problem due to the rains and snowmelt. River and stream flooding occurred in the afternoon of the 19th and continued through the next day. Several roofs collapsed during the new few days in response to an extremely heavy load of water brought on a previous blizzard and the heavy rains. Flooding was so widespread and severe that the event was known was the Deluge of '96. The storm and related flooding temporarily closed many roads, closed businesses, and killed 10 people throughout the State. Total damages in New York State reached $160 million. In Putnam County, flooding blocked a major north-south highway, Route 9, and also blocked roads near Cold Spring. Damage estimates in Putnam County were not available. |
| February 25, 1996 | High Wind | N/A | N/A | Winds gusted from 50 to nearly 70 MPH and caused numerous trees and power lines to fall. One fatality and one injury were reported. |
| August 23, 1996 | TSTM Wind | N/A | N/A | High winds knocked down several trees which also fell on power lines. Route 6 was closed between Brewster, NY and Danbury, CT due to numerous downed trees. In addition, wind damage was also reported just north of the village of Cold Spring. Numerous shingles were torn off about eight houses. |
| September 16-18, 1996 | Heavy Rain | N/A | N/A | Heavy rain caused street and poor drainage flooding along with significant within bank rises of local area rivers. Winds that gusted from 40 to 50 MPH caused tree limbs and branches to fall. High winds also caused scattered power outages. |
| October 8-9, 1996 | Heavy Rains and Flooding (Remnants of Tropical Storm Josephine) | N/A | N/A | The remnants of Tropical Storm Josephine moved rapidly northeast and passed east of Long Island on the 9th. It produced one to three inches of rain that caused localized flooding of streets and poor drainage areas across the region. It also brought gusty winds, with gusts ranging from 40 to 50 mph. Damage estimates in Putnam County were not available. |
| October 19, 1996 | Severe Storms, Flooding, Heavy Rains, High Winds (also known as a Nor'Easter) | DR-1146 | No | High winds and heavy rain impacted the area on the 19th which downed numerous trees and power lines. Peak wind gusts ranged from 30 mph to 55 mph. Strong east winds blowing over a long distance caused tides to average three to six feet above normal. Three to five inches of rain fell, with isolated higher amounts. Damage estimates in Putnam County were not available. |
| July 3, 1997 | TSTM Wind | N/A | N/A | A severe thunderstorm moved east across Putnam Valley. It straddled the Southern Putnam and Northern Westchester County Border. It produced high winds that downed trees. |
| July 7, 1997 | TSTM Wind | N/A | N/A | Scattered severe thunderstorms produced high winds and heavy rain. High winds downed trees and power lines in Unionville, Goshen, and New Windsor of Orange County and in Carmel of Putnam County. Car accidents caused by slippery |

**Table 5.4.5-8. Severe Storm Events between 1950 and 2014**

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts |
|---|---|---|---|---|
| | | | | pavement resulted in 7 injuries near Lake Carmel of Purnam County. High winds also downed a tree that fell on a multi-family house in Springfield Gardens. Numerous families were displaced from the destroyed house. Trees and powerlines were also downed in Woodmere. |
| July 9, 1997 | TSTM Wind | N/A | N/A | Numerous trees fell on powerlines in Lake Carmel and Brewster of Putnam County. A funnel cloud was also sighted in Putnam County. Patterson and Putnam Lake were also hit hard. The school, "Green Chimneys Children's Services," on Putnam Lake Road in Brewster suffered about $30,000 in damages. |
| May 29, 1998 | Lightning; TSTM Wind | N/A | N/A | High winds caused widespread damage to trees and power lines in Putnam County. In addition, lightning struck and ignited a fire that damaged a home on Corey Lane in Cold Springs. The extent of the damage is unknown. |
| May 31, 1998 | Hail; TSTM Wind | N/A | N/A | High winds downed many trees onto power lines, into houses, and onto cars. Frequent lightning strikes caused numerous brush and structure fires and downed trees onto power lines and houses. There were significant interruptions of power for up to 48 hours following these storms. |
| June 20, 1998 | TSTM Wind | N/A | N/A | High winds downed tree limbs, hail up to one-half inch in diameter, and heavy downpours were experienced at Mahopac. Another thunderstorm produced lightning that struck a house in Hewlett. Lightning destroyed about 75 percent of the house. |
| September 16-18, 1999 | Hurricane Floyd | DR-1296; EM-3149 | Yes | New York State experienced approximately $62.2 million in eligible damages as a result of property damage and debris accumulation (NYSDPC). Orange, Putnam, Rockland and Westchester Counties were declared disaster areas. For these 4 counties, the initial cost estimates were $14.6 million dollars. In Putnam County, damages were estimated at $1.9 million. Serious widespread flooding of low-lying and poor drainage areas resulted in the closure of many roads and basement flooding across the entire region. Maximum rainfall rates from one to around two inches per hour lasted for at least three consecutive hours across parts of the Lower Hudson Valley from 2 pm until 6 pm on the 16th. Rainfall in Putnam County ranged from 11.73 inches at the George Fischer M.S. Weather Station in Carmel to 13.70 inches at Brewster. Strong and gusty winds combined with torrential rain downed many trees, tree limbs, and power lines across the area. Significant power outages resulted. |
| November 2, 1999 | High Wind | N/A | N/A | High winds downed numerous tree limbs, trees, wires, and power lines. Some of these fell on and damaged cars. During the peak, Con Edison reported 69,000 customers without power across the area. Damage was widespread across the area. |
| December 11, 1999 | High Wind | N/A | N/A | Estimated wind gusts of at least 58 mph downed numerous trees and utility poles across Putnam and Northern Westchester Counties. Tree limbs were strewn across and blocked many roads in this area. Local electric utility companies reported almost 1500 customers without power as a result of these high winds. |

**Table 5.4.5-8. Severe Storm Events between 1950 and 2014**

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts |
|---|---|---|---|---|
| May 10, 2000 | Lightning | N/A | N/A | A man was injured when he was struck by lightning in Port Jervis. During an evening thunderstorm, lightning struck and damaged a building in Garrison. The amount of property damage was unknown. |
| June 2, 2000 | TSTM Wind | N/A | N/A | Based on a storm survey performed by NWS staff, an F1 tornado occurred around 7:05 pm EDT in the continental village region of the town of Cortlandt, about 3 miles north of Peekskill on the Westchester and Putnam Counties border. Damage occurred to about 20 houses, with 7 houses incurring moderate damage. Numerous trees of 1 1/2 to 2 feet in diameter were snapped, mainly about 20 to 25 feet above the ground. Three telephone poles were snapped in the middle. In Putnam County, several trees and power lines were downed in Carmel and Brewster. |
| June 11, 2000 | TSTM Wind | N/A | N/A | Downed trees in Walden and trees and power lines in Carmel, Riverhead, Greenwood Lake and Palisades. |
| December 12, 2000 | High Wind | N/A | N/A | High winds downed many trees onto houses, cars, power lines, and streets. In urban areas, high winds downed signs, collapsed scaffolds, and caused five partial building collapses. 1 fatality and 6 injuries were reported. Significant property damage and power outages. |
| December 17, 2000 | TSTM Wind | N/A | N/A | High winds downed several trees and power lines throughout the county. Large trees fell across Route 6N in Mahopac Falls, which caused a partial road closure. |
| June 17, 2001 | Lightning | N/A | N/A | In Putnam County, lightning struck a home that ignited a fire. The house suffered considerable damage, but no injuries were reported. |
| July 1, 2001 | TSTM Wind | N/A | N/A | Damaging winds in excess of 50 mph caused numerous large trees to topple, and led to scattered power outages. Frequent cloud to ground lightning strikes also accompanied these thunderstorms. |
| May 31, 2002 | TSTM Wind | N/A | N/A | As a severe thunderstorm moved east, it produced high winds that downed several tree limbs in Patterson. |
| June 26, 2002 | TSTM Wind | N/A | N/A | As severe thunderstorms moved across the region, they produced high winds and heavy rain. High winds downed many trees and power lines across the region. |
| July 9, 2002 | Lightning | N/A | N/A | About 1,400 customers lost power; approximately $500,000 in property damages. |
| August 2, 2002 | TSTM Wind | N/A | N/A | In Carmel, severe winds toppled a tree on top of a vehicle parked in a driveway. Approximately 25,000 customers suffered a power interruption. |
| September 28, 2003 | Heavy Rain | N/A | N/A | Closure of Mill Road in Philipstown. |

**Table 5.4.5-8. Severe Storm Events between 1950 and 2014**

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts |
|---|---|---|---|---|
| October 27, 2003 | TSTM Wind | N/A | N/A | This storm produced damaging winds that knocked several large tree limbs down. As a cold front approached the East coast, scattered showers and isolated thunderstorms developed just out ahead of the frontal boundary. Aided by a 50 to 60 knot jet located just above the boundary layer, a few thunderstorms became severe by mixing down these winds to the surface. The strong vertical wind profile also created enough shear to produce a weak tornado. |
| November 13, 2003 | High Wind | N/A | N/A | High winds downed numerous trees and power lines, which resulted in widespread power outages throughout the area. Thousands of power outages were confirmed by local utility companies. 1 fatality was reported. |
| May 13 – June 17, 2004 | Severe Storms and Flooding | DR-1534 | Yes | Streets closed throughout the County. |
| April 2-4, 2005 | Severe Storms and Flooding | DR-1589 | Yes | New York State experienced approximately $66.2 million in eligible damages. FEMA approved more than $5 million in disaster aid to the State to help fund recovery efforts in several counties and jurisdictions. Putnam County received over $57,000 in public assistance due to the flooding. |
| June 6, 2005 | TSTM Wind | N/A | N/A | A line of thunderstorms formed along the cold front, some of which produced wind damage such as knocking over large trees and downing power lines. Frequent lightning occurred as well. |
| July 27, 2005 | TSTM Wind | N/A | N/A | As the thunderstorms moved into the Lower Hudson Valley, they became severe and knocked down several trees which caused power outages. |
| January 18, 2006 | High Wind | N/A | N/A | Wind gusts approaching 70 mph downed many trees and power lines, which caused widespread power outages. |
| February 17, 2006 | High Wind | N/A | N/A | High wind gusts downed several trees, power lines, and wires across the region. A roof was torn off from a building and another building partially collapses in Brewster. |
| June 1, 2006 | TSTM Wind | N/A | N/A | Trees and power lines downed by thunderstorm winds. |
| July 18, 2006 | Hail | N/A | N/A | Severe thunderstorms produced damaging winds and large hail across many locations. High winds downed many whole trees, large tree branches, and power lines. News radio WCBS reported up to 150,000 power outages across the tri-state region. A few trees fell on houses and cars. |
| July 28, 2006 | TSTM Wind | N/A | N/A | Severe thunderstorms produced damaging winds and large hail across many locations. High winds downed many whole trees, large tree branches, and power lines. News radio WCBS reported up to 150,000 power outages across the tri-state region. A few trees fell on houses and cars. |

**Table 5.4.5-8. Severe Storm Events between 1950 and 2014**

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts |
|---|---|---|---|---|
| August 3, 2006 | TSTM Wind | N/A | N/A | A cluster of severe thunderstorms moved east across the Lower Hudson Valley. High winds downed trees and power lines. |
| April 14-18, 2007 | Severe Storms and Inland and Coastal Flood (also identified as a Nor'Easter) | DR-1692 | Yes | A Nor'Easter occurred during April 15th and 16th. It brought heavy rain and high winds that caused widespread and significant river, stream, and urban flooding of low lying and poor drainage areas. Many small rivers, streams, and brooks rose over their banks within 12 hours of the heavy rainfall. New York State experienced millions in eligible damages. FEMA gave out more than $61 million in assistance to affected counties within the State. The Taconic State Parkway and I-84 intersection near Miller Hill Road was flooded. |
| June 1, 2007 | TSTM Wind | N/A | N/A | Trees were downed across Route 9D. |
| June 2, 2007 | TSTM Wind | N/A | N/A | Downed trees and power lines. |
| July 19, 2007 | TSTM Wind | N/A | N/A | Downed trees along Woods Street in South Mahopac. |
| May 31, 2008 | TSTM Wind | N/A | N/A | Multiple tree limbs were reported down across Route 22, blocking traffic. |
| June 14, 2008 | TSTM Wind | N/A | N/A | Numerous trees and power lines were reported down in Fishkill. Approximately $5,000 in property damages. |
| August 11, 2008 | Lightning | N/A | N/A | Lightning struck a 19th century barn on Burdick Road in Milltown, destroying the barn and an antique truck in the barn. Approximately $75,000 in property damages. |
| February 12, 2009 | High Wind | N/A | N/A | There were several thousand power outages across southeast New York. New York State Electric and Gas Corp. reported several thousand customers without power due to downed power lines in the morning. |
| June 24, 2010 | TSTM Wind | N/A | N/A | A tree fell onto a car at Little Stony Point in Hudson Highlands State Park. Approximately $10,500 in property damages. |
| September 22, 2010 | TSTM Wind | N/A | N/A | Multiple trees were reported down on US Highway 9 in Graymoor. Approximately $5,000 in property damages. |
| June 22, 2011 | Heavy Rain | N/A | N/A | 1 fatality due to a motor vehicle accident |
| August 1, 2011 | TSTM Wind | N/A | N/A | A tree was reported down between Route 301 and Old Route 301 near Kent Cliffs. Approximately $6,000 in property damages. |
| August 8, 2011 | TSTM Wind | N/A | N/A | Trees were reported down in Glenclyffe, including along Route 9D and Route 403. Approximately $3,000 in property damages. |

**Table 5.4.5-8. Severe Storm Events between 1950 and 2014**

| Dates of Event | Event Type | FEMA Declaration Number | County Designated? | Losses / Impacts |
|---|---|---|---|---|
| August 19, 2011 | TSTM Wind | N/A | N/A | Multiple trees and wires were reported down throughout Carmel. Approximately $17,500 in property damages. |
| August 21, 2011 | TSTM Wind | N/A | N/A | One tree was reported down in Mahopac. In addition, large branches and limbs were reported down on Sheryl Lane and Russ Road. Approximately $5,000 in property damages. |
| August 28, 2011 | Hurricane Irene | DR-4020; EM-3328 | Yes | Copious amounts of tropical moisture within the storm produced extended periods of heavy rainfall, which resulted in widespread moderate to major flooding across the area. |
| July 26, 2012 | TSTM Wind | N/A | N/A | Multiple trees were reported down around Lake Carmel. Approximately $3,000 in damages was reported. |
| September 8, 2012 | TSTM Wind | N/A | N/A | A tree was reported down on Reservoir Road near the intersection of Lower Mine Road. Approximately $1,000 in property damages. |
| October 28, 2012 | Flood (Hurricane Sandy) | DR-4085; EM-3351 | Yes | Hurricane Sandy caused 60 deaths and widespread property damages of over $42 billion. Widespread power outages affected over two million people and lasted for up to two weeks. Putnam County received more than $1.5 million in public assistance to fund emergency efforts, remove debris, and rebuild infrastructure. |
| May 23, 2013 | Heavy Rain and Flood | N/A | N/A | 2.16 inches of rain fell in Putnam County. |
| July 14-15, 2014 | Heavy Rain and Flash Flooding | N/A | N/A | Severe thunderstorms hit the area, bringing lightning strikes, hail, downed trees and flooding in homes. Heavy rain flooded major roads in parts of the Tri-State area. A flash flood watch was issued for New York City, Long Island, Westchester, Rockland, and Putnam Counties. Between 1.23 inches and 3.10 inches of rain fell in Putnam County |

*Sources:* *FEMA, 2014; NOAA-NCDC, 2014; NWS, 2014; SHELDUS, 2014*

*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). The following table provides the probability of occurrences of severe storm events. Based on historic occurrences, wind events are the most common in Putnam County, followed by rain events. However, the information used to calculate the probability of occurrences is only based on using NOAA-NCDC storm events database results.

**Table 5.4.5-9. Probability of Occurrence of Severe Storm Events**

| Hazard Type | Number of Occurrences Between 1950 and 2014 | Probability |
|---|---|---|
| Hail | 29 | 0.45 |
| Hurricane | 1 | 0.02 |
| Wind | 112 | 1.75 |
| Rain | 34 | 0.53 |
| Tornado | 4 | 0.06 |
| Lightning | 6 | 0.09 |

*Source: NOAA-NCDC 2014*
*Note: Probability was calculated using the available data provided in the NOAA-NCDC storm events database.*

It is estimated that Putnam 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.

In Section 5.3, the identified hazards of concern for Putnam 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).

## Climate Change Impacts

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. Putnam County is part of Region 5, East Hudson and Mohawk River Valleys. Some of the issues in this region, affected by climate change, include: more frequent heat waves and above 90°F days, more heat-related deaths, increased frequency of heavy precipitation and flooding, decline in air quality, etc. (NYSERDA, 2011).

Temperatures in New York State are warming, with an average rate of warming over the past century of 0.25° F per decade. Average annual temperatures are projected to increase across New York State by 2° F to 3.4° F by the 2020s, 4.1° F to 6.8° F by the 2050s, and 5.3° F to 10.1° F by the 2080s. By the end of the century, the greatest warming is projected to be in the northern section of the State (NYSERDA, 2014).

Regional precipitation across New York State is projected to increase by approximately one to eight-percent by the 2020s, three to 12-percent by the 2050s, and four to 15-percent by the 2080s. By the end of the century, the greatest increases in precipitation are projected to be in the northern areas of the State (NYSERDA, 2014).

Sea level rise projections that do not include significant melting of polar ice sheets suggest one to five inches of rise by the 2020s; five to 12 inches by the 2050s; and eight to 23 inches by the 2080s. Scenarios that include rapid melting of polar ice projects four to 10 inches by the 2020s; 17 to 29 inches by the 2050s; and 37 to 55 inches by the 2080s (NYSERDA, 2011).

In Region 5, it is estimated that temperatures will increase by 3.5ºF to 7.1ºF by the 2050s and 4.1ºF to 11.4ºF by the 2080s (baseline of 47.6ºF). Precipitation totals will increase between 2 and 15% by the 2050s and 3 to 17% by the 2080s (baseline of 38.6 inches). Table 5.4.5-10 displays the projected seasonal precipitation change for the East Hudson and Mohawk River Valleys ClimAID Region (NYSERDA, 2011).

**Table 5.4.5-10. Projected Seasonal Precipitation Change in Region 5, 2050s (% change)**

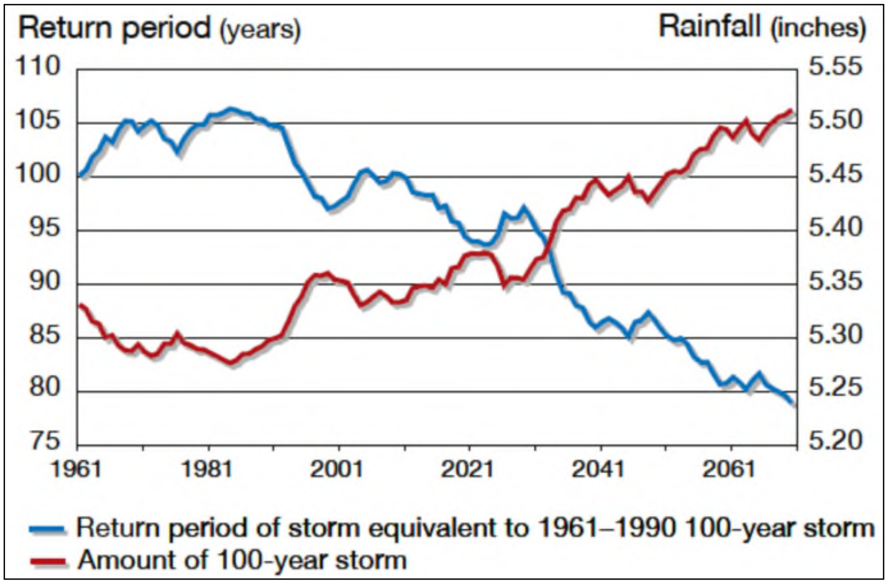
| Winter | Spring | Summer | Fall |
|---|---|---|---|
| 5 to +15 | -5 to +10 | -5 to +5 | -5 to +10 |

*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). 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 5.4.5-16 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 5.4.5-16. Projected Rainfall and Frequency of Extreme Storms**




*Source: NYSERDA, 2011*

## 5.4.5.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For severe storms, all of Putnam County has been identified as exposed. Therefore, all assets in the County (population, structures, critical facilities and lifelines), as described in the Putnam County Profile section (Section 4), are exposed and potentially 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
- Effect of climate change on vulnerability
- Further data collections that will assist understanding of this hazard over time

### 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.

Losses from wind are primarily associated with severe thunderstorm or tropical depression/storm-related winds and rain (see flooding discussion in Section 5.4.3 Flood). Secondary flooding associated with the torrential downpours during severe storms is also a primary concern in Putnam County. The County has experienced flooding in association with numerous severe storms in the past.

The entire inventory of Putnam 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 Putnam 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 Putnam 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 Putnam County. Data used to assess this hazard include data available in the HAZUS-MH 2.1 hurricane model, professional knowledge, information provided by the Steering and Planning Committees and input from public citizens.

A probabilistic scenario was run for Putnam 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 2.1 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 99,710 people) is exposed to the severe 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 Putnam 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 2.1. 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 $11 billion 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 5.4.5-11 summarizes the definition of the damage categories.

**Table 5.4.5-11. 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 |
|---|---|---|---|---|---|---|

**Table 5.4.5-11. 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 3-second peak gust wind speeds for Putnam County to range from 69 to 82 mph, characteristic of a Tropical Storm to Category 1 hurricane, associated with this event. HAZUS estimates $16,888,151 in damages to the general building stock (structure only). This estimated damage total is less than one-percent of Putnam County's building inventory.

HAZUS estimates the 500-year MRP peak gust wind speeds for Putnam County to range from 88 to 104 mph. This is characteristic of a Category 2 to 3 hurricane. HAZUS estimates $104,943,868 in damages to the general building stock (structure only). This is also less than one-percent of Putnam County's building inventory. The residential buildings are estimated to experience approximately 90% of the damage. Table 5.4.5-12 summarizes the building value (structure only) damage estimated for the 100- and 500-year MRP wind-only events, as well as the annualized event, 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 total residential replacement value (structure) for the entire County, an estimated $98 Million in residential building damage can be anticipated for the 500-year event. Residential building damage accounts for approximately 90% of the damages associated with the 500-year wind-only event. This illustrates residential structures are the most vulnerable to the wind hazard.

Annualized losses were also examined for Putnam County. A total of $1.3 Million is estimated as the annualized loss for the entire County; see Table 5.4.5-13. Please note that annualized loss does not predict what losses will occur in any particular year.

**Table 5.4.5-12. Estimated Building Replacement Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Winds for All Occupancy Classes**

| Municipality | Total Building Replacement Value (Structure Only) | Total Building Damage (All Occupancies) | | | | | | Residential Buildings | | All Other Occupancies | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Annualized | | 100 Year | | 500 Year | | | | | |
| | | Loss | % of GBS RCV Total | Loss | % of GBS RCV Total | Loss | % of GBS RCV Total | 100 Year | 500 Year | 100 Year | 500 Year |
| Village of Brewster | $201,581,179 | $23,916 | 0.01 | $306,916 | 0.2 | $2,558,956 | 1.3 | $293,676 | $2,348,005 | $13,240 | $210,951 |
| Town of Carmel | $3,847,178,692 | $461,231 | 0.01 | $6,308,487 | 0.2 | $38,107,604 | 1.0 | $6,171,429 | $36,229,679 | $137,058 | $1,877,925 |
| Village of Cold Spring | $269,493,110 | $18,968 | 0.01 | $116,325 | 0.0 | $963,114 | 0.4 | $108,602 | $914,599 | $7,723 | $48,515 |
| Town of Kent | $1,329,512,766 | $150,114 | 0.01 | $1,961,731 | 0.1 | $14,014,037 | 1.1 | $1,940,150 | $13,654,316 | $21,581 | $359,721 |
| Village of Nelsonville | $75,570,251 | $4,849 | 0.01 | $33,410 | 0.0 | $258,119 | 0.3 | $31,855 | $248,477 | $1,555 | $9,642 |
| Town of Patterson | $1,180,896,788 | $161,518 | 0.01 | $2,365,016 | 0.2 | $16,007,967 | 1.4 | $2,307,864 | $14,803,860 | $57,152 | $1,204,107 |
| Town of Philipstown | $1,048,614,861 | $81,211 | 0.01 | $735,046 | 0.1 | $4,696,162 | 0.4 | $715,871 | $4,562,607 | $19,175 | $133,555 |
| Town of Putnam Valley | $1,352,509,644 | $128,960 | 0.01 | $1,423,418 | 0.1 | $9,093,192 | 0.7 | $1,410,216 | $8,937,972 | $13,202 | $155,220 |
| Town of Southeast | $1,905,798,783 | $237,512 | 0.01 | $3,637,802 | 0.2 | $19,244,718 | 1.0 | $3,478,689 | $17,128,756 | $159,113 | $2,115,962 |
| **Putnam County (Total)** | **$11,211,156,075** | **$1,268,279** | **0.01** | **$16,888,151** | **0.2** | **$104,943,868** | **0.9** | **$16,458,353** | **$98,828,271** | **$429,798** | **$6,115,597** |

*Source: HAZUS-MH 2.1*

*Note: (1) The valuation of general building stock and loss estimates are based on the custom building inventory developed for Putnam County. 'All other occupancies' includes commercial, industrial, agricultural, religious, government and education buildings.*

## 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 MRP wind event.

**Table 5.4.5-13. Estimated Impacts to Critical Facilities for the 500-Year Mean Return Period Hurricane-Related Winds**

| Facility Type | 500-Year Event | | | | |
|---|---|---|---|---|---|
| | Loss of Days | Percent-Probability of Sustaining Damage | | | |
| | | Minor | Moderate | Severe | Complete |
| EOC | 0 | 9 | 1 | 0 | 0 |
| Medical | 0 | 1 - 7 | 0 - 3 | 0 - <1 | 0 |
| Police | 0 | 2 - 10 | 0 - 2 | <1 | 0 |
| Fire | 0 | <1 - 5 | <1 - 2 | <1 | 0 |
| Schools | 0 - 77 | 2 - 10 | 0 - 7 | < 1 | 0 |

*Source: HAZUS-MH 2.1*

At this time, HAZUS-MH 2.1 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 $200,000 in business interruption costs sustained mainly by the residential occupancy class from relocation and rental costs as a result of the 100-year MRP wind-only event. For the 500-year MRP wind only event, HAZUS-MH an estimated $7.7 Million in business interruption losses for Putnam County also sustained mainly by the residential occupancy from relocation and rental costs. Of the $7.7 Million, the commercial occupancy class is estimated to sustain approximately $1.6 Million in income, relocation, rental and wage loss.

HAZUS-MH 2.1 also estimates the amount of debris that may be produced a result of the 100- and 500-year MRP wind events. Table 5.4.5-14 and Table 5.4.5-15 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. According to the HAZUS-MH Hurricane User Manual: *'The Eligible Tree Debris columns provide estimates of the weight and volume of downed trees that would likely be collected and disposed at public expense. As discussed in Chapter 12 of the HAZUS-MH Hurricane Model Technical Manual, the eligible tree debris estimates produced by the Hurricane Model tend to underestimate reported volumes of debris brought to landfills for a number of events that have occurred over the past several years. This indicates that that there may be other sources of vegetative and non-vegetative debris that are not currently being modeled in HAZUS. For landfill estimation purposes, it is recommended that the HAZUS debris volume estimate be treated as an approximate lower bound. Based on actual reported debris volumes, it is recommended that the HAZUS results be multiplied by three to obtain an approximate upper bound estimate. It is also important to note that the Hurricane Model assumes a bulking factor of 10 cubic yards per ton of tree debris. If the debris is chipped prior to transport or disposal, a bulking factor of 4 is recommended. Thus, for chipped debris, the eligible tree debris volume should be multiplied by 0.4'*.

**Table 5.4.5-14. Debris Production (Tons) for 100-Year MRP Wind Event**

| Municipality | Brick and Wood (tons) | Concrete and Steel (tons) | Trees (tons) | Eligible Tree Weight (tons) | Eligible Tree Volume (cubic yards) |
|---|---|---|---|---|---|
| Village of Brewster | 47 | 0 | 38 | 31 | 300 |
| Town of Carmel | 380 | 0 | 2,089 | 841 | 8,562 |
| Village of Cold Spring | 4 | 0 | 9 | 8 | 115 |
| Town of Kent | 67 | 0 | 1,523 | 267 | 2,919 |
| Village of Nelsonville | 1 | 0 | 0 | 0 | 16 |
| Town of Patterson | 126 | 0 | 2,879 | 457 | 4,730 |
| Town of Philipstown | 7 | 0 | 783 | 107 | 1,093 |
| Town of Putnam Valley | 62 | 0 | 1,525 | 230 | 2,428 |
| Town of Southeast | 250 | 0 | 4,518 | 1,097 | 10,985 |
| **Putnam County (Total)** | **944** | **0** | **13,364** | **3,038** | **31,147** |

*Source: HAZUS-MH 2.1*

**Table 5.4.5-15. Debris Production (Tons) for 500-Year MRP Wind Event**

| Municipality | Brick and Wood (tons) | Concrete and Steel (tons) | Trees (tons) | Eligible Tree Weight (tons) | Eligible Tree Volume (cubic yards) |
|---|---|---|---|---|---|
| Village of Brewster | 394 | 0 | 227 | 181 | 1,818 |
| Town of Carmel | 4,319 | 5 | 16,355 | 6,537 | 65,284 |
| Village of Cold Spring | 110 | 0 | 150 | 121 | 1,227 |
| Town of Kent | 1,582 | 0 | 18,477 | 3,140 | 31,427 |
| Village of Nelsonville | 30 | 0 | 306 | 76 | 748 |
| Town of Patterson | 1,809 | 7 | 19,693 | 2,893 | 28,897 |
| Town of Philipstown | 347 | 0 | 16,865 | 1,769 | 17,660 |
| Town of Putnam Valley | 864 | 0 | 17,325 | 2,615 | 26,109 |
| Town of Southeast | 2,184 | 1 | 15,582 | 4,010 | 40,117 |

| Municipality | Brick and Wood (tons) | Concrete and Steel (tons) | Trees (tons) | Eligible Tree Weight (tons) | Eligible Tree Volume (cubic yards) |
|---|---|---|---|---|---|
| **Putnam County (Total)** | **11,639** | **13** | **104,980** | **21,341** | **213,287** |

*Source: HAZUS-MH 2.1*

## Future Growth and Development

As discussed in Sections 4 and 9, areas targeted for future growth and development have been identified across Putnam 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 each jurisdictional annexes in Volume II, Section 9 of this plan.

## Effect of Climate Change on Vulnerability

Climate is defined not simply as average temperature and precipitation but also by the type, frequency and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extremes such as storms, including those which may bring precipitation high winds and tornado events. While predicting changes of wind and tornado events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society and the environment (U.S. Environmental Protection Agency [EPA], 2006).

Refer to 'Climate Change Impacts' subsection earlier in this profile for more details on climate change pertaining to New York State.

## Additional Data and Next Steps

Over time, Putnam 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 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.