5.4.2 SEVERE STORM

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

HAZARD PROFILE

This section provides profile information including description, extent, location, previous occurrences and losses and the probability of future occurrences.

Description

For the purpose of this HMP and as deemed appropriated by the County, the severe storm hazard includes hailstorms, windstorms, lightning, thunderstorms, tornadoes, and tropical cyclones (e.g. hurricanes, tropical storms, and tropical depressions), which are defined as 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 5.4.3 Severe Winter Storm.

Hailstorm: According to the National Weather Service (NWS), hail is defined as a showery precipitation in the form of irregular pellets or balls of ice more than 5 millimeters in diameter, falling from a cumulonimbus cloud (NWS, 2005). Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until, having developed sufficient weight; they fall as precipitation, in the form of balls or irregularly shaped masses of ice. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size. Hailstorms are a potential damaging outgrowth of severe thunderstorms [Northern Virginia Regional Commission (NVRC), 2006]. They cause over $1 billion in crop and property damages each year in the U.S., making hailstorms one of the most costly natural disasters (Federal Alliance for Safe Homes, Inc., 2006).

Windstorm: According to the Federal Emergency Management Agency (FEMA), wind is air moving from high to low pressure. It is rough horizontal movement of air (as opposed to an air current) caused by uneven heating of the Earth's surface. It occurs at all scales, from local breezes generated by heating of land surfaces and lasting tens of minutes to global winds resulting from solar heating of the Earth. The two major influences on the atmospheric circulation are the differential heating between the equator and the poles, and the rotation of the planet. Windstorm events are associated with cyclonic storms (e.g. hurricanes), thunderstorms and tornadoes (FEMA, 1997).

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

Thunderstorm: According to the NWS, a thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS, 2005). A thunderstorm forms from a combination of moisture, rapidly rising warm air and a force capable of lifting air such as a warm and cold front, a sea breeze, or a mountain. Thunderstorms form from the equator to as far north as Alaska. These storms occur most commonly in the tropics. Many tropical land-based locations experience over 100 thunderstorm days each year (Pidwirny, 2007). Although thunderstorms generally affect a small area when they occur, they are very dangerous because of their ability to generate tornadoes, hailstorms, strong winds, flash flooding, and damaging lightning. A thunderstorm produces wind gusts less than 57 miles per hour (mph) and hail, if any, of less than 3/4-inch diameter (20 millimeters) at the surface. A severe thunderstorm has thunderstorm related surface winds (sustained or gusts) of 57 mph or greater and/or surface hail 3/4-inch (20 millimeters) or larger (NWS, 2005). Wind or hail damage may be used to infer the occurrence/existence of a severe thunderstorm (Office of the Federal Coordinator for Meteorology, 2001).

Tornado: A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. It is spawned by a thunderstorm (or sometimes as a result of a hurricane) and produced when cool air overrides a layer of warm air, forcing the warm air to rise rapidly. Tornado season is generally March through August, although tornadoes can occur at any time of year (FEMA, 2004). Tornadoes tend to strike in the afternoons and evening, with over 80 percent (%) of all tornadoes striking between noon and midnight [New Jersey Office of Emergency Management (NJOEM), 2005]. The average forward speed of a tornado is 30 mph, but can vary from nearly stationary to 70 mph (NWS, 1995). The NOAA Storm Prediction Center (SPC), indicates that the total duration of a tornado can last between a few seconds to over one hour; however, a tornado typical lasts less than 10 minutes (Edwards, 2007). High-wind velocity and wind-blown debris, along with lightning or hail, result in the damage caused by tornadoes. Destruction caused by tornadoes depends on the size, intensity, and duration of the storm. Tornadoes cause the greatest damage to structures that are light, such as residential homes and mobile homes, and tend to remain localized during impact (NVRC, 2006).

Tropical Cyclone: Tropical cyclone is a generic term for a cyclonic, low-pressure system over tropical or sub-tropical waters (National Atlas, 2007); containing a warm core of low barometric pressure which typically produces heavy rainfall, powerful winds and storm surge [New York City Office of Emergency Management (NYCOEM), 2007]. It feeds on the heat released when moist air rises and the water vapor in it condenses (Dorrego, Date Unknown). Depending on their location and strength, there are various terms by which tropical cyclones are known, such as hurricane, typhoon, tropical storm, cyclonic storm and tropical depression (Pacific Disaster Center, 2006). While tropical cyclones begin as a tropical depression, meaning the storm has sustained winds below 38 mph, it may develop into a tropical storm (with sustained winds of 39 to 73 mph) or a hurricane (with winds of 74 mph and higher).

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

Tropical Storm: A tropical storm is an organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds between 39 and 73 mph (FEMA, 2007). Once a storm has reached tropical storm status, it is assigned a name. During this time, the storm itself becomes more organized and begins to become more circular in shape, resembling a hurricane. The rotation of a tropical storm is more recognizable than a tropical depression. Tropical storms can cause a lot of problems, even without becoming a hurricane; however, most of the problems stem from heavy rainfall (University of Illinois, Date Unknown).

Hurricane: A hurricane is an intense tropical cyclone with wind speeds reaching a constant speed of 74 mph or more (FEMA, 2004). It is a category of tropical cyclone characterized by thunderstorms and defined surface wind circulation. They are caused by the atmospheric instability created by the collision of warm air with cooler air. They form in the warm waters of tropical and sub-tropical oceans, seas, or Gulf of Mexico (NWS, 2000). Most hurricanes evolve from tropical disturbances. A tropical disturbance is a discrete system of organized convection (showers or thunderstorms), that originate in the tropics or subtropics, does not migrate along a frontal boundary, and maintains its identity for 24 hours or more (NWS, 2004). Hurricanes begin when areas of low atmospheric pressure move off the western coast of Africa and into the Atlantic, where they grow and intensify in the moisture-laden air above the warm tropical ocean. Air moves toward these atmospheric lows from all directions and circulates clock-wise under the influence of the Coriolis effect, thereby initiating rotation in the converging wind fields. When these hot, moist air masses meet, they rise up into the atmosphere above the low pressure area, potentially establishing a self-reinforcing feedback system that produces weather systems known to meteorologists as tropical disturbances, tropical depressions, tropical storms, and hurricanes (Frankenberg, 1999).

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

- *Storm Surge* is simply water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with the normal tides to create the hurricane storm tide, which can increase the mean water level 15 feet or more. Storm surge is responsible for nearly 90-percent of all hurricane-related deaths and injuries.
- *Wind Damage* is the force of wind that can quickly decimate the tree population, down power lines and utility poles, knock over signs, and damage/destroy homes and buildings. Flying debris can also cause damage to both structures and the general population. When hurricanes first make landfall, it is common for tornadoes to form which can cause severe localized wind damage.
- *Rainfall / Flooding* the torrential rains that normally accompany a hurricane can cause serious flooding. Whereas the storm surge and high winds are concentrated around the "eye", the rain may extend for hundreds of miles and may last for several days, affecting areas well after the hurricane has diminished (Mandia, 2007).

Extent

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

Tornado

The magnitude or severity of a tornado was originally categorized using the Fujita Scale (F-Scale) or Pearson Fujita Scale introduced in 1971, based on a relationship between the Beaufort Wind Scales (B-Scales) (measure of wind intensity) and the Mach number scale (measure of relative speed). It is used to rate the intensity of a tornado by examining the damage caused by the tornado after it has passed over a man-made structure (Tornado Project, Date Unknown). The F-Scale categorizes each tornado by intensity and area. The scale is divided into six categories, F0 (Gale) to F5 (Incredible) (SPC, 2007). Table 5.4.2-1 explains each of the six F-Scale categories.

Table 5.4.2-1. 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, Date Unknown

Although the F-Scale has been in use for over 30 years, there are limitations of the scale. The primary limitations are a lack of damage indicators, no account of construction quality and variability, and no definitive correlation between damage and wind speed. These limitations have led to the inconsistent rating of tornadoes and, in some cases, an overestimate of tornado wind speeds. The limitations listed above led to the development of the Enhanced Fujita Scale (EF Scale). The Texas Tech University Wind Science and Engineering (WISE) Center, along with a forum of nationally renowned meteorologists and wind engineers from across the country, developed the EF Scale (NWS, 2007).

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 Degrees of Damage (DOD), which help better estimate the range of wind speeds produced by the tornado. From that, a rating is assigned, similar to that of the F-Scale, with six categories from EF0 to EF5, representing increasing 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, 2007). Table 5.4.2-2 displays the EF Scale and each of its six categories.

Table 5.4.2-2. Enhanced Fujita Damage Scale

F-Scale Number	Intensity Phrase	Wind Speed (mph)	Type of Damage Done
EF0	Light tornado	65–85	Light damage. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over.

F-Scale Number	Intensity Phrase	Wind Speed (mph)	Type of Damage Done
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, 2007

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 damage indicators (DIs), such as building type, structures, and trees. For each damage indicator, there are 8 degrees of damage (DOD), ranging from the beginning of visible damage to complete destruction of the damage indicator. Table 5.4.2-3 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 5.4.2-3. Enhanced F-Scale Damage Indicators

Number	Damage Indicator	Abbreviation	Number	Damage Indicator	Abbreviation
1	Small barns, farm outbuildings	SBO	15	School - 1-story elementary (interior or exterior halls)	ES
2	One- or two-family residences	FR12	16	School - jr. or sr. high school	JHSH
3	Single-wide mobile home (MHSW)	MHSW	17	Low-rise (1-4 story) bldg.	LRB
4	Double-wide mobile home	MHDW	18	Mid-rise (5-20 story) bldg.	MRB

Number	Damage Indicator	Abbreviation	Number	Damage Indicator	Abbreviation
5	Apt, condo, townhouse (3 stories or less)	ACT	19	High-rise (over 20 stories)	HRB
6	Motel	M	20	Institutional bldg. (hospital, govt. or university)	IB
7	Masonry apt. or motel	MAM	21	Metal building system	MBS
8	Small retail bldg. (fast food)	SRB	22	Service station canopy	SSC
9	Small professional (doctor office, branch bank)	SPB	23	Warehouse (tilt-up walls or heavy timber)	WHB
10	Strip mall	SM	24	Transmission line tower	TLT
11	Large shopping mall	LSM	25	Free-standing tower	FST
12	Large, isolated ("big box") retail bldg.	LIRB	26	Free standing pole (light, flag, luminary)	FSP
13	Automobile showroom	ASR	27	Tree - hardwood	TH
14	Automotive service building	ASB	28	Tree - softwood	TS

Source: SPC, Date Unknown

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

Hurricanes

The extent of a hurricane is categorized by the Saffir-Simpson Hurricane Scale. This scale categorizes or rates hurricanes from 1 (Minimal) to 5 (Catastrophic) based on their intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline, in the landfall region [National Hurricane Center (NHC), 2007]. Table 5.4.2-4 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes land fall.

Table 5.4.2-4. The Saffir-Simpson Scale

Category	Wind Speed (mph)	Storm Surge (above normal sea level)	Expected Damage
1	74-95	4 – 5 feet	Minimal: Damage is done primarily to shrubbery and trees, unanchored mobile homes are damaged, some signs are damaged, and no real damage is done to structures.

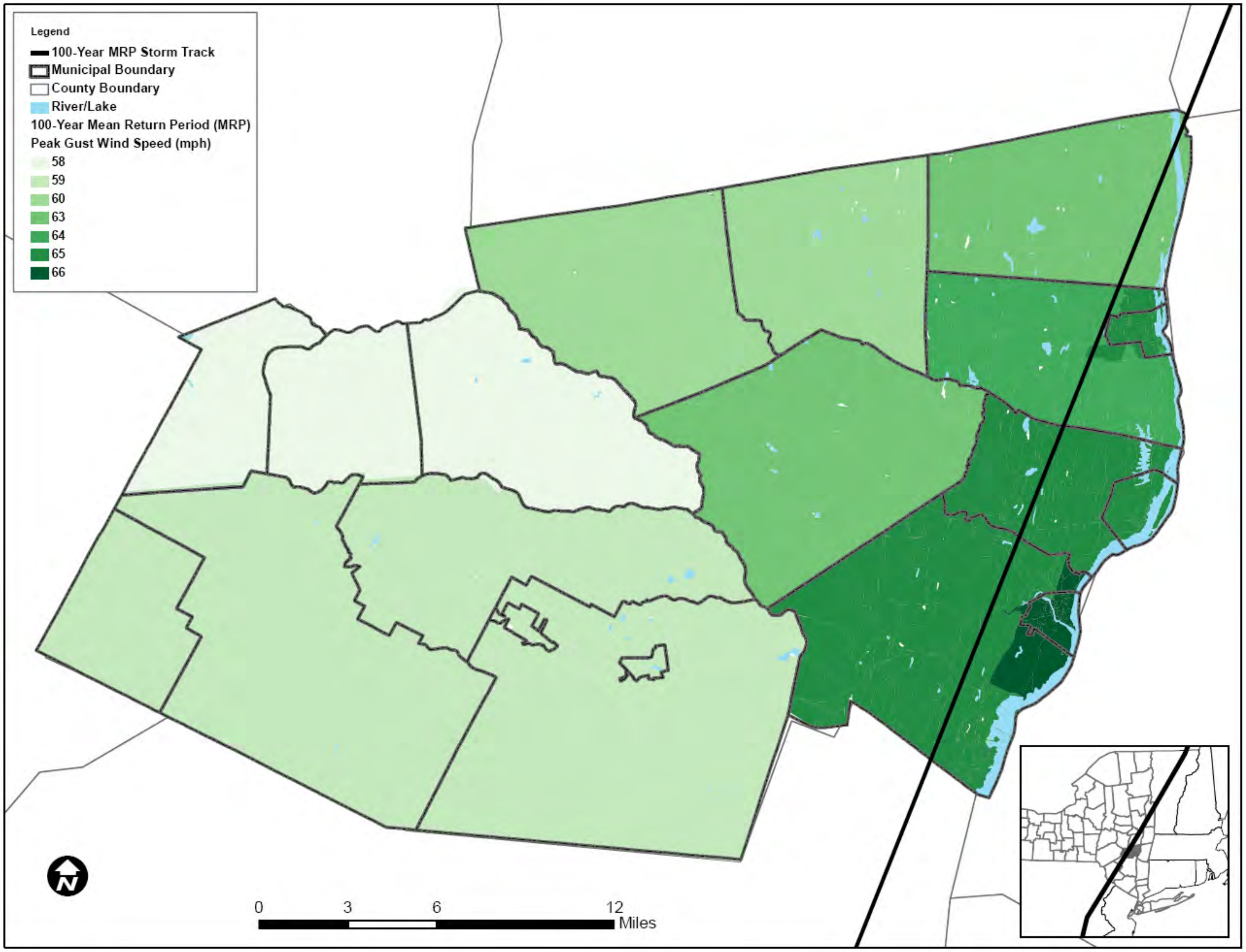
Category	Wind Speed (mph)	Storm Surge (above normal sea level)	Expected Damage
2	96-110	6 – 8 feet	Moderate: Some trees are toppled, some roof coverings are damaged, and major damage is done to mobile homes.
3	111-130	9 – 12 feet	Extensive: Large trees are toppled, some structural damage is done to roofs, mobile homes are destroyed, and structural damage is done to small homes and utility buildings.
4	131-155	13 – 18 feet	Extreme: Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; and some curtain walls fail.
5	> 155	> 18 feet	Catastrophic: Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures, and entire buildings could fail.
Additional Classifications			
Tropical Storm	39-73	0 - 3 feet	NA
Tropical Depression	< 38	0	NA

Source: FEMA, 2007
mph = Miles per hour
> = Greater than
NA = Not applicable or not available

In evaluating the potential for hazard events of a given magnitude, a mean return period (MRP) is often used. The MRP provides an estimate of the magnitude of an event that may occur within any given year based on past recorded events. MRP is the average period of time, in years, between occurrences of a particular hazard event (equal to the inverse of the annual frequency of exceedance) (Dinicola, 2005).

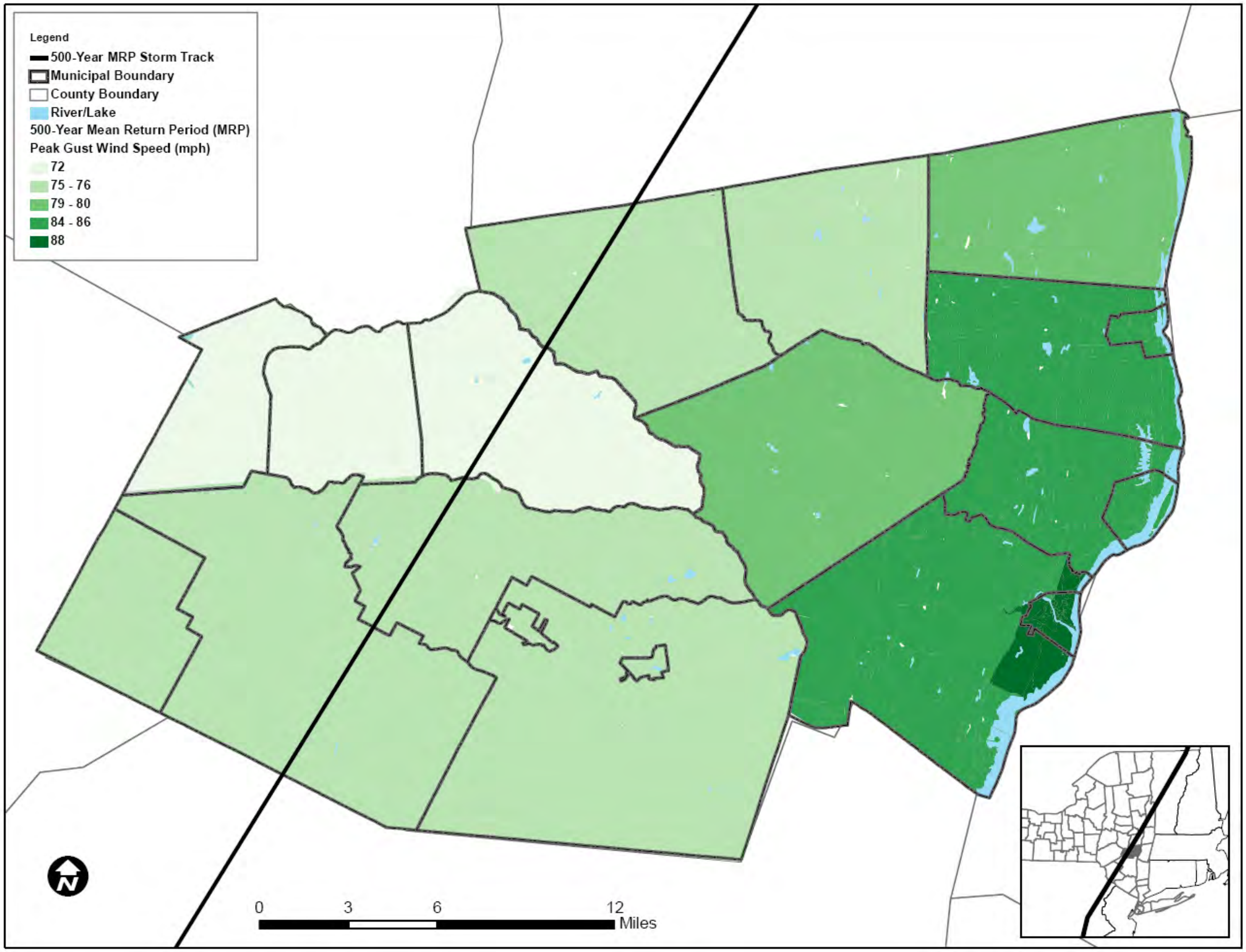
Figures 5.4.2-1 and 5.4.2-2 show the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP HAZUS-MH model runs. The estimated hurricane track for the 100- and 500-year event is also shown. The maximum 3-second gust wind speeds for the County range from 58 to 66 mph for the 100-year MRP event; wind speeds characteristic of a tropical storm. The maximum 3-second gust wind speeds for the County range from 72 to 88 mph for the 500-year MRP event; wind speeds characteristic of a Category 1 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 5.4.2-1. Peak Wind Speeds for the 100-Year MRP Wind Event in Greene County



Source: HAZUS-MH MR3, 2007

Figure 5.4.2-2. Peak Wind Speeds for the 500-Year MRP Wind Event in Greene County



Source: HAZUS-MH MR3, 2007

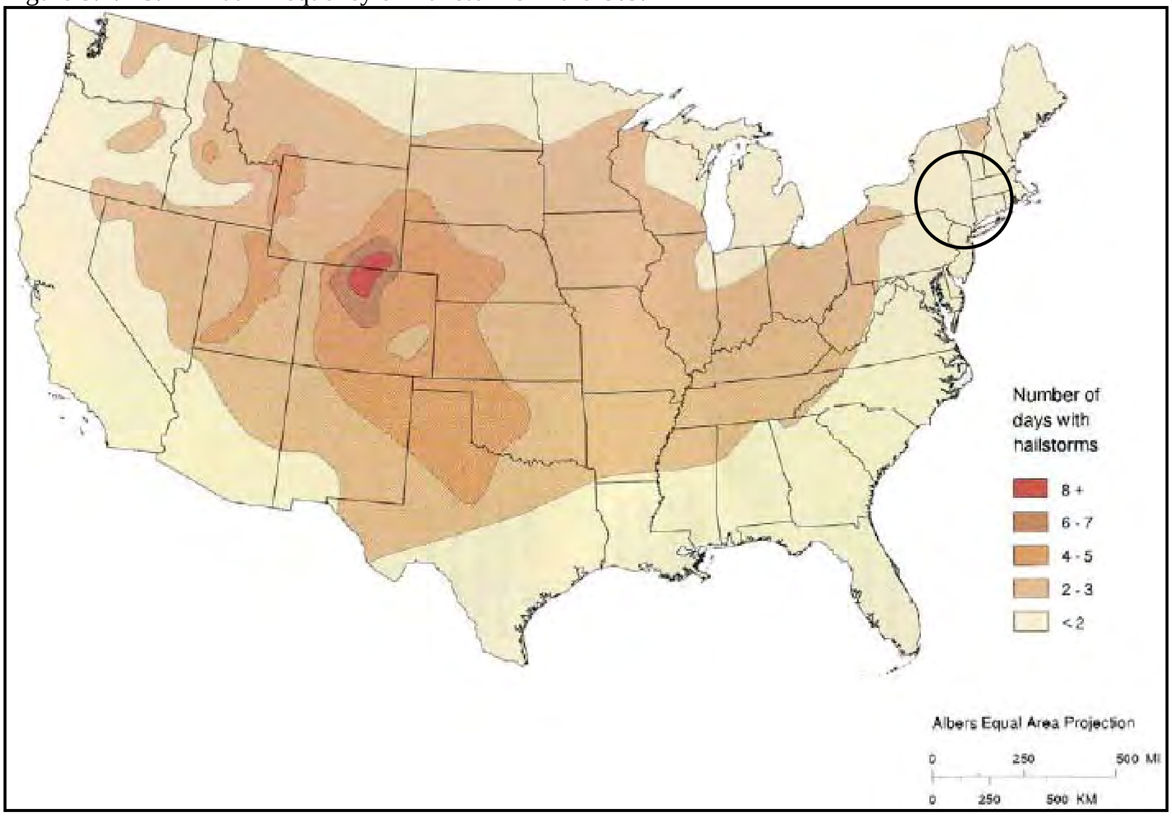
Location

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 (NYSDPC, 2008).

Hailstorms

Hailstorms are more frequent in the southern and central plain states, where the climate produces violent thunderstorms. However, hailstorms have been observed in almost every location where thunderstorms occur (Federal Alliance for Safe Homes, Inc, 2006). Figure 5.4.2-3 illustrates that Greene County and most of New York State experience less than two hailstorms per year.

Figure 5.4.2-3. Annual Frequency of Hailstorms in the U.S.



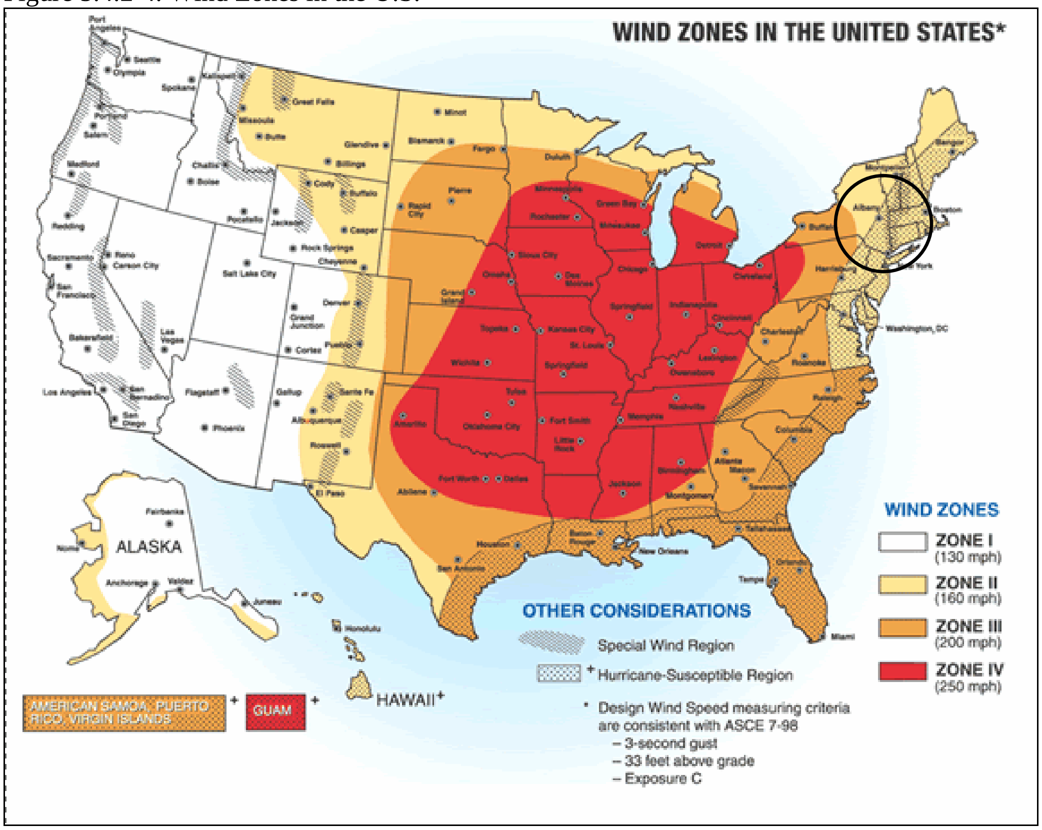
Source: NVRC, 2006

Note: The black circle indicates the approximate location of Greene County. Greene County experiences less than 2 hailstorms a year.

Windstorms

Figure 5.4.2-4 indicates how the frequency and strength of windstorms impacts the U.S. and the general location of the most wind activity. This is based on 40 years of tornado history and 100 years of hurricane history, collected by FEMA. States located in Wind Zone IV have experienced the greatest number of tornadoes and the strongest tornadoes (NVRC, 2006). Greene County is located in Wind Zone II with speeds up to 160 miles per hour. The County is also located within the Hurricane Susceptibility Region, which extends along the northeastern coastline of the U.S. (FEMA, 2006). The New York State Hazard Mitigation Plan (NYS HMP) identifies counties most vulnerable to wind, as determined by a rating score. Counties accumulate points based on the value of each vulnerability indicator, the higher then indication for wind exposure the more points assigned, resulting in a final rating score. Greene County was given a rating score of 12, a medium vulnerability to wind exposure (NYSDPC, 2008).

Figure 5.4.2-4. Wind Zones in the U.S.

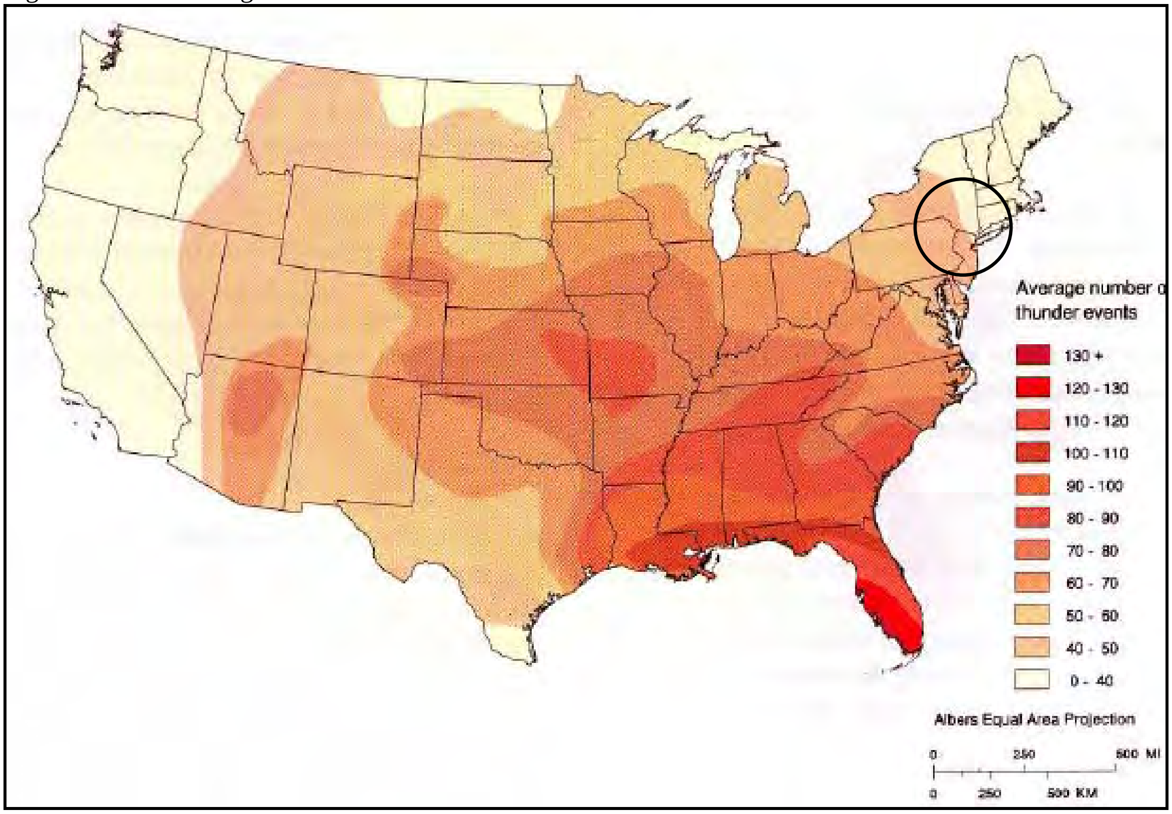


Source: FEMA, 2006
Note: The black circle indicates the approximate location of Greene County.

Thunderstorms

Thunderstorms affect relatively small localized areas, rather then large regions much like winter storms, and hurricane events (NWS, 2005). Thunderstorms can strike in all regions of the U.S.; however, they are most common in the central and southern states. The atmospheric conditions in these regions of the country are most ideal for generating these powerful storms (NVRC, 2006). More than 100,000 thunderstorms occur each year in the U.S., however, only about 10-percent are classified as "severe" (NOAA, 2005). The NWS collected data for thunder days, number and duration of thunder events, and lightening strike density for the 30-year period from 1948 to 1977. A map was produced by the NWS, illustrating thunderstorm hazard severity in the U.S., based on the annual average number of thunder events between 1948 and 1977 (Figure 5.4.2-5) (NVRC, 2006). This figure indicates that Greene County experienced between 0 and 40 annual thunder events during this time period.

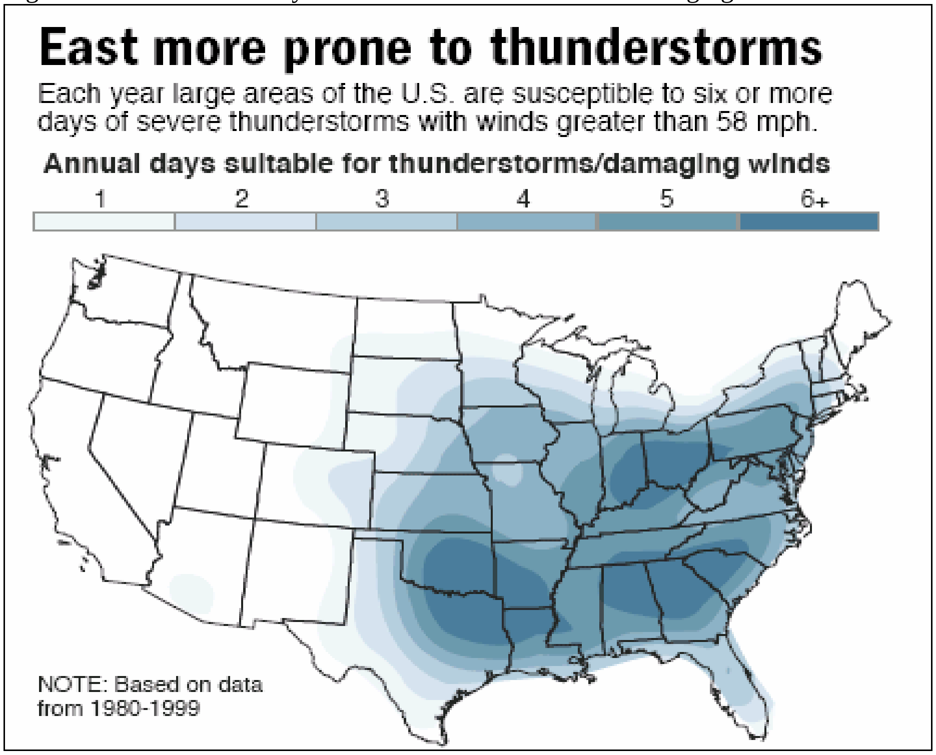
Figure 5.4.2-5. Average Number of Thunderstorms between 1948 and 1977 in the U.S.



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

NASA scientists suggest that the U.S. will face more severe thunderstorms in the future, with deadly lightning, damaging hail and the potential for tornadoes in the event of climate change (Borenstein, 2007). A recent study conducted by NASA predicts that smaller storm events like thunderstorms will be more dangerous due to climate change (Figure 5.4.2-6). As prepared by the NWS, Figure 5.4.2-6 identifies those areas, particularly within the eastern U.S. that are more prone to thunderstorms, which includes New York State.

Figure 5.4.2-6. Annual Days Suitable for Thunderstorms/Damaging Winds

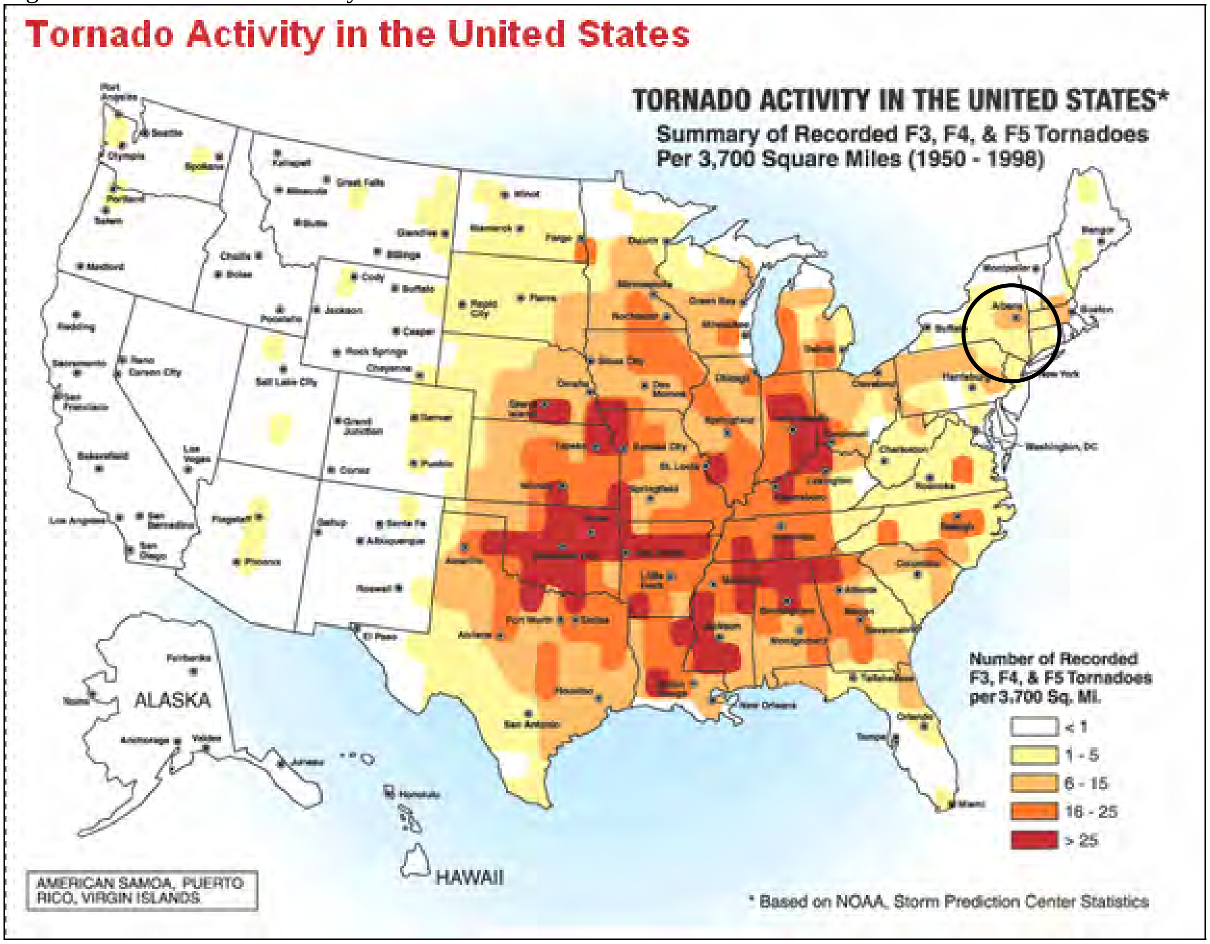


Source: MSNBC.com, 2007

Tornado

According to the NWS, an average of 800 tornadoes affects the U.S. each year. These tornadoes typically result in approximately 80 deaths and over 1,500 injuries annually. The highest concentration of tornadoes in the U.S. has been in Oklahoma, Texas, Kansas, and Florida, as well as the Great Plains region of the central U.S. Tornadoes have also been observed in the central and eastern portions of the U.S (NVRC, 2006). Figure 5.4.2-7 shows tornado activity in the U.S., between 1950 and 1998, based on the number of recorded tornadoes per 3,700 square miles.

Figure 5.4.2-7. Tornado Activity in the U.S.

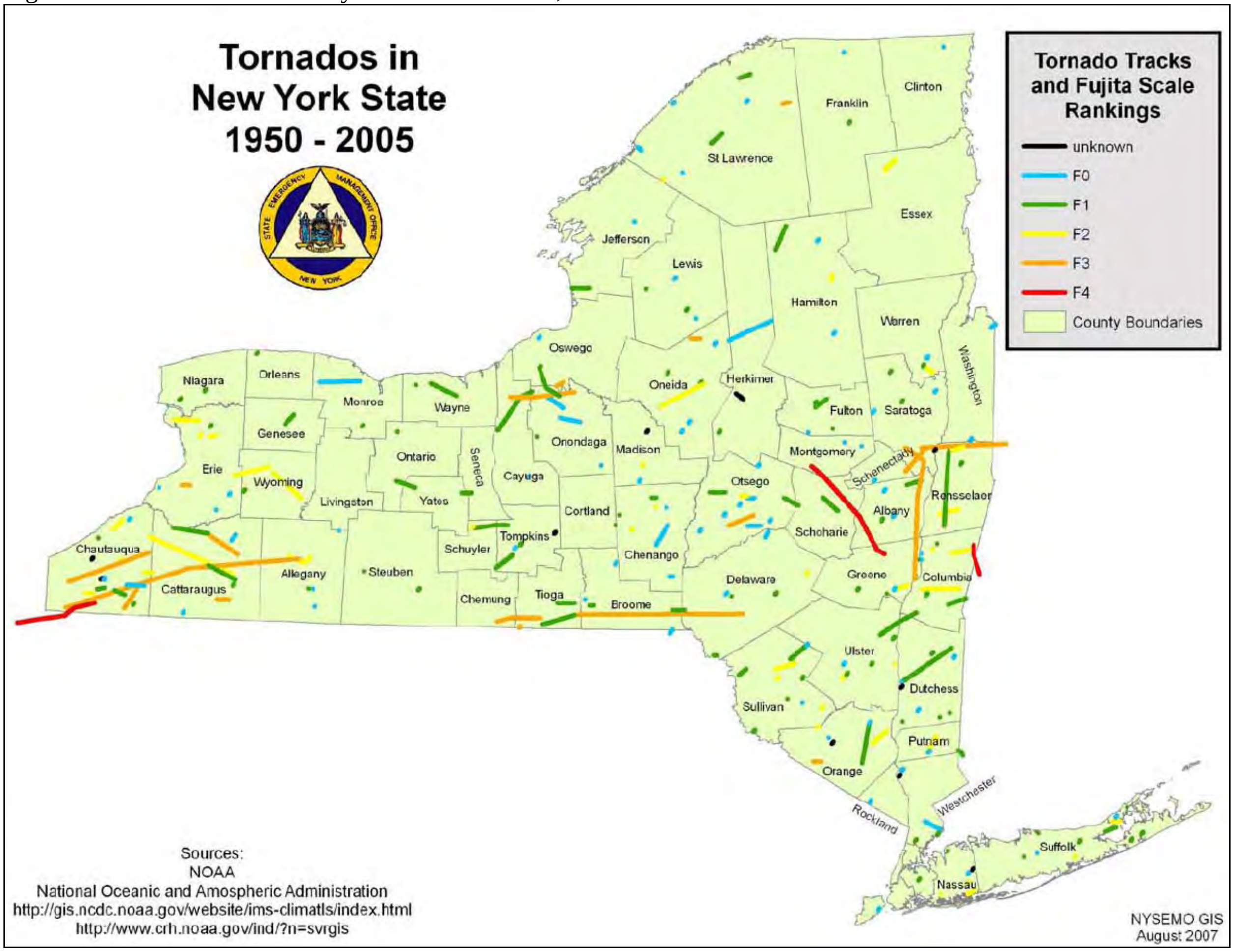


Source: FEMA, 2006

Note: The black circle indicates the approximate location of Greene County. Greene County experiences between 1 and 15 tornadoes per 3,700 square miles.

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, New York ranks 35th (The Disaster Center, 2007). New York State has a definite vulnerability to tornadoes and can occur, based on historical occurrences, in any part of the State. According to Figure 5.4.2-8, New York State experiences between 0 and 15 tornadoes per 3,700 square miles and since 1950. The State has experienced 359 tornadoes, ranging from F0 to F4 on the Fujita-Pearson Tornado Intensity Scale. Every county in New York State has experienced a tornado between 1950 and 2007 (NYSDPC, 2008) (Figure 5.4.2-8).

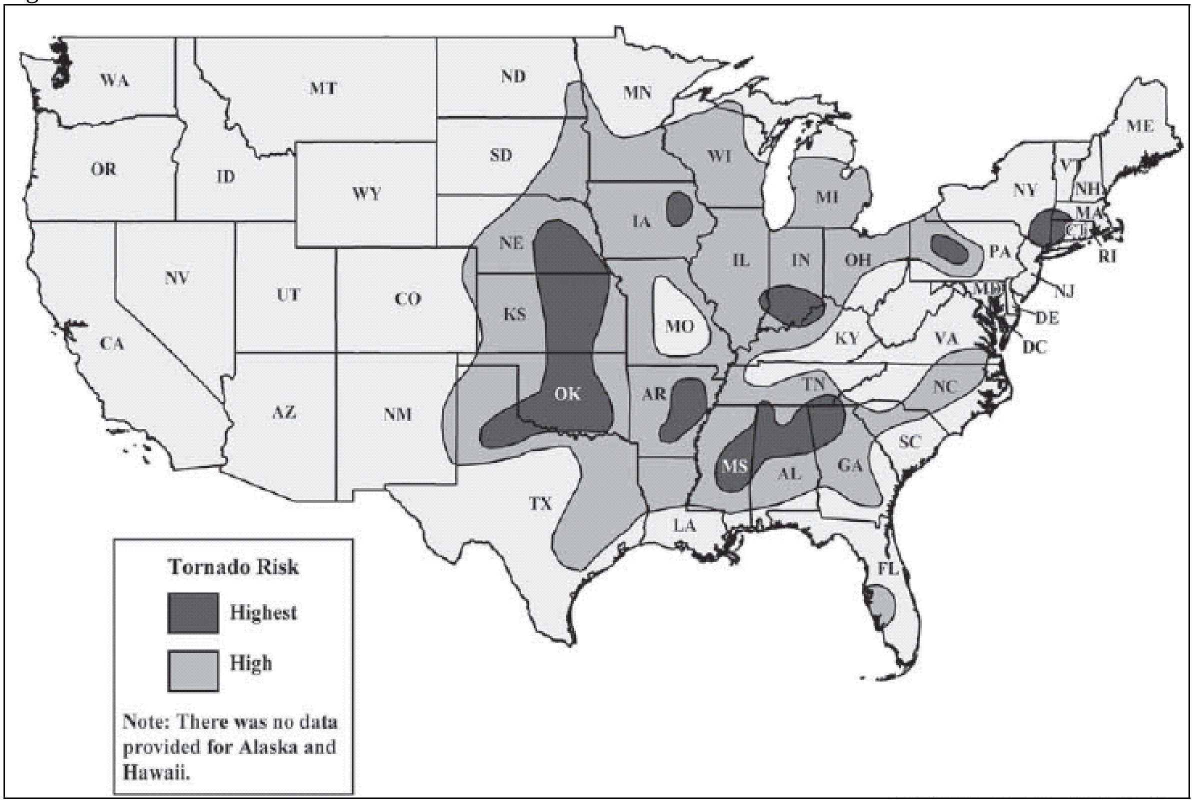
Figure 5.4.2-8. Tornado Activity in New York State, 1950-2005



Source: NYSDPC, 2008

Figure 5.4.2-9 indicates that a majority of the State, with the exception of the southeastern section (Mid-Hudson Region), has an overall low risk of tornado activity, which includes portions of Greene County. Details regarding historical tornado events are discussed in the next section (Previous Occurrences and Losses) of this profile.

Figure 5.4.2-9. Tornado Risk in the U.S.



Source: NYS DPC, 2007
Note: Greene County is shown has having a high risk and highest risk of tornado occurrences.

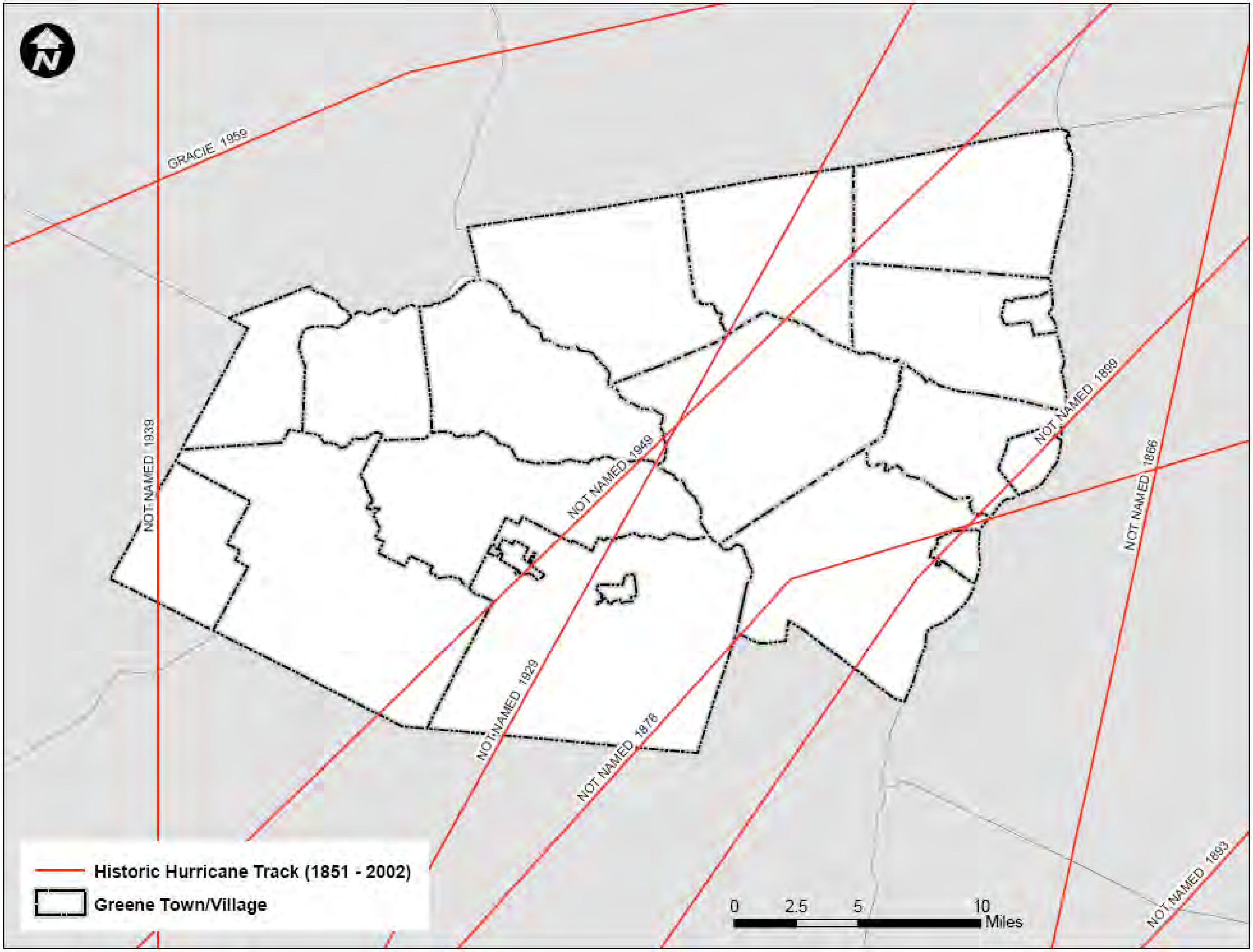
Hurricanes / Tropical Storms

Due to Greene County's inland location, hurricanes do not appear to make direct landfall on the mitigation study area. However, the County has been known to experience the indirect landward effects, including high winds, heavy rains, and major flooding associated with hurricane and/or tropical storm events. Hurricanes and tropical storms can impact New York State from June to November, the official eastern U.S. hurricane season. However, late July to early October is the period hurricanes and tropical storms are most likely to impact New York State, due to the coolness of the North Atlantic Ocean waters (NYSDPC, 2008). Figure 5.4.2-10 illustrates the historic hurricane tracks near Greene County from 1851 to 2002.

From 1903 to 1989, 24 hurricanes and numerous tropical storms have crossed over New York State. The vast majority of these storms have been over the eastern part of the State, specifically in the southeastern corner. This area includes the New York City metropolitan area and the mid and lower Hudson Valley areas. These areas comprise approximately 61-percent of New York State's population (NYSDPC, 2008).

Multiple sources have indicated that Greene County has been impacted by many hurricanes, tropical storms and tropical depressions. The County has felt the direct and indirect landward effects associated with several hurricanes and tropical storms in recent history, such an unnamed hurricane in 1878, and unnamed tropical depression in 1939 and an unnamed tropical storm in 1949.

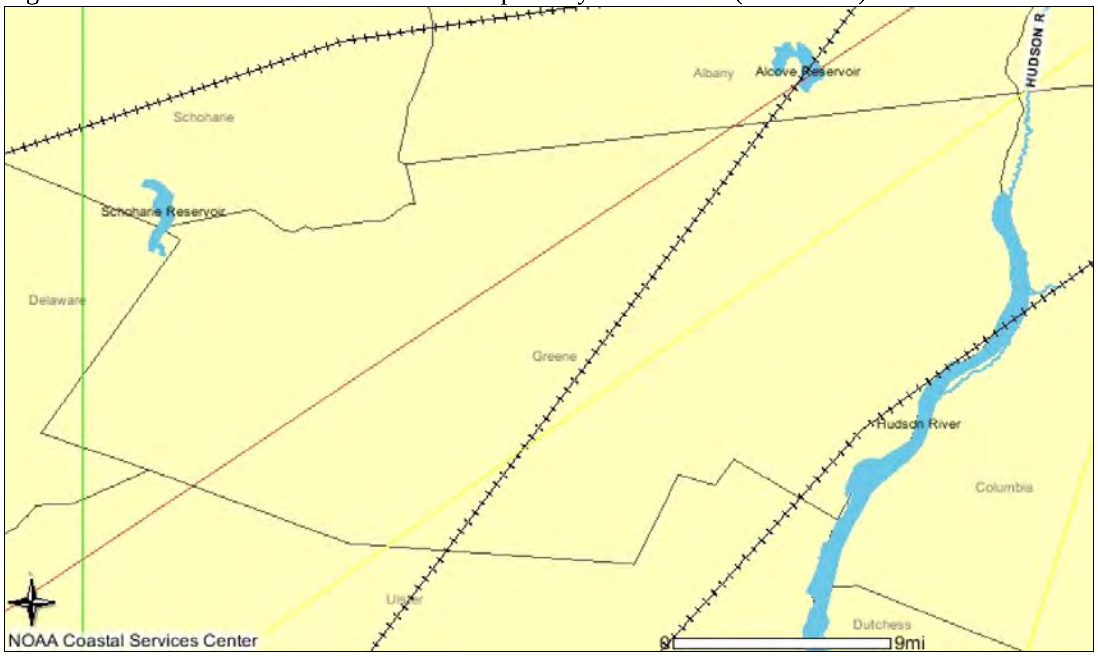
Figure 5.4.2-10. Historic North Atlantic Tropical Cyclone Tracks, 1851-2002



Source: NOAA, 2003

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 1851 to 2006. Figure 5.4.2-11 displays tropical cyclone tracks for Greene County; however, the associated names for some of these events are unknown. Between 1851 and 2006, Greene County has experienced 43 tropical cyclone events. These events occurred within 65 nautical miles of the County (NHC, 2006).

Figure 5.4.2-11. Historical North Atlantic Tropical Cyclone Tracks (1851-2006)



Source: NHC, 2006

Note: —— = Unnamed Category 1 Hurricane, 1878

+++ = Unnamed Extra-tropical storm, 1929

—— = Unnamed Tropical Storm, 1949

Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with severe storms throughout New York State and Greene 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.

Between 1955 and 2007, FEMA declared that New York experienced 39 severe storm-related disasters classified as one or a combination of the following disaster types: severe storms, hurricane (Ivan-2004, Floyd-1999, Bob-1991, Gloria-1985, Belle-1976, Agnes-1972), coastal storms, flooding, high tides and heavy rain (FEMA, 2007). Of those events, multiple sources, including FEMA, indicated that Greene County was declared a disaster area as a result of seven severe storm events. FEMA couples some disasters as severe storms and flooding events; therefore, those severe storm disasters that are also listed as flooding events have been discussed in Section 5.4.1 (Flood) as well. Table 5.4.2-5 summarizes the FEMA Presidential Disaster (DR) or Emergency Declarations (EM) for severe storm events in Greene County.

Table 5.4.2-5. Presidential Disaster Declarations for Severe Storm Events in Greene County

Type of Event*	Date**	Declaration Number	Cost of Losses (approximate)***
Hurricane / Floods	August 1955	DR-45	New York State experienced property damage, road closures, 4 deaths, and damages in the millions (NYSDPC). The Schoharie Creek at Prattsville had a water discharge of 25,100 cfs. This event was also considered a major flood event in the Batavia Kill watershed. Losses in Greene County are unknown.
Severe Storms and Flooding	January 1996	DR-1095	New York State experienced between $100 and $160 M in eligible damages, road closures, closed businesses, and 10 deaths (NYSDPC and GCSWCD). New York State received $16.7 M in individual assistance and $103.7 M in public assistance. NOAA-NCDC and SHELDUS indicate that Greene County experienced approximately $10 M in flood damages. USGS indicated, through information provided by FEMA, that Greene County received approximately $916 K in individual disaster aid and $4.4 M in public assistance (1997 USD).
Hurricane Floyd (Hurricane Floyd/Tropical Storm Floyd)	September 1999	DR-1296	New York State experienced approximately $62.2 M in eligible damages as a result of property damage and debris accumulation (NYSDPC). NOAA-NCDC and SHELDUS indicate that Greene County experienced approximately $3 M in flood damages. As of December 6, 1999, FEMA indicated that Greene County was approved for over $121 K in public assistance. In Cairo, 12.21 inches of rainfall was recorded (the most associated with the storm). This event created unstable conditions along many rivers and streams throughout County and exacerbated the instability and degradation that was initially created during the January 1996 flood.
Severe Storms	May - September 2000	DR-1335	New York State experienced approximately $34.6 M in eligible damages (NYSDPC). NOAA-NCDC and SHELDUS indicate that Greene County experienced nearly $115 K in flood damages from all storms that occurred during this time period (particularly from a Nor'Easter on June 6, 2000).
Severe Storms, Tornadoes, and Flooding	July - August 2003	DR-1486	New York State experienced approximately $23 M in eligible damages as a result of property damages and road closures (NYSDPC). More than $5.3 M in disaster aid has been approved for the State. NOAA-NCDC and SHELDUS indicated that Greene County experienced nearly $1.1 M in tornado damages.

Type of Event*	Date**	Declaration Number	Cost of Losses (approximate)***
Severe Storms and Flooding	April 2005	DR-1589	New York State experienced approximately $66.2 M in eligible damages (NYSDPC). NOAA-NCDC and SHELDUS indicated that Greene County experienced approximately $1.3 M in flood damages. The floodwaters overflowed creeks and tributaries, uprooted trees, destroyed roadways and many private properties and created the need for a few evacuations in Leeds. Over 40 roads throughout the County were closed. Many homes and businesses suffered significant damage, particularly in and around Tannersville and Jewett. As of September 14, 2005, more than $34.9 M in disaster aid has been approved for the State. The Greene County Department of Emergency Services indicated that as of June 1, 2005, FEMA approved over $2.2 M in public assistance reimbursements for various restoration and mitigation project costs generated as a result of flood damages during this event; particularly in the Towns of Hunter, Jewett and Tannersville. However, the September 14, 2005 press release indicated that FEMA only approved $1.1M in public assistance reimbursements to the County, for the Towns of Cairo, Coxsackie, Durham, Greenville, Halcott, Hunter, Jewett, Lexington, New Baltimore, Prattsville and Windham; the Villages of Catskill, Hunter and Tannersville; and the East Durham, Lexington and Palenville fire departments.
Severe Storms and Flooding	June / July 2006	DR-1650	This event was the largest and most costly natural disaster that New York State encountered since Hurricane Agnes in 1972. Resulted in a Disaster Declaration for 19 New York State counties (DR-1650). New York State experienced approximately $246.3 M in eligible damages (NYSDPC). As of December 29, 2006, more than $227 M in disaster aid was approved for the State. The Greene County Department of Emergency Services indicated that as of August 25, 2006, FEMA approved over $609 K in public assistance reimbursements for various restoration and mitigation project costs generated as a result of flood damages during this event; particularly in the Towns of Catskill and Greenville. Greene County received between 3 and 8 inches of rain from this event. Law enforcement personnel reported that several roads in Greene County were closed in and near the Towns of Catskill, Cairo and Haines Falls due to flooding. Part of Route 23-A remained closed between Palenville and Haines Falls, where a retaining wall gave way.

Type of Event*	Date**	Declaration Number	Cost of Losses (approximate)***
Severe Storms and Inland and Coastal Flooding (also identified as a Nor'easter)	April 2007	DR-1692	New York State experienced between $12.8 and $60 M in eligible damages (NYSDPC; Alarcon-The Daily Mail). The Greene County Department of Emergency Services indicated that preliminary storm damage totals eligible for federal public assistance for the County totaled approximately $472 K, with the Town of Cairo and Village of Catskill experiencing the most losses. Preliminary storm damage totals for individual assistance in the County totaled $111 M, with the Town and Village of Catskill experiencing the most losses, totaling approximately $110 M. Individual assistance losses to the County were denied by FEMA (Greene County Department of Emergency Services). Other sources indicate that final losses eligible for public assistance were estimated at $1.3 M as a result of damage, response and debris removal costs throughout the County. Final losses to homeowners were tallied at $547 K (Alarcon – The Daily Mail). The different sources cite various monetary loss estimates, making the total losses experienced by the County unclear. More than $61 M in Federal disaster aid has been approved for the State. As of July 11, 2007, public assistance to Greene County totaled $58 K. The latest public assistance details were not made available through the materials reviewed for this plan. Additionally, a landslide occurred along Warren Stein Road in Cairo.

Source(s): FEMA, 2008; NYSDPC, 2008; Hazards & Vulnerability Research Institute (SHELDUS), 2008; NCDC, 2008; NYSEMO, 2006; Greene County Department of Emergency Services

* The 'Type of Event' is the disaster classification that was assigned to the event by FEMA.

** Represents the date of the event

Note (1): Dollars rounded to nearest thousand. Recorded losses indicate the dollar value of covered losses paid, as available through the public records reviewed. Some of these events overlap with events shown under the Flood and Severe Winter Storm hazard profiles of this Plan.

Based on all sources researched, many notable severe storm events have impacted Greene County. All other severe storm events are identified in Table 5.4.2-6 below; however, severe storm documentation for New York State is extensive and, therefore, not all sources may have been identified or researched. Hence, Table 5.4.2-6 may not include all events that have occurred throughout the region.

Table 5.4.2-6. Severe Storm Events between 1878 and 2007

Event Name / Date	Location	Losses / Impacts	Source(s)
Hurricane October 23, 1878	Multi-State	Heavy rain and wind affected the east coast. At the time, the storm was the most severe the eastern coast has experienced in several years. Many buildings were blown down or unroofed. Boats were sunk. The hurricane hit Greene County as a Category 1.	New York Times, National Atlas
Heavy Rain November 19, 1899	Athens	Many low-lying areas inundated. Number of homes collapsed, railroad was partially washed away, many drownings, and overall, an enormous amount of damage.	New York Times
Hurricane / Floods August 12-19, 1955 (Remnants of Hurricane Diane) (FEMA DR-45)	Southeastern New York State	See FEMA Disaster Declarations (Table 5.4.2-5)	NYSDPC, FEMA, USGS
Remnants of Hurricane Donna August 29 – September 14, 1960	Multi-State	In the Batavia Kill watershed this event was considered to be the most damaging on record, causing over $750 K in damages (1960 dollars) (GCSWCD). The storm resulted in damage to over 75 residences ($100 K), 27 businesses ($130 K) and state, county, and town roads ($425 K). In addition, damages occurred to the Windham Country Club, two churches, Windham Ashland School and utilities. During the event, seven bridges were lost in the Batavia Kill Watershed. The flood also contaminated the Windham water system resulting in a period of boil water advisory. In Ashland, Fire Chief Paul Alle was swept away by the rushing waters of the Batavia Kill. The Schoharie Creek at Prattsville had a water discharge of 49,900 cfs and crested 18.35 feet (6.35 feet above 12-foot flood stage) from this flood event.	NYSDPC, GCSWCD, AHPS, USGS, FEMA
Tornado (F3) June 16, 1974	Athens	F3 tornado near Athens created $2.5 M in property damages.	NOAA-NCDC
Tornado (F1) April 2, 1977	Hunter	F1 tornado near Hunter created $25 K in property damages.	NOAA-NCDC
Tornado (F3-F4) July 10, 1989	Multi-County	F3 to F4 tornado hit Montgomery, Schoharie, Albany and Greene Counties. F4 hit near Greenville and Durham.	NOAA-NCDC, Grazulis, NWS, Hazards and Vulnerability

Event Name / Date	Location	Losses / Impacts	Source(s)
"Northeastern U.S. Tornado Outbreak"			Research Institute (SHELDUS)
Lightning August 28, 1994	Freehold (Greenville)	$500 K in damages	NOAA-NCDC
Lightning May 22, 1995	Athens	A bolt of lightning struck a mobile home and caused extensive damage to the home and its contents. Approximately $20 K in damages.	NOAA-NCDC
TSTM July 14-15, 1995 "The Ontario-Adirondack Derecho"	Multi-State	Strong TSTMs produced severe weather, bringing 90 mph winds to certain areas. The system produced several weak tornadoes in parts of Ontario. As it entered New York State, winds gusted to over 100 mph at several points. About 900,000 acres of forest land was damaged. New York State had five deaths, 11 injuries and almost $400 M in damages. Greene County had approximately $60 K in property damage due to strong winds. Most damage was observed in Coxsackie, Greenville, Haines Falls, and New Albany.	SPC, NOAA-NCDC, Hazards and Vulnerability Research Institute (SHELDUS)
Severe Storms and Flood January 18-20, 1996 (FEMA DR-1095) "Deluge of 1996"	Northeastern U.S.	See FEMA Disaster Declarations (Table 5.4.2-5)	FEMA, NOAA-NCDC, NYS HMP, NWS, Lumia (USGS WRIR 97-4252), Hazards & Vulnerability Research Institute (SHELDUS)
TSTM / Hail June 4-8, 1996	Multi-County	Three-quarter inch hail and damaging winds accompanied TSTMS in Greene and Dutchess Counties. Heavy rain affected parts of western Massachusetts, central New York, western Pennsylvania and northwestern Maryland. Damage was widespread throughout New York State and surrounding areas.	NRCC, NOAA-NCDC, Hazards and Vulnerability Research Institute (SHELDUS)
Lightning August 24, 1996	Lexington	Lightning struck a house, which caused a fire and destroyed the home. Approximately $60 K in property damage.	NOAA-NCDC
TSTM / Winds May 31, 1998 "Tornado Outbreak"	Multi-County	Several lines of severe TSTMs formed in eastern New York State. The series of storms resulted in 3 tornadoes and storm damage in every county. Widespread power outages occurred throughout eastern New York State. Strong winds downed power lines, power poles and trees. Some counties were declared disaster areas by Governor Pataki. Approximately $50 K in property damage in Greene County. Greenville had quarter-sized hail.	NOAA-NCDC, NWS, Stewart, Hazards and Vulnerability Research Institute (SHELDUS)

Event Name / Date	Location	Losses / Impacts	Source(s)
TSTM / Lightning May 25, 1999	Countywide (Catskill)	Strong TSTMs hit Columbia and Greene Counties during the afternoon. The storms became severe and produced gusty winds. Lightning struck a church in Catskill and was heavily damaged. Approximately $50 K in property damage.	NOAA-NCDC
TSTM / Flood July 3-6, 1999	Multi-County	On July 3rd, cluster of TSTMs developed over the Great Lakes and moved east towards the Mohawk Valley and Capital Region. The storms produced isolated damage, which included fallen trees, downed power lines, and power outages. On July 4th, two more clusters of TSTMs developed and moved into the Mohawk Valley, brining torrential rain and strong winds. Many areas were flooded. Heavy rains measuring up to 4 inches washed out six roads in Halcott (Greene County). Approximately $49 K in damages in Greene County.	NOAA-NCDC
Remnants of Hurricane/Tropical Storm Floyd September 16, 1999 (FEMA DR-1296)	Multi-State	See FEMA Disaster Declarations (Table 5.4.2-5)	NYSDPC, GSCWCD, AHPS, USGS, NWS, Hazards and Vulnerability Research Institute (SHELDUS), NOAA-NCDC, New York State Floodplain and Stormwater Managers Association
High Wind November 2, 1999	Multi-County	The front of a storm produced high winds over eastern New York State. The winds brought down many trees and power lines. Wind gusts of 80 mph were reported in Platte Clove (Hunter). Approximately $35 K in damages.	NOAA-NCDC
Severe Storm May – September 2000 (FEMA DR-1335)	Multi-County	See FEMA Disaster Declarations (Table 5.4.2-5)	Governor Pataki Press Release, FEMA, NYSDPC, NOAA-NCDC, Hazards and Vulnerability Research Institute (SHELDUS)
TSTM / Hail / Lightning June 20, 2001	Multi-County	An unstable air mass produced scattered severe TSTMs across eastern New York State. Most storm reports indicate hail was accompanied with the storms. Hail was reported in Albany, Greene and Columbia Counties. In Greenville, quarter size hail was reported. Coxsackie had three different hail incidents, ranging from quarter size to	NOAA-NCDC

Event Name / Date	Location	Losses / Impacts	Source(s)
		baseball size hail. About 80 cars were damaged in Coxsackie. Catskill had three separate storm events that produced hail ranging from dime size to ping pong ball size. Cairo reported dime size hail. The hail destroyed 99% of the apple and peach orchards in Climax. Lightning from the storms struck two houses in Athens and caused a fire in both homes. $370 K in property damage and $400 K in crop damage.	
High Wind September 11, 2002	Multi-County	Strong winds, with speeds of up to 67 mph, affected eastern New York State. Many trees were down in Greene County and surrounding counties. Approximately $118 K in property damage.	NOAA-NCDC
TSTM August 14-16, 2002	Multi-County	Numerous TSTMs move across eastern New York State, some being severe at times. Many trees were reported down in Windham and Greenville. A tree near Greenville crashed through a roof of a house. Lightning struck a nearby barn and resulted in a fire. Approximately $140 K in property damage.	NOAA-NCDC
Severe Storms, Tornadoes and Flood July – August 2003 (FEMA DR-1486)	Multi-County	See FEMA Disaster Declarations (Table 5.4.2-5)	FEMA, NOAA-NCDC, NOAA, NWS, Hazards & Vulnerability Research Institute (SHELDUS), NYS DPC
Remnants of Hurricane Ivan September 18, 2004	Multi-County	Greene County suffered many road closures in Windham, Climax, Jewett, Catskill, Coxsackie, Leeds, Lexington, Prattsville, and Kiskatom. In Catskill, the Catskill Creek flooded Cauterskill Road, trapping a person in their car. Schoharie Creek at Prattsville had a water discharge of 26,500 cfs and crested 14.11 feet (2.11 feet above 12-foot flood stage) from this flood event. On the West Kill at the West Kill gage, storm flow responded to precipitation very rapidly, with streamflow increasing from about 150 cfs to nearly 3,000 cfs within 24 hours. The Batavia Kill exceeded its flood stage of 5.0 feet, cresting at 7.47 feet at the Red Falls gage. The Bear Kill exceeded its flood stage of 5.0 feet, cresting at 7.82 feet at the Prattsville gage. This storm was the highest recorded peak for this water year and one of the highest for the entire period of record at this location.	NOAA-NCDC, GCSWCD, USGS
Severe Storm	Multi-State	See FEMA Disaster Declarations	NCDC, NWS, FEMA, NYS

Event Name / Date	Location	Losses / Impacts	Source(s)
April 2-4, 2005 (FEMA DR-1589)		(Table 5.4.2-5)	DPC, NOAA-NCDC, Hazards & Vulnerability Research Institute (SHELDUS), NYSEMO
Remnants of Tropical Cyclone Tammy October 7-9, 2005	Multi-County	Rainfall amounts in Greene County include: 7.63 inches in Catskill, 6.64 inches in East Jewett and 4.87 inches in Cairo.	NWS
Severe Storms and Flood June 25 - July 10, 2006 (FEMA DR-1650)	Multi-State	See FEMA Disaster Declarations (Table 5.4.2-5)	FEMA, NOAA-NCDC, NWS, NYSEMO, NYSDPC, Eyewitness News, USGS, NEWS10, NOAA, Greene County Department of Emergency Services, Alarcon (The Daily Mail)
Severe Storms / Inland and Coastal Flood April 14-17, 2007* (also identified as a Nor'easter) (FEMA DR-1692)	Multi-State	See FEMA Disaster Declarations (Table 5.4.2-5)	FEMA, USGS, Greene County Department of Emergency Services, Macko (The Daily Mail), Alarcon (The Daily Mail)

Note (1): The intensity of tornado events to affect Greene County is measured by the Fujita Scale in this Table, which was decommissioned on February 2007. NOAA-NCDC storm query indicated that Greene County has experienced 189 severe storm events between January 1, 1950 and February 28, 2008 (including Thunderstorms, Hail, Wind, Hurricane, Lightning, and Tornado events). However, not all of these events were identified in this table due to a lack of detail and/or their minor impact upon the County.

Note (2): 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.

* According to many sources, these events were known as Nor'Easters, therefore, they are not discussed further in this hazard profile and are further mentioned in Section 5.4.3 (Severe Winter Storm) and the flooding impact of the events are mentioned in Section 5.4.1 (Flood)

AHPS Advanced Hydrologic Prediction Service
CBS Central Broadcasting Station
DR Federal Disaster Declaration
F Fujita Scale (F0 – F5)
FEMA Federal Emergency Management Agency
HMP Hazard Mitigation Plan
K Thousand ($)
M Million ($)
NCDC National Climate Data Center
NOAA National Oceanic Atmospheric Administration
NWS National Weather Service
NYS New York State
NYS DPC New York State Disaster Preparedness Commission
NYSEMO New York State Emergency Management Office
NRCC Northeast Regional Climate Center
OEM Office of Emergency Management
SHELDUS Spatial Hazard Events and Losses Database for the U.S.
SPC Storm Prediction Center (NOAA)
TSTM Thunderstorm
U.S. United States
USD U.S. Dollars
USGS U.S. Geological Survey
WRIR Water Resources Investigation Report

Further descriptions of select severe storm events that have impacted Greene County are provided below for selected events where details regarding their impact (where available). These descriptions are provided to give the reader a context of the severe storm events that have affected the County and to assist local officials in locating event-specific data for their municipalities based on the time and proximity of these events. Many severe storm events resulted in major flooding throughout the County; therefore, the flood impacts of these events are further mentioned in Section 5.4.1 (Flood). Also, certain severe storm events have been classified as Nor'Easters; therefore, they are not discussed further in this hazard profile and are further included in Section 5.4.3 (Severe Winter Storm).

Monetary figures within the following event descriptions were U.S. Dollar (USD) figures calculated during or within the approximate time of the event (unless present day recalculations were made by the sources reviewed). If such an event would occur in the present day, monetary losses would be considerably higher in USDs as a result of increased inflation.

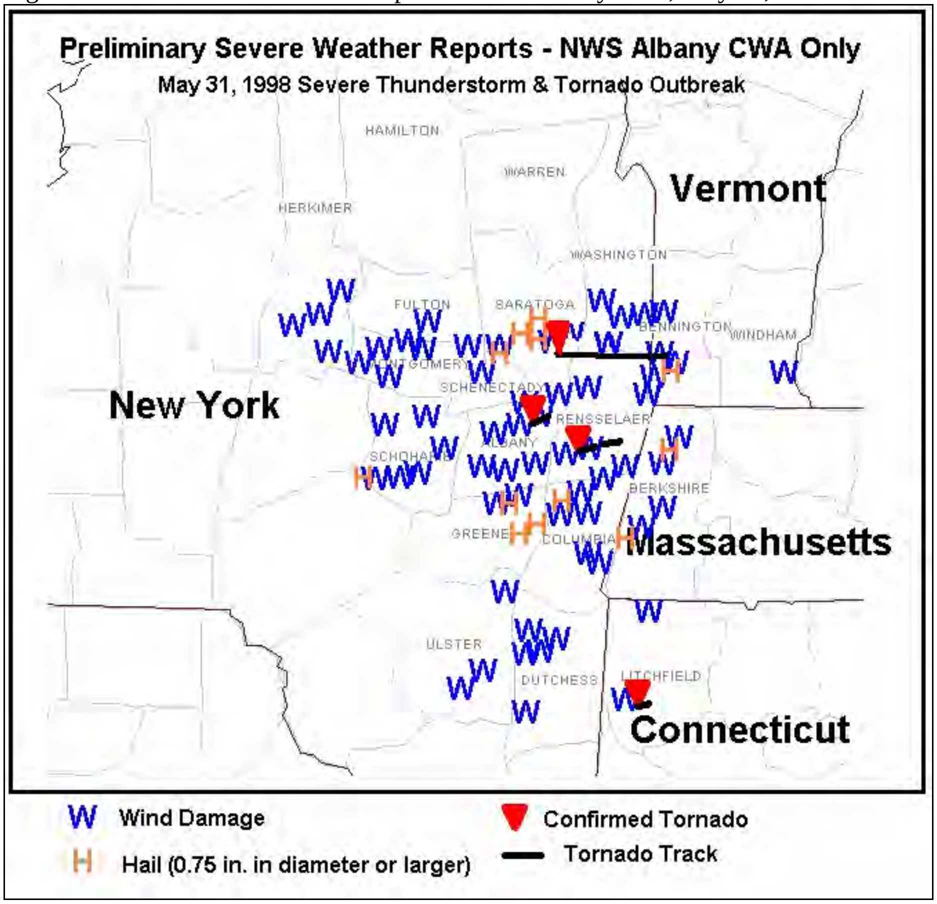
August 29 - September 14, 1960 (Hurricane Donna): This event holds the record for retaining "major hurricane" status (Category 3 or greater on the Saffir-Simpson Hurricane Scale) in the Atlantic Basin for the longest period of time on record (a total of 17 days). The storm affected every state along the East Coast, producing hurricane-force winds (up to 115 mph) from South Carolina to Maine (Barnes and Lyons, 2007). Fifty fatalities were reported in the U.S., with damages totaling approximately $3 billion (2004 USD) (Blake et al., 2005). Greene County experienced between 5 and 7 inches of rain.

In Greene County, the impacts of this event fell primarily within the Batavia Kill watershed. The Greene County Soil Conservation Service indicated that the storm was devastating to the Town of Windham, producing in excess of $750,000 in damages (1960 USD) to over 75 residences, 27 businesses, utilities, seven bridges, and multiple state, county, and town roads. Damages also occurred to the Windham Country Club, two churches, and the Windham Ashland School (GCSWCD, 2003). The flood impact and losses of this event are further discussed in more detail in Section 5.4.1 (Flood). Information regarding other areas throughout the County impacted from this event is limited or has not been disclosed in the materials reviewed to develop this plan. Cost estimates of property damage in Greene County were unavailable in the materials reviewed to develop this plan.

July 10, 1989 (Northeastern U.S. Tornado Outbreak): This event was a series of tornadoes which caused more then $130 million (1989 USD) in damage across the northeastern U.S. The storm system produced severe weather events that included hail up to 2.5 inches in diameter, thunderstorm winds up to 90 mph, and 17 tornadoes. More than 150 people were injured and one fatality occurred as a result of the tornado outbreak and one fatality occurred as a result of winds. Several towns in New York State and Connecticut were especially hit hard (NCDC, 2007).

In New York State, the tornado outbreak reportedly devastated areas from Montgomery County to Greene County, injuring 20 people and causing $20 million in property damages. Although the SPC archives state that this outbreak was a single tornado, other sources indicate that it was actually three or more tornadoes, each ranking F3 or F4 on the F-Scale. The first tornado to hit the area touched ground three miles east of Ames (Montgomery County), moving southeast. It then passed through the Towns of Carlisle, Howe Caverns, Central Bridge and Schoharie before lifting. The storm continued traveling southeast for 10 miles, and produced another tornado briefly near Rensselaerville. After another 10 miles, a third tornado touched down in Greenville and Surprise (Greene County) (Grazulis, 1993). Figure 5.4.2-12 shows the areas that were affected in New York State. Greene County experienced wind and hail damage. According to SHELDUS, Greene County had approximately $1.25 million in property damages, $125,000 in crop damages, and five injuries.

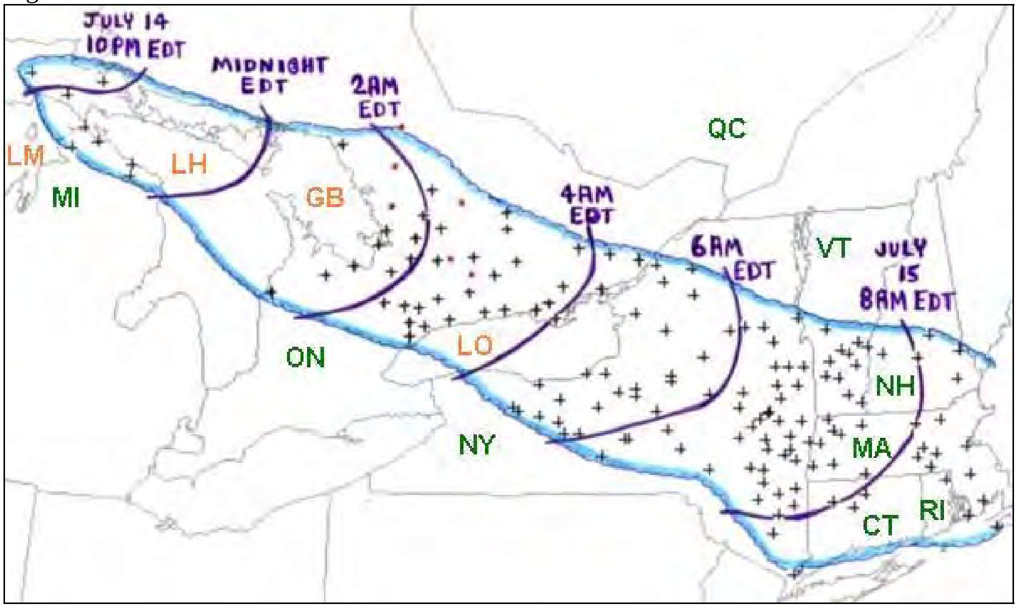
Figure 5.4.2-12. Severe Weather Reports for the Albany Area, May 31, 1998



Source: NWS, 2001

July 14-15, 1995 ("The Ontario-Adirondack Derecho"): On the evening of July 14th, thunderstorms producing severe weather were occurring over upper Michigan and adjacent portions of Ontario near Sault Saint Marie. By late evening, the storms developed into a bowing line just northwest of the Mackinac Bridge. The thunderstorm gust front hit the bridge and a gust of 90 mph was measured. Sustained winds above 80 mph continued on the bridge for several minutes, which was the beginning of the "Ontario-Adirondacks Derecho". This system caused hundreds of millions of dollars in damage, several deaths, and many injuries as it moved from the Great Lakes region to the Atlantic coast (SPC, Date Unknown). Figure 5.4.2-13 illustrates the storm path of this system.

Figure 5.4.2-13. The Ontario-Adirondack Derecho



Source: SPC, Date Unknown

Note: Curved purple lines represent the approximate locations of the "gust front". "+" symbols indicate the locations of wind damage or wind gusts above severe limits (58 mph or greater). Red dots represent tornado occurrences.

In Canada, as the system crossed northern Lake Huron and Georgian Bay, it grew in scale and the derecho winds affected a large area of southern Ontario during the early morning of July 15th. Wind gusts were calculated at 100 mph or more in some locations, causing extensive damage. Several brief tornadoes were associated with this system as well. Most of the tornadoes were weak, but a strong F2 tornado hit the Town of Bridgenorth, destroying a marina and damaging 20 homes. Particularly hard hit was a portion of south central Ontario, with some of the severe damage in the towns of Huntsville, Bracebridge, Orillia, Minden and Fenelon Falls. Power outages in these areas lasted from several days to a week. According to a report from the Insurance Bureau of Canada, this system resulted in $53 million in 1995 Canadian dollars (SPC, Date Unknown).

As the "Ontario-Adirondacks Derecho" entered New York State on July 15th, severe wind damage continued in this area. Winds were estimated to be 100 mph or greater at several points along a band from Jefferson and western St. Lawrence Counties. In the Adirondack Mountain region, over 30 campers and hikers in the area had to be removed by helicopter since their paths out of the forest were blocked by thousands of fallen trees. The NYS DEC estimated about 900,000 acres of forest were damaged with a value loss of timber over $200 million. In the more populated areas of central and eastern New York State, almost $190 million in damage was done to structures and vehicles. Many mobile homes were overturned and numerous homes and businesses were damaged. Several hundred thousands of people were without power due to the powerful derecho winds. Overall, New York State had five deaths, 11 injuries and nearly $400 million in damages (SPC, Date Unknown).

According to NOAA-NCDC and SHELDUS, Greene County suffered approximately $66,000 in property damages due to winds from the derecho. The most damage was seen in Coxsackie, Greenville, Haines Falls (Hunter), and New Albany (NCDC, 2008; Hazards and Vulnerability Research Institute, 2007).

January 18-20, 1996 (FEMA DR-1095): Unseasonably warm air ahead of a storm overspread the Northeast on January 18th and 19th. Temperatures reached the mid-50s to the mid and upper-60s. Melting snow and ice break-up during the evening of the 18th caused ice jam flooding across scattered areas of western Pennsylvania and western New York State. The storm brought over two inches of rain from northern West Virginia through Central Pennsylvania and over the Catskill Mountains in New York State. The worst of the flooding began on the 19th, due to the heavy rains causing rapid snow melt. Many drainage basins were overwhelmed and widespread flooding broke out. Thousands of people were forced to evacuate their homes in parts of Ohio, Pennsylvania, West Virginia, New Jersey, Maryland and New York (NRCC, 1996).

The storm produced damaging winds across eastern New York State, resulting in reports of downed trees, limbs, and power lines, producing $120,000 in property damage (NCDC, 2007). Overall, this event claimed 10 lives, stranded hundreds of people, damaged or destroyed thousands of homes and businesses, and closed hundreds of roads. The most severely affected region was the Catskill Mountains. More than 4.5 inches of rain fell on at least 45 inches of snow in the Catskill Mountain region during this event and caused major flooding throughout the southeastern section of New York State (Lumia, 1998; NYSDPC, 2008).

In Greene County, the severe storms downed large limbs in Surprise (Greenville), causing approximately $2,000 in property damage (NCDC, 2007). According to SHELDUS, Greene County had another $8,000 in property damage due to wind. The majority of damage was due to flooding along the major waterways of the County. The flood impact and losses of this event are further discussed in more detail in Section 5.4.X (Flood). Overall, according to NOAA-NCDC and SHELDUS, Greene County experienced approximately $10 million in total property damages from this event (NCDC, 2008; Hazards and Vulnerability Research Institute, 2007).

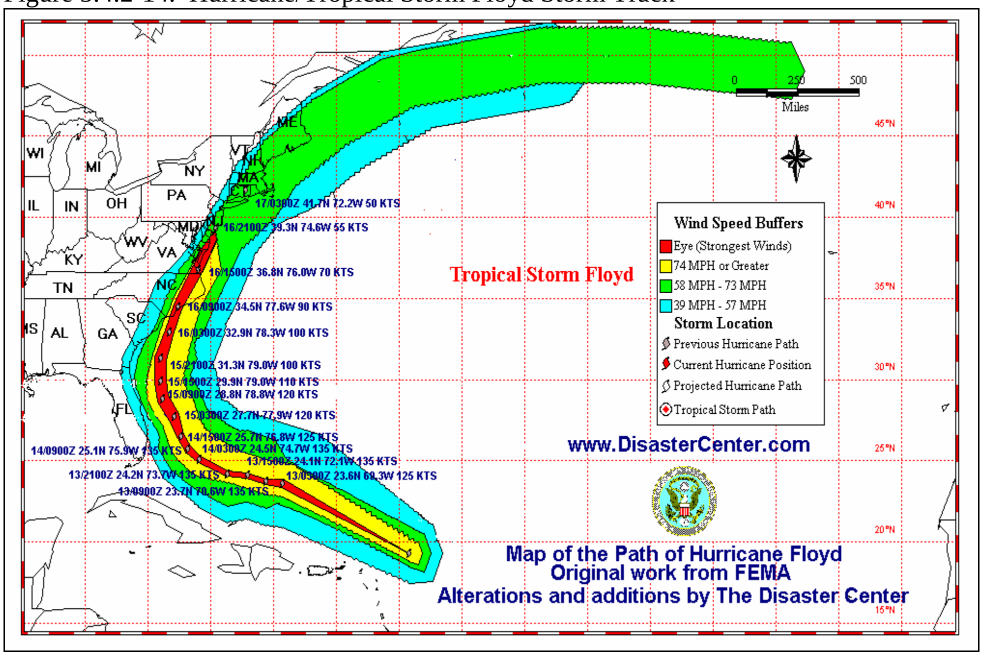
This storm resulted in a FEMA Disaster Declaration (FEMA DR-1095) on January 24, 1996. Through this declaration, the following 41 counties were declared eligible for Federal and State disaster funds: Albany, Allegany, Broome, Cattaraugus, Cayuga, Chemung, Chenango, Clinton, Columbia, Cortland, Delaware, Dutchess, Essex, Franklin, Greene, Herkimer, Jefferson, Lewis, Livingston, Madison, Montgomery, Onondaga, Ontario, Orange, Otsego, Putnam, Rensselaer, St. Lawrence, Saratoga, Schenectady, Schoharie, Schuyler, Steuben, Sullivan, Tioga, Tompkins, Ulster, Warren, Washington, Wyoming and Yates (NYSEMO, 2006; FEMA, 2008; NYSDPC, 2008). Disaster assistance for all counties affected in the State totaled approximately $16.7 million in individual assistance and $103.7 million in public assistance (1997 USD). Greene County received $916,839 in individual assistance and $4.4 million in public assistance (1997 USD) (Lumia, 1998).

June 4 – 8, 1996: Severe thunderstorms entered the region on June 4th as a cold front moved east. Up to one-inch diameter hail fell on several parts of New York State and Pennsylvania. Quarter-size hail covered the ground in parts of Maryland. The storm produced strong winds, downing trees and causing minor damage to home. It spawned a small tornado near Mt. Airy, Maryland that took down several large trees. On the 5th, unstable weather was reported in New England. Hail and gusty winds were reported in Maine and New Hampshire. On the 7th, thunderstorms blasted through northeastern Pennsylvania, downing trees and power lines. In New York State, a roof of a barn was blown off in Tioga County and a mobile home was knocked over in Columbia County (NRCC, 1996).

The storms continued on the 8th, brining three-quarter inch diameter hail and damaging winds to Greene and Dutchess Counties in New York State, due to thunderstorms. Heavy rain drenched parts of western Massachusetts, central New York State, western Pennsylvania, and northwestern Maryland (NRCC, 1996). Damage in Greene County included lightning in Palenville and wind and lightning in Coxsackie, resulting in $29,000 in property damage (NCDC, 2008; SHELDUS, 2007).

September 16-17, 1999 (Hurricane/Tropical Storm Floyd) (FEMA DR-1296): According to the NOAA NHC, this event was a large and intense storm that pounded the central and northern Bahama islands, seriously threatened Florida, struck near the coast of North Carolina and moved up the east coast of the U.S. into New England as a tropical storm. It neared the threshold of a Category 5 on the Saffir/Simpson Hurricane Scale as it approached the Bahamas, and caused a flood disaster of immense proportions in the eastern U.S., particularly from the eastern coast of North Carolina through New Jersey (Pasch et al., 1999). Much of Floyd's impact was due to heavy rainfall, creating major losses from floodwaters throughout the eastern U.S. Common rainfall totals ranged between 4 and 12 inches (NWS, 1999). Ten states were declared major disaster areas, which included Connecticut, Delaware, Florida, Maryland, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, and Virginia (NCDC, 2000). Figure 5.4.2-14 illustrates the storm track of Floyd.

Figure 5.4.2-14. Hurricane/Tropical Storm Floyd Storm Track



Source: The Disaster Center, 1999

As the remnants of Floyd passed by eastern New York State, strong winds pummeled the region with numerous reports of power outages and downed trees. Some of the reported downed trees were the result of the soft ground due to the excessive amount of rain (NWS, 1999). According to the NWS, rainfall totals for Greene County ranged between 6.9 inches (Prattsville) to 12.21 inches (Cairo) (NWS, 1999). Greene County's damage was mainly a result of flooding. The flood impact and losses of this event are further discussed in more detail in Section 5.4.1 (Flood).

This storm resulted in a FEMA Disaster Declaration (FEMA DR-1296) on September 19, 1999. Through this declaration, the following 15 counties were declared eligible for Federal and State disaster funds: Albany, Dutchess, Essex, Greene, Nassau, Orange, Putnam, Rensselaer, Rockland, Schenectady, Schoharie, Suffolk, Ulster, Warren and Westchester counties (NYSEMO, 2006; FEMA, 2008; NYSDPC, 2008). Disaster assistance for all counties affected in the State has not been clearly documented. However, as of December 6, 1999, FEMA and the State have approved 69 Disaster Housing grants throughout Greene County, totaling $121,485 (FEMA, 2003).

May through September 2000 (FEMA DR-1335): Between May and September 2000, multiple severe storm events occurred throughout New York State, resulting in significant flooding and over $34.6 million in damage throughout the State. The flood impact and losses of this event are discussed in more detail in Section 5.4.1 (Flood).

The first series of storms began on May 18, 2000. A strong cold front crossed eastern New York State, brining very strong winds. This system spawned a line of thunderstorms, producing the largest outbreak of severe weather across eastern New York State in nearly two years. The vast majority of damage was from thunderstorm winds, along with hail damage and two confirmed tornadoes. Thunderstorm winds knocked down large trees and powerlines in Albany, Columbia, Greene, Montgomery, Saratoga, Schoharie, and Ulster Counties. In Greene County, shingles were blown off a roof in Cairo (NOAA-NCDC, 2007). According to NOAA-NCDC and SHELDUS, Greene County had approximately $110,000 in property damage due to this storm (NCDC, 2008; Hazards & Vulnerability Research Institute, 2007).

The second series of storms hit the area on June 2, 2000. A powerful cold front moved across eastern New York State, brining an unstable air mass in front of a cold front. This generated straight line thunderstorm winds and hail and caused widespread severe weather damage. Overall, over 40 separate events of severe weather were reported. In Greene County, one-inch diameter hail was reported in Catskill. According to NOAA-NCDC and SHELDUS, Greene County had approximately $23,000 in property damage from this storm (NCDC, 2008; Hazards & Vulnerability Research Institute, 2007).

On June 6, 2000, an area of low pressure developed over the Delmarva Peninsula. The storm tracked up the coast and became a full-blown Nor'Easter. Tropical moisture was trapped and produced a very heavy rainstorm across eastern New York State, mainly from Albany southward. Albany had a total of 3.5 inches fall on June 6th, while heavier rain fell across the Catskills with as much as 5.77 inches falling in East Jewett (Greene County). Many roads and bridges were closed throughout Greene County due to flooding. According to NOAA-NCDC and SHELDUS, Greene County had approximately $115,000 in property damage from this storm, mainly related to flooding (NCDC, 2008; Hazards & Vulnerability Research Institute, 2007).

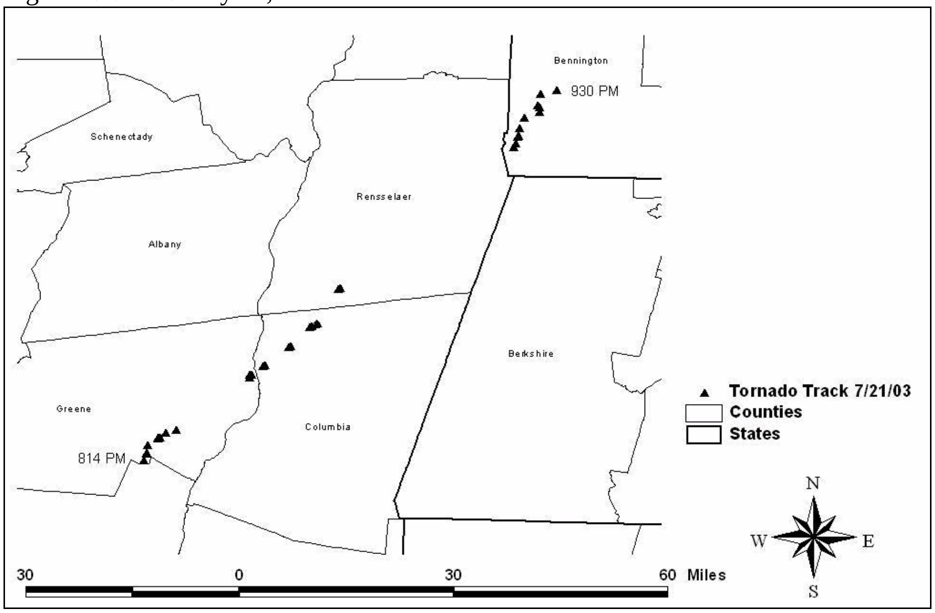
On August 3, 2000, numerous thunderstorms developed, producing dime size hail to a couple of New York State counties. Many other reports were in relation to wind damage. Many trees and power lines were down in several counties. In Greene County, a man was struck my lightning at the Earlton Hill Campground in Coxsackie. Cost estimates of property damage in Greene County were unavailable in the materials reviewed to develop this plan.

These storms resulted in a FEMA Declaration Disaster (FEMA DR-1335) on July 21, 2000. Through this declaration, the following 27 counties were declared eligible for Federal and State disaster funds: Albany, Allegany, Cattaraugus, Columbia, Dutchess, Erie, Essex, Greene, Herkimer, Lewis, Livingston, Madison, Montgomery, Niagara, Oneida, Onondaga, Orleans, Otsego, Rensselaer, Schenectady, Schoharie, Steuben, Sullivan, Tioga, Tompkins, Ulster and Yates (FEMA, 2003). According to the Schoharie Creek SMP, Greene County received approximately $176,596 in disaster aid from this event (GCSWCD, 2007).

July 21 – August 13, 2003 (FEMA DR-1486): A series of slow-moving thunderstorms accompanied by torrential rainfall caused a tornado outbreak and flash flooding throughout much of New York State (including Greene County). This system produced a significant severe weather outbreak and the largest tornado outbreak since May 1998. The flood impact and losses of this event are further discussed in more detail in Section 5.4.1 (Flood).

The first line of thunderstorms worked across the region during the afternoon of July 21st. This line of storms produced spotty wind damage and downed trees and wires across Albany, Greene, Rensselaer, Schenectady, Saratoga and Schoharie Counties. The heavy rainfall caused torrential rains and flash flooding in some areas. During the evening hours of July 21st, a stronger line of storms moved east from central to eastern New York State. One cell broke loose from the line of thunderstorms and became a supercell as it reached the mid-Hudson Valley, spawning a significant tornado. The tornado initially touched down in southeastern Greene County and produced a discontinuous path of 17 miles in the County, 12.2 miles in northwestern Columbia County and 4.8 miles in southern Renesselaer County. The tornado left a swath of destruction, including hundreds of trees uprooted and power and telephone wires down. Many roads in these counties were impassable due to debris (NCDC, 2008). Figure 5.4.2-15 illustrates the path of the tornado.

Figure 5.4.2-15. July 21, 2003 Tornado Track



Source: NOAA, 2003

As the storm moved into Greene County, an F1 tornado (about 50 yards wide and a half-mile long) touched down in Palenville, near Pennsylvania Avenue. The tornado then touched down in the hamlet of Kiskatom, located in the town of Catskill. The storm damage in Kiskatom was rated F2, with a path width of 100 yards and a length of over one mile. Several houses were damaged beyond repair and several mobile homes were destroyed. Seven people were injured as a result of this tornado in Kiskatom (NOAA, 2003; Smith, 2003).

The tornado path continued into Athens, where it was rated between an F0 and an F1. It had a path width of 50 yards and a length of one-half mile. In Coxsackie, the tornado was an F1 and caused damage to trees and a manufactured home. The total discontinuous path length of tornadic damage in Greene County was approximately 17 miles (NOAA, 2003). At the height of the storm, 6,000 residents in Greene County were without power. The areas that saw the most damage from this storm was Pennsylvania Avenue in Palenville; Route 23 in Kiskatom; the flats at Lasher's Farm on Cauterskill Road; Paul Saxe Road; and Vedder Road. In Catskill, firefighters responded to reports of downed wires and trees, some on Woodland Avenue (Smith, 2003). According to NOAA-NCDC and SHELDUS, Greene County had over $1.1 million in property damage due to the storms (NCDC, 2008; Hazards & Vulnerability Research Institute, 2007).

On August 2nd, the area experienced another severe weather event when isolated thunderstorms affected the Catskill region. Approximately 4 to 5 inches of rain fell in less than two hours time throughout eastern Greene County. This heavy rainfall resulted in flooded roads in both Leeds and Catskill. In Catskill, the Catskill Creek overflowed onto State Highway 23B and a mudslide was reported on Sandy Plain Road. The Poltic Creek overflowed its banks and washed away a small bridge. Homes in the cities of Catskill and Athens took on significant water in their basements (NCDC, 2008). According to NOAA-

NCDC and SHELDUS, Greene County had approximately $60,000 in property damage due to the storms (NCDC, 2008; Hazards & Vulnerability Research Institute, 2007).

Another slow-moving series of thunderstorms developed in the area on August 11th, producing flooding rains. A first batch of storms caused flooding in Greene and Columbia Counties, washing out portions of Route 296 in Hensonville (Greene County). Flooding was also noted on Route 23 near Cairo, also in Greene County. According to NOAA-NCDC and SHELDUS, Greene County had approximately $15,000 in property damage due to the storms (NCDC, 2008; Hazards & Vulnerability Research Institute, 2007).

These storms resulted in a FEMA Disaster Declaration (DR-1486) on August 29, 2003. Through this declaration, the following 17 counties were declared eligible for Federal and State disaster funds: Allegany, Cattaraugus, Chemung, Columbia, Delaware, Fulton, Greene, Livingston, Madison, Montgomery, Ontario, Rensselaer, Schuyler, Steuben, Sullivan, Wyoming, and Yates. On October 30, 2003, FEMA approved $5.3 million to New York State residents that were affected by the severe storms, widespread flooding and multiple tornadoes that struck the state (FEMA, 2003). Disaster aid for Greene County was not available in the materials reviewed to develop this plan.

April 2-4, 2005 (FEMA DR-1589): A slow moving storm moved up through the Appalachians and into the northeast U.S. The heavy rain fall from this event produced flooding in parts of New York, New Jersey and Pennsylvania (NCDC, 2005). Prior to this storm, the rivers and streams in the area already had high flow-rates due to a previous rainstorm on March 28th and a snowmelt; therefore, flooding increased substantially and created additional damage as a result of this April storm.

In New York State, the heaviest rain and worst flooding reportedly occurred in Ulster and Greene Counties (NWS, 2005). The NYS HMP indicated that the State experienced approximately $66.2 million in damages from this event (NYSDPC, 2008). Rainfall totals for Greene County ranged between 1.5 inches in New Baltimore to 5.54 inches in East Jewett (NWS, 2005). According to NOAA-NCDC and SHELDUS, Greene County experienced approximately $1.3 million in flood damages from this event (NCDC, 2008; Hazards and Vulnerability Research Institute, 2007). The flood impact and losses of this event are further discussed in more detail in Section 5.4.1 (Flood).

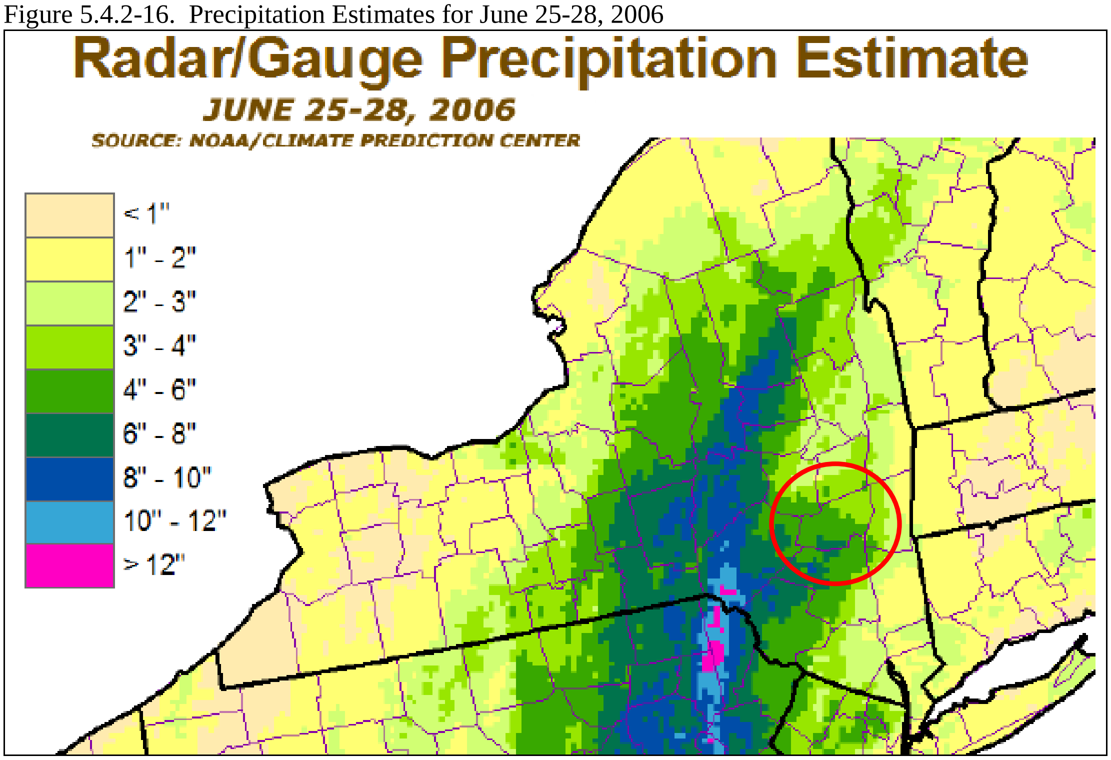
This storm resulted in a FEMA Disaster Declaration (DR-1589) on April 19, 2005. Through this declaration, the following 20 counties were declared eligible for Federal and State disaster funds: Broome, Cayuga, Chautauqua, Chenango, Columbia, Cortland, Delaware, Greene, Madison, Montgomery, Niagara, Orange, Otsego, Putnam, Rensselaer, Schoharie, Sullivan, Tioga, Ulster and Westchester (NYSDPC, 2008; FEMA, 2008). In a September 14, 2005 Press Release, FEMA indicated that nearly $35 million in disaster aid was made available to all declared counties as result of this event. In this press release, FEMA approved $1.1 million in public assistance reimbursements for the Towns of Cairo, Coxsackie, Durham, Greenville, Halcott, Hunter, Jewett, Lexington, New Baltimore, Prattsville and Windham; the Villages of Catskill, Hunter and Tannersville; and the East Durham, Lexington and Palenville fire departments (FEMA, 2005). However, documentation provided by FEMA to Greene County Department of Emergency Services indicated that as of June 1, 2005, the County was approved for over $2.2 million in public assistance reimbursements. Aid was provided for various restoration and mitigation project costs generated as a result of flood damages during this event; particularly in the Towns of Hunter, Jewett and Tannersville (Greene County Department of Emergency Services, 2005).

June 26 – July 10, 2006 (FEMA DR-1650): This severe storm event resulted in a significant flood that affected much of the Mid-Atlantic region. The flooding was widespread, affecting numerous rivers, lakes and communities from upstate New York to North Carolina. Rain totals across the affected states ranged between 2 and 16.67 inches. Overall, the storm resulted in over 16 deaths and millions in damages throughout the affected states (NOAA, 2006).

Some sources indicated that this flooding event was the largest and most costly natural disaster that New York State has encountered since Hurricane Agnes in 1972. The NYS HMP indicated that the counties affected throughout the State experienced approximately $246.3 million in damages during this flood (NYSDPC, 2008).

In Greene County, precipitation totals averaged between 3 to 10 inches of rain, with largest accumulations generated in the south central portion of the County (Figure 5.4.2-16). Rain totals from June 26 through June 30, 2006 included: Tannersville (12.20 inches), East Jewett (8.3 inches), Catskill (4.43 inches) and Windham (3.14 inches) (NWS, 2006). The heavy rain led to widespread flooding throughout the County. The flood impact and losses of this event are further discussed in more detail in Section 5.4.1 (Flood).

Figure 5.4.2-16. Precipitation Estimates for June 25-28, 2006



Source: NOAA, 2006
Note: The red circle within New York State indicates the approximate location of Greene County.

This event resulted in a FEMA Emergency Declaration (FEMA EM-1650) on July 1, 2006. Through this declaration, the following 19 Counties were declared eligible for Federal and State disaster funds: Broome, Chenango, Cortland, Delaware, Fulton, Greene, Hamilton, Herkimer, Madison, Montgomery, Oneida, Otsego, Rensselaer, Schoharie, Schenectady, Sullivan, Tioga, Tompkins, and Ulster Counties (FEMA, 2008). As of December 29, 2006, FEMA indicated that nearly $227 million in disaster aid was made available to all declared counties as result of this event (FEMA, 2008). The Greene County Department of Emergency Services indicated that as of August 25, 2006, FEMA approved over $609,000 in public assistance reimbursements for various restoration and mitigation project costs generated as a result of flood damages during this event; particularly in the Towns of Catskill and Greenville (Greene County Department of Emergency Service, 2006).

April 14-18, 2007 (FEMA DR-1692): An intense and powerful Nor'Easter brought flooding rains and heavy wet snowfall to the northeast U.S. Rainfall totals of six to eight inches were reported across the eastern Catskill Mountains, mid-Hudson Valley and western New England, resulting in widespread flooding. Snowfall accumulations of one to 1 ½ feet were reported across the southern Adirondacks, eastern Catskills, Berkshires, and southern Green Mountains (NWS, Date Unknown). The combined effects of high winds and heavy rainfall during this event led to flooding, storm damages, power outages, and evacuations, and disrupted traffic and commerce.

Various counties in the eastern Catskills and Mid-Hudson Region of New York State were impacted by several inches of rain during this event (NWS, 2007). New York State experienced between $12.8 and $60 million in damages from this event (NYSDPC, 2008; Alarcon, 2007). In Greene County, the heavy rains led to widespread flooding of small streams and creeks across the County (NCDC, 2008). Rainfall totals ranged from 3.97 inches in Cairo to 7.9 inches in Tannersville (NWS, 2007). This storm is discussed in Section 5.4.3 (Severe Winter Storm); however, the storm produced heavy rain and flooding. The flood impact and losses of this event are further discussed in more detail in Section 5.4.1 (Flood).

The Greene County Department of Emergency Services indicated that preliminary storm damage totals eligible for federal public assistance in Greene County totaled nearly $472,000; with the Town of Cairo and Village of Catskill experiencing the most losses. Storm damage totals for individual assistance in the County totaled $111 million, with the Town/Village of Catskill experienced the most losses, totaling $110 million. Individual assistance losses to the County were denied by FEMA (Greene County Department of Emergency Service, 2007). Other sources indicate that final losses eligible for public assistance were estimated at $1.3 million as a result of flood damage, response and debris removal costs throughout the County. Additionally, final loss estimates to homeowners were tallied at $547,000 (Alarcon, 2007). These conflicting monetary figures indicate that a discrepancy exists regarding total damages to the County.

This Nor'Easter resulted in a FEMA Emergency Declaration (FEMA EM-1692) on April 24, 2007. Through this declaration, the following 13 Counties were declared eligible for federal and State disaster funds: Albany, Columbia, Dutchess, Essex, Greene, Montgomery, Orange, Putnam, Rockland, Schoharie, Suffolk, Ulster and Westchester Counties (FEMA, 2007). As of August 13, 2007, FEMA indicated that nearly $61 million in disaster aid was made available to all declared counties as result of this event (FEMA, 2007). On July 11, 2007, FEMA approved $58,000 in public assistance reimbursements for Greene County (FEMA, 2007). Details regarding the latest public assistance reimbursements were not available in materials reviewed for this plan.

Probability of Future Events

In Section 5.3, the identified hazards of concern for Greene 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 County Planning Committee, the probability of occurrence for severe storms in Greene County is considered "frequent" (likely to within 25 years, as presented in Table 5.3-1); however, impacts only related to severe storms, excluding those associated with hurricanes, tropical storms, Nor'easters and flooding, are expected to be minimal.

It is estimated that Greene 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.

The Role of Global Climate Change on Future Probability

Global climate change poses risks to human health and to terrestrial and aquatic ecosystems. Important economic resources such as agriculture, forestry, fisheries, and water resources also may be affected. Warmer temperatures, more severe droughts, storms and floods, and sea level rise could have a wide range of impacts. All these stresses can add to existing stresses on resources caused by other influences such as population growth, land-use changes, and pollution.

Climate is defined not simply as average temperature and precipitation but also by the type, frequency and intensity of weather events. Human-induced climate change has the potential to alter the prevalence and severity of extremes such as heat waves, cold waves, severe storms, floods and droughts. Though predicting changes in these types of events under a changing climate is difficult, understanding vulnerabilities to such changes is a critical part of estimating future climate change impacts on human health, society and the environment.

It is important to understand that directly linking any one specific extreme event (for example, a severe hurricane) to climate change is not possible. However, climate change and global warming may increase the probability of some ordinary weather events reaching extreme levels or of some extreme events becoming more extreme [U.S. Environmental Protection Agency (USEPA), 2006]. It remains very difficult to assess the impact of global warming on extreme weather events, in large part because this analysis depends greatly on regional forecasts for global warming. Global warming will almost certainly have different effects on different regions of the Earth, so areas will not be equally susceptible to increased or more intense extreme weather events. Although regional climate forecasts are improving, they are still uncertain (Climate Institute, Date Unknown). These many uncertainties may exist regarding magnitude or severity, however, many sources indicate that future weather patterns and increased intensities are anticipated as a result of climate change, along with atmospheric, precipitation, storm and sea level changes (USEPA, 2007).

VULNERABILITY ASSESSMENT

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

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

Overview of Vulnerability

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

Due to the County's inland location, the loss associated with hurricanes is primarily associated with severe thunderstorm or tropical storm/hurricane-related rains (see flooding discussion in Section 5.4.1 Flood) and severe winds. Secondary flooding associated with the torrential downpours during hurricanes/tropical storms is also a primary concern in the County. The County has experienced flooding in association with several hurricanes and tropical storms in the past.

In the study area, winds associated with a hurricane event are similar to a severe wind storm and therefore, can support analysis of the severe storm event for this study area. The entire inventory of the County is at risk of being damaged or lost due to impacts of severe wind. Certain areas, infrastructure, and types of building are at greater risk than others due to proximity to falling hazards and/or their manner of construction.

Potential losses associated with high wind events were calculated for the County for two probabilistic hurricane events, the 100-year and 500-year mean return period (MRP) hurricane events. The impacts on population, existing structures and critical facilities 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 hurricane hazard for Greene County. Data used to assess this hazard include data available in the HAZUS-MH hurricane model, NOAA NCDC data, professional knowledge, information provided by the Planning Committee, and public input.

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 hurricane event (severe wind impacts). Locally available inventory data were reviewed to determine their appropriateness for inclusion. Other than data for critical facilities, the default data in HAZUS-MH was the best available for use in this evaluation. The 11 residential and 10 commercial occupancy classes available in HAZUS-MH were condensed into the following occupancy classes (residential, commercial, industrial, agricultural, religious, government, and educational) to facilitate the analysis and the presentation of results. Residential loss estimates address both multi-family and single family dwellings. In addition, impacts to critical facilities were evaluated for the 100-year and 500-year MRP events.

Impact on Life, Health and Safety

The impact of severe storms on life, health and safety is dependent upon the severity of the storm event. 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. It is assumed that the entire County population is exposed to the severe storm hazard. 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. Table 5.4.2-7 summarizes the population over the age of 65 and individuals living below the Census poverty threshold. Additionally, residents living in mobile homes are particularly vulnerable to wind events due to the construction of their housing. The Impact on General Building Stock subsection below discusses mobile homes in the County further.

Table 5.4.2-7. Vulnerable Population Exposed to Severe Storm Events in Greene County

Population Category	Number of Persons Exposed	Percent of Total County Population
Elderly (Over 65 years of age) (1)	7,544	15.7
Persons living below Census poverty threshold* (1)	5,432	12.2
Elderly (Over 65 years of age) living below Census poverty threshold (2)	751	1.6

Source(s): (1) HAZUS-MH MR3, 2007; (2) U.S. Census, 2000.
* The Census poverty threshold for a three person family unit is approximately $15,000.

For a 100-year MRP event, HAZUS-MH estimates that no households will be displaced and zero households will require temporary shelter. HAZUS-MH estimates 12 tons of brick and wood debris and a total of 6,218 tons of tree debris will be generated. For a 500-year MRP event, HAZUS-MH also estimates that no households will be displaced and zero households will require temporary shelter. HAZUS-MH estimates 1,262 tons of brick and wood debris and a total of 75,806 tons of tree debris will be generated. Table 5.4.2-8 estimates the debris produced for the 500-year MRP event.

Please note that the HAZUS-MH Hurricane Model Technical Manual and User Manual recommend that the estimated debris volume be treated as a low estimate. There may be other sources of vegetative and non-vegetative debris (i.e., flooding) not being modeled in HAZUS-MH in combination with the wind. Therefore, this is likely a conservative estimate and may be higher if multiple impacts occur.

Table 5.4.2-8. Debris Production for 500-Year MRP Event Winds

Jurisdiction	Brick and Wood (tons)	Concrete (tons)	Tree (tons)
Town of Ashland	5	0	836
Town of Athens	86	0	5,834
Town of Cairo	87	0	11,510
Town of Catskill	269	0	18,635
Town of Coxsackie	92	0	8,698
Town of Durham	6	0	1,574
Town of Greenville	15	0	1,243
Town of Halcott	5	0	1,475
Town of Hunter	28	0	5,611
Town of Jewett	14	0	3,219
Town of Lexington	8	0	5,098
Town of New Baltimore	45	0	7,978
Town of Prattsville	3	0	626
Town of Windham	22	0	1,447
Village of Athens	68	0	857
Village of Catskill	323	0	707
Village of Coxsackie	168	0	289
Village of Hunter	12	0	100
Village of Tannersville	6	0	69
Sleepy Hollow Lake	34	0	791
Greene County	**1,262**	**0**	**75,806**

Source: HAZUS-MH MR3, 2007
Note: The Town of Coxsackie, Town of Athens and Village of Athens total exposure values include the estimated debris production for Sleepy Hollow Lake.

Impact on General Building Stock

After considering the population exposed to the severe storm hazard, the value of general building stock exposed to and damaged by 100- and 500-year MRP events was evaluated. Potential damage is the modeled loss that could occur to the exposed inventory. HAZUS-MH estimates there are 29,159 structures in Greene County with a total building replacement value (structure only) of greater than $4 billion. Approximately 94-percent of the buildings and nearly 75-percent of the building stock value are associated with residential housing. The analysis below uses the default general building stock data as reported in HAZUS-MH, generated using 2000 U.S. Census data.

Table 5.4.2-9 presents the total exposure value for general building stock by occupancy class for the County.

Table 5.4.2-9. Building Stock Replacement Value (Structure Only) by Occupancy Class

Jurisdiction	Total RV	Residential RV	Commercial RV	Industrial RV
Town of Ashland	$79,217,000	$75,237,000	$2,343,000	$807,000
Town of Athens	$177,002,000	$149,888,000	$15,445,000	$3,860,000
Town of Cairo	$435,647,000	$373,452,000	$37,567,000	$7,158,000
Town of Catskill	$630,183,000	$489,993,000	$101,223,000	$26,133,000
Town of Coxsackie	$250,639,000	$213,492,000	$26,414,000	$7,084,000
Town of Durham	$228,679,000	$190,794,000	$22,256,000	$5,803,000
Town of Greenville	$246,389,000	$189,853,000	$35,993,000	$9,556,000
Town of Halcott	$26,860,000	$25,660,000	$691,000	$0
Town of Hunter	$247,935,000	$225,219,000	$14,498,000	$1,786,000
Town of Jewett	$200,500,000	$161,785,000	$24,397,000	$3,527,000
Town of Lexington	$86,606,000	$77,261,000	$1,802,000	$1,828,000
Town of New Baltimore	$221,794,000	$181,794,000	$20,442,000	$3,002,000
Town of Prattsville	$48,729,000	$36,521,000	$10,124,000	$809,000
Town of Windham	$289,567,000	$241,802,000	$32,707,000	$3,266,000
Village of Athens	$135,876,000	$104,062,000	$15,673,000	$8,514,000
Village of Catskill	$349,902,000	$237,824,000	$79,869,000	$8,308,000
Village of Coxsackie	$237,432,000	$155,333,000	$36,593,000	$5,585,000
Village of Hunter	$76,747,000	$67,088,000	$8,436,000	$441,000
Village of Tannersville	$53,827,000	$49,815,000	$2,209,000	$1,770,000
Sleepy Hollow Lake*	$77,082,000	$71,770,000	$3,410,000	$1,902,000
Greene County	**$4,023,531,000**	**$3,246,873,000**	**$488,682,000**	**$99,237,000**

Source: HAZUS-MH MR3, 2007

Notes:

(1) Replacement value (RV) reflects the building structure and does not include building contents. The valuation of general building stock and the loss estimates determined in Greene County were based on the default general building stock database provided in HAZUS-MH MR3. The general building stock valuations provided in HAZUS-MH MR3 are Replacement Cost Value from RSMeans as of 2006.

(2) Total RV is the sum of all building classes (Residential, Commercial, Industrial, Agricultural, Religious, Government and Education).

(3) The total RV for the agricultural occupancy class is $16,393,000; the total RV for the religious occupancy class is $52,299,000; the total RV for the government occupancy class is $57,912,000; and the total RV for the education occupancy class is $62,135,000.

* The Sleepy Hollow Lake community (SHL) is located within the Towns of Coxsackie and Athens, and Village of Athens. The exposure for SHL was calculated based on the Census blocks located within an approximate area (polygon) generated in GIS of the community (2,474 acres). The Town of Coxsackie, Town of Athens and Village of Athens total exposure values include the inventory of SHL.

The HAZUS-MH hurricane analysis considers damage associated with significant winds. Such wind impacts also could occur as a result of the severe wind storms or tornadoes and therefore, are considered relevant to the severe storm hazard. Rain often is associated with severe storms and heavy rains could result in flooding. Flooding is addressed under the flood hazard (Section 5.4.1).

The entire study area is considered at risk for the severe storm wind hazard. Expected building damage was evaluated by HAZUS-MH across the following damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 5.4.2-10 summarizes the definition of the damage categories.

Table 5.4.2-10. 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
1. No Damage or Very Minor Damage Little or no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very Limited water penetration.	≤2%	No	No	No	No	No
2. Minor Damage Maximum of one broken window, door or garage door. Moderate roof cover loss that can be Covered to prevent additional water Entering the building. Marks or dents on walls requiring painting or patching for repair.	>2% and ≤15%	One window, door, or garage door failure	No	<5 impacts	No	No
3. Moderate Damage Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water.	>15% and ≤50%	> one and ≤ the larger of 20% & 3	1 to 3 panels	Typically 5 to 10 impacts	No	No
4. Severe Damage Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	>50%	> the larger of 20% & 3 and ≤50%	>3 and ≤25%	Typically 10 to 20 impacts	No	No
5. Destruction 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

The estimated expected building damage by general occupancy type of various severities for the wind-only analysis is summarized for the entire County HAZUS-MH run for the 100- and 500-year events in Table 5.4.2-11.

Table 5.4.2-11. Estimated Building Damage by Occupancy Class for 100- and 500-Year Hurricane-Related Wind Events for Greene County

Occupancy Class	Severity of Expected Damage	100-Year		500-Year	
		Building Count	Percent Buildings in Occupancy Class	Building County	Percent Buildings in Occupancy Class
Residential Exposure (Single and Multi-Family Dwellings)	None	27,496	>99%	26,970	98%
	Minor	15	0.05%	511	1.9%
	Moderate	1	0	29	0.01%
	Severe	0	0	0	0
	Complete Destruction	0	0	0	0
Commercial Buildings	None	1,035	>99%	1,017	97.9%
	Minor	3	0.3	19	1.9%
	Moderate	0	0	2	0.2
	Severe	0	0	0	0
	Complete Destruction	0	0	0	0
Industrial Buildings	None	318	>99%	313	>98%
	Minor	1	0	6	1.8
	Moderate	0	0	0	0
	Severe	0	0	0	0
	Complete Destruction	0	0	0	0

Source: HAZUS-MH MR3, 2007

HAZUS-MH estimates approximately 32 buildings will be at least moderately damaged in a 500-year MRP event. No buildings will be completely destroyed as a result of this event. Residential buildings comprise the majority of the building inventory and are estimated to experience the majority of building damage. Wind speeds associated with a 500-year event, as described earlier in this profile, equate to a Category 1 hurricane.

Table 5.4.2-12 summarizes the general building stock damage estimated for the 100- and 500-year MRP hurricane events for the County as a whole. Table 5.4.2-13 summarizes the general building stock damage estimated for the 100- and 500-year MRP hurricane events for each participating jurisdiction. The data shown in both tables indicate total losses associated with wind damage to building structure only. The damage estimates include buildings damaged at all severity levels from minor damage to total destruction and the total dollar damage reflects the overall impact to buildings at an aggregate level.

Table 5.4.2-12. Estimated Greene County Building Replacement Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Winds

Occupancy Category	Building Value Damage (Structure Only)	
	100-Year	500-Year
Residential	$734,940	$8,204,740
Commercial	$33,320	$224,100
Industrial	$7,320	57,520
Agricultural, Religious Government , Education	$11,920	$86,130

Source: HAZUS-MH MR3, 2007

Table 5.4.2-13. Estimated Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Winds

Jurisdiction	Total Buildings		Percentage of Total Building Value		Residential Buildings		Commercial Buildings		Industrial Buildings	
	100 Yr	500 Yr	100 Yr	500 Yr	100 Yr	500 Yr	100 Yr	500 Yr	100 Yr	500 Yr
Town of Ashland	$7,288	$67,428	0.01	0.09	$7,288	$67,030	$0	$234	$0	$81
Town of Athens	$59,251	$636,946	0.03	0.36	$56,600	$619,068	$1,545	$9,849	$386	$3,222
Town of Cairo	$78,471	$726,028	0.02	0.17	$72,081	$711,541	$3,757	$8,447	$967	$2,546
Town of Catskill	$154,672	$1,851,389	0.02	0.29	$140,967	$1,765,400	$10,122	$59,067	$2,660	$18,511
Town of Coxsackie	$77,262	$693,769	0.03	0.28	$73,765	$676,122	$2,641	$10,988	$708	$4,449
Town of Durham	$17,158	$252,410	0.01	0.11	$17,158	$248,621	$0	$2,226	$0	$580
Town of Greenville	$18,155	$260,920	0.01	0.11	$18,155	$255,267	$0	$3,599	$0	$956
Town of Halcott	$2,566	$38,924	0.01	0.14	$2,566	$38,773	$0	$101	$0	$0
Town of Hunter	$17,130	$269,372	0.01	0.11	$17,130	$266,809	$0	$1,735	$0	$185
Town of Jewett	$13,601	$215,251	0.01	0.11	$13,601	$210,638	$0	$3,116	$0	$417
Town of Lexington	$7,612	$116,335	0.01	0.13	$7,612	$115,361	$0	$202	$0	$200
Town of New Baltimore	$56,745	$451,832	0.03	0.20	$52,840	$442,886	$2,044	$4,441	$354	$861
Town of Prattsville	$3,476	$33,410	0.01	0.07	$3,476	$32,190	$0	$1,012	$0	$81
Town of Windham	$21,198	$198,723	0.01	0.07	$21,198	$193,947	$0	$3,271	$0	$327
Village of Athens	$40,116	$439,319	0.03	0.32	$36,955	$417,786	$1,567	$9,140	$851	$8,303
Village of Catskill	$109,546	$1,327,553	0.03	0.38	$98,396	$1,225,249	$7,987	$71,977	$831	$10,323
Village of Coxsackie	$94,297	$848,297	0.04	0.36	$86,195	$775,096	$3,659	$33,372	$565	$6,261
Village of Hunter	$4,520	$77,699	0.01	0.10	$4,520	$76,567	$0	$1,010	$0	$44
Village of Tannersville	$4,435	$66,887	0.01	0.12	$4,435	$66,396	$0	$311	$0	$177
Sleepy Hollow*	$28,072	$277,209	0.04	0.4	$27,541	$274,530	$341	$1,773	$190	$906
Greene County	**$787,498**	**$8,572,492**	**0.02**	**0.21**	**$734,936**	**$8,204,744**	**$33,323**	**$224,097**	**$7,323**	**$57,522**

Source: HAZUS-MH MR3, 2007

Notes:

(1) Values represent replacement values (RV) for building structure only (does not include contents).

(2) The valuation of general building stock and the loss estimates determined in Greene County were based on the default general building stock database provided in HAZUS-MH MR3. The general building stock valuations provided in HAZUS-MH MR3 are Replacement Cost Value from RSMeans as of 2006.

* The Sleepy Hollow Lake community (SHL) is located within the Towns of Coxsackie and Athens, and Village of Athens. The estimated losses for SHL were calculated based on the general building stock damages for the Census blocks located within an approximate area (polygon) generated in GIS of the community (2,474 acres). The Town of Coxsackie, Town of Athens and Village of Athens total loss estimates includes the losses for SHL.

Residential buildings account for a majority of the building stock damage and also comprise the majority of the building inventory. Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Figures 5.4.2-17 through 5.4.2-18 show the density of damage estimated for residential structures for the 100-year MRP event and 500-year MRP events.

Mobile homes are particularly vulnerable to severe storms. HAZUS-MH estimates there are 3,409 mobile homes in Greene County with a total structural replacement value of approximately $112,008,000 or $32,857 for each mobile home.

Impact on Critical Facilities

100-Year MRP Event – HAZUS-MH estimates the police departments, fire stations and schools will not suffer damage during a 100-year event. Shelters, senior care facilities and user-defined facilities (listed in the County Profile, Section 4) have a less than one-percent chance of suffering minor damage. All facilities are estimated to be fully functional (no loss of use).

500-Year MRP Event – HAZUS-MH estimates the police departments, fire stations and schools, shelters and senior care facilities have less than one-percent chance of suffering minor damage during a 500-year event. All facilities are estimated to be fully functional (no loss of use).

Impact on Economy

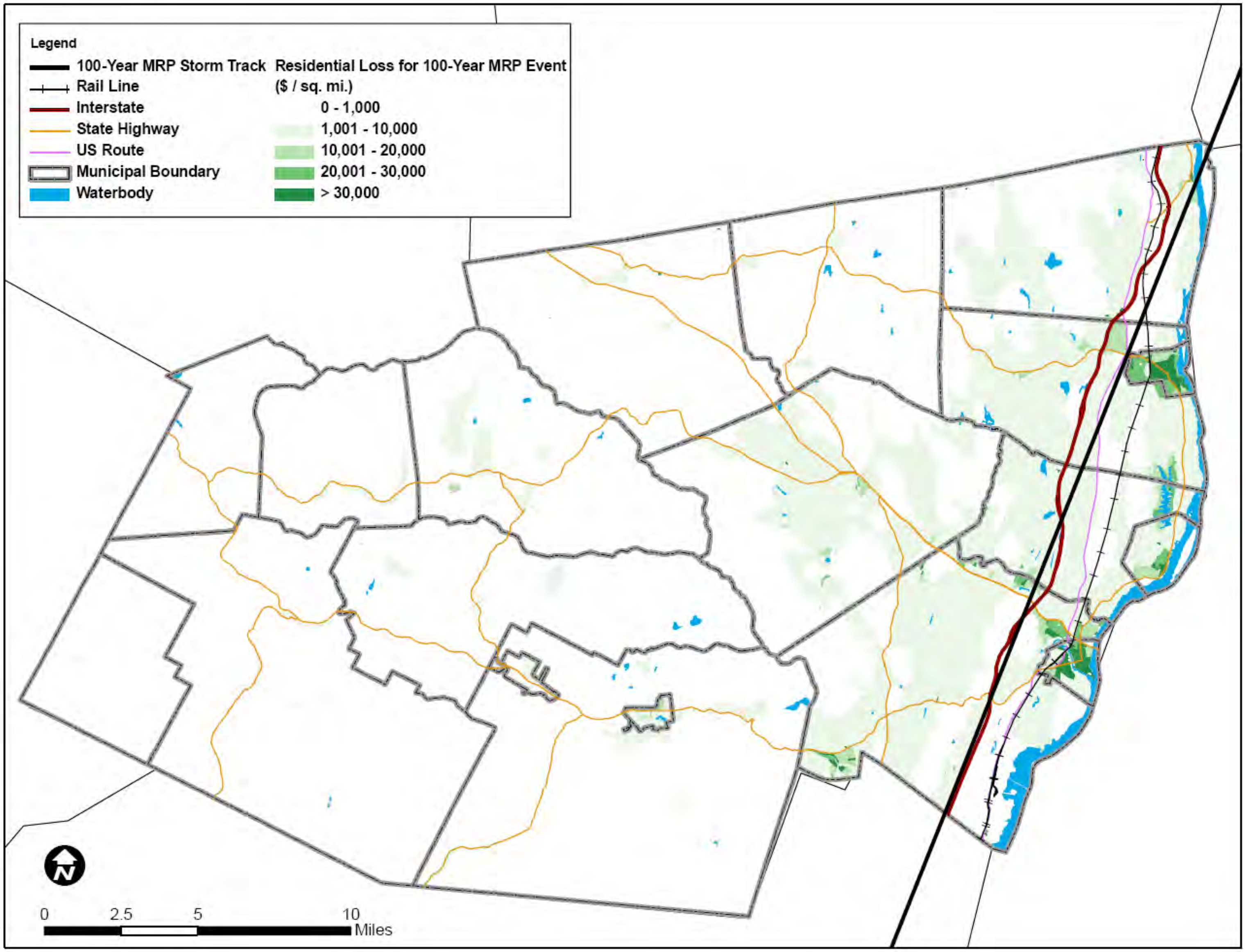
Severe storms also have impacts on the economy, including: loss of business function, damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. HAZUS-MH estimates the total economic loss associated with each storm scenario (direct building losses and 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 damage sustained during the earthquake.

HAZUS-MH does not estimate that any commercial or industrial business interruption loss will occur for the 100-year MRP event. For the 500-year MRP event, HAZUS-MH estimates a loss of approximately $500,000 for the County as a whole; associated with loss of income, and relocation and rental costs.

Transportation lifelines are not considered particularly vulnerable to the 100- and 500-year MRP severe storm wind hazard. However, 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).

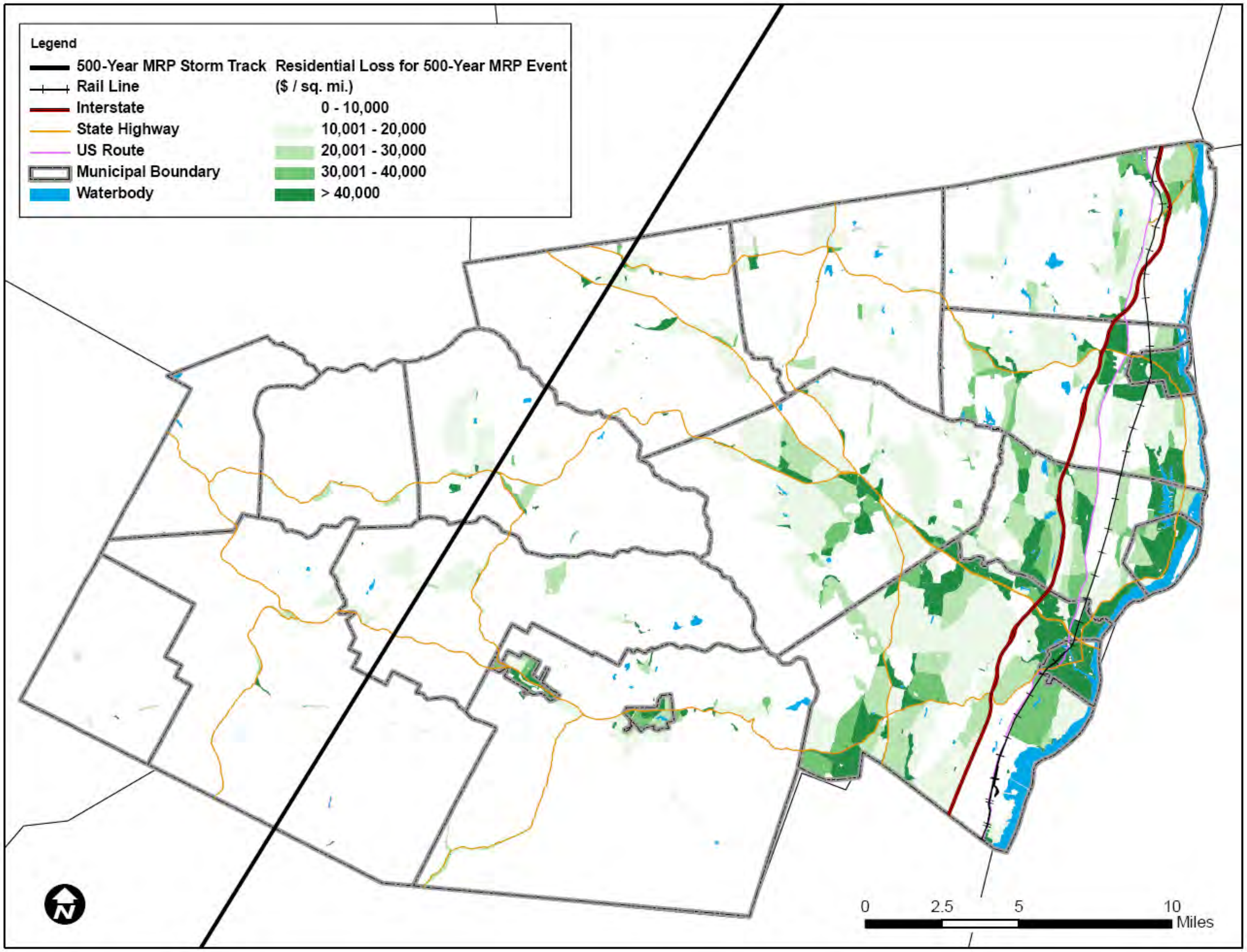
It is estimated that the impact to the economy, as a result of severe storm event, would be considered "High" in accordance with the risk ranking shown in Table 5.3-3.

Figure 5.4.2-17. Density of Losses for Residential Structures (Structure Only) for the 100-Year MRP Wind Event



Source: HAZUS-MH MR3, 2007

Figure 5.4.2-18. Density of Losses for Residential Structures (Structure Only) for the 500-Year MRP Wind Event



Source: HAZUS-MH MR3, 2007

Future Growth and Development

As discussed in Section 4, areas targeted for future growth and development have been identified across the County. Any areas of growth could be potentially impacted by the severe storm hazard because the entire planning area is exposed and vulnerable.

Additional Data and Next Steps

Over time, Greene 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, additional information on estimated frequency of these events, and future data regarding events and damages as they occur. In addition, information on particular buildings or infrastructure and their value will support updates regarding the particular assets in the County that are most vulnerable to severe storm (wind-related) events. Additional utility data would support an improved assessment of potential damage for this infrastructure category.

For the severe storm events that cannot currently be modeled in HAZUS-MH (tornado, thunderstorm, etc.), additional detailed loss data from past and future events will assist in assessing potential future losses. Based on these values and a sufficient number of data points, future losses could be modeled. Alternately, -percent of damage estimates could be made and multiplied by the inventory value to estimate potential losses. This methodology is based on FEMA's How To Series (FEMA 386-2), Understanding Your Risks, Identifying and Estimating Losses (FEMA, 2001) and FEMA's Using HAZUS-MH for Risk Assessment (FEMA 433) (FEMA, 2004). Finally, with time, HAZUS-MH will be released with modules that address hurricane wind and associated flooding as one model and will include a tornado module. As this version of HAZUS-MH is released, the County can run analyses for the tornado hazard and re-run an analysis for an overall picture of the hurricane-associated wind and flood damages.

Overall Vulnerability Assessment

Severe storms are common in the study area, often causing impacts and losses to the structures, facilities, utilities, and population in Greene County. Existing and future mitigation efforts should continue to be developed and employed that will enable the study area to be prepared for these events when they occur. The overall hazard ranking determined by the Planning Committee for this hazard is 'High' with a 'frequent' occurrence (hazard event that occurs more frequently than once in 25 years) (see Tables 5.3-3 through 5.3-6).