5.4.5 Severe Storm

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and impact of climate change) and vulnerability assessment for the severe storm hazard in Warren County.

5.4.5.1 Profile

Hazard Description

For the purpose of this HMP and as deemed appropriated by the Warren County Steering and Planning Committees, the severe storm hazard includes: hail, high winds, and thunderstorms, which are defined below.

Hailstorms

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

High Winds

High winds, other than tornadoes, are experienced in all parts of the United States. Areas that experience the highest wind speeds are coastal regions from Texas to Maine, and the Alaskan coast; however, exposed mountain areas experience winds at least as high as those along the coast (Federal Emergency Management Agency [FEMA] 1997; Robinson 2013). Wind begins with differences in air pressures. It is rough horizontal movement of air caused by uneven heating of the earth's surface. Wind occurs at all scales, from local breezes lasting a few minutes to global winds resulting from solar heating of the earth (Ilicak 2005). High winds have the potential to down trees, tree limbs and power lines which lead to widespread power outages and damaging residential and commercial structures throughout Warren County. High winds are often associated by other severe storm events such as thunderstorms, tornadoes, hurricanes and tropical storms (all discussed further in this section). The following table provides the descriptions of winds used by the NWS.

Table 5.4.5-1. NWS Wind Descriptions

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

Source: NWS 2015
mph miles per hour

Thunderstorms

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

Lighting is a bright flash of electrical energy produced by a thunderstorm. The resulting clap of thunder is the result of a shock wave created by the rapid heating and cooling of the air in the lightning channel. All thunderstorms produce lightning and are very dangerous. It ranks as one of the top weather killers in the United States and kills approximately 50 people and injures hundreds each year. Lightning can occur anywhere there is a thunderstorm.

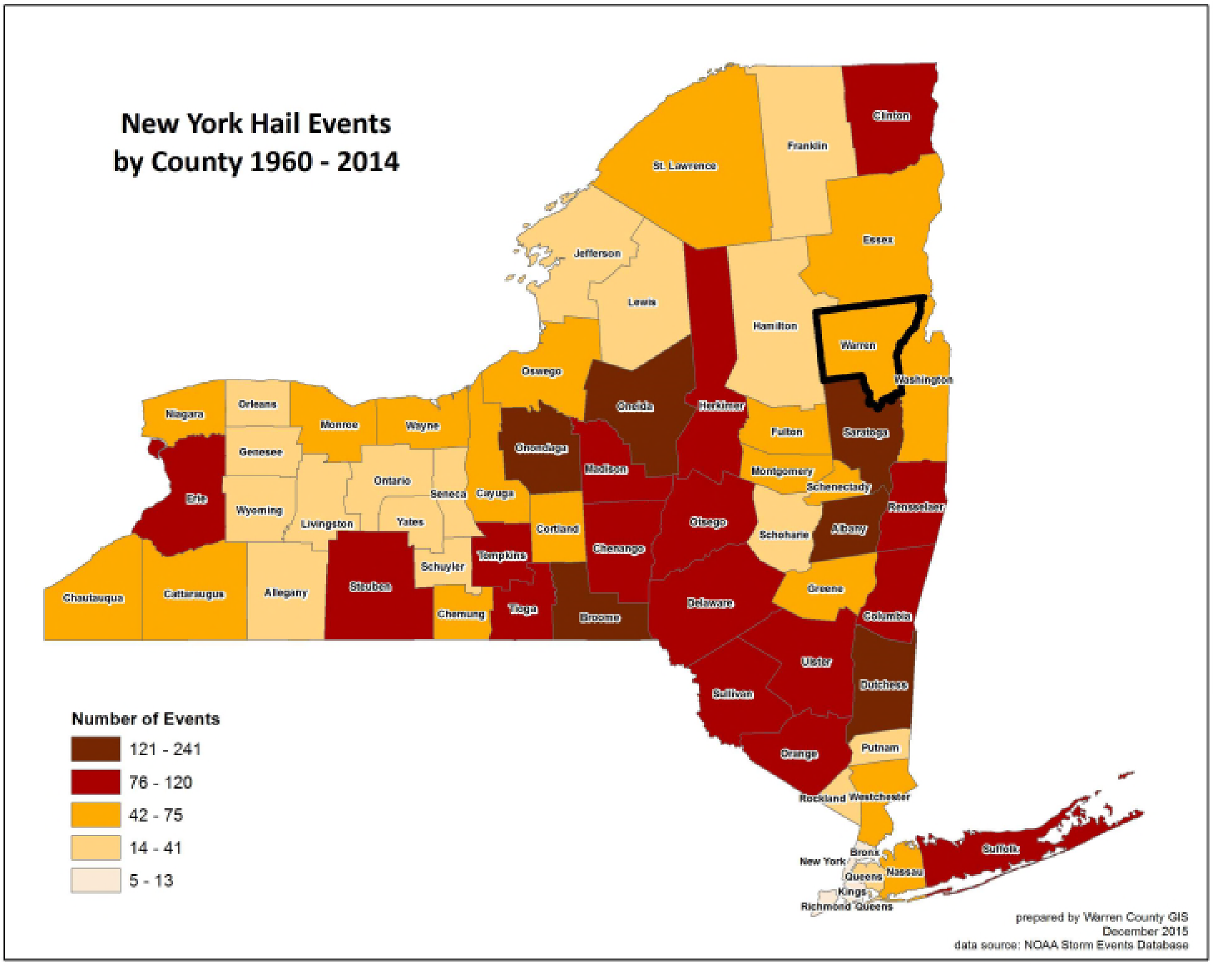
Thunderstorms can lead to flooding, landslides, strong winds, and lightning. Roads may become impassable from flooding, downed trees or power lines, or a landslide. Downed power lines can lead to utility losses, such as water, phone and electricity. Lightning can damage homes and injure people. In the U.S., an average of 300 people are injured and 50 people are killed by lightning each year. Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes. An estimated 100,000 thunderstorms occur each year in the U.S., with approximately 10% of them classified as severe. During the warm season, thunderstorms are responsible for most of the rainfall.

Location

Hailstorms

Hailstorms are most frequent in the southern and central plains states in the United States, where warm moist air off of the Gulf of Mexico and cold dry air from Canada collide, and thereby spawning violent thunderstorms. This area of the United States is known as hail alley and lies within the states of Texas, Oklahoma, Colorado, Kansas, Nebraska, and Wyoming. In New York State, hailstorms can occur anywhere within the State independently or during a tornado, thunderstorm or lightning event. Figure 5.4.5-1 shows the number of hail events from 1960 to 2014 across New York State. The figure indicates that Warren County experienced 47 hail events during this timeframe (National Oceanic and Atmospheric Administration [NOAA]).

Figure 5.4.5-1. New York Hail Events by County 1960-2014

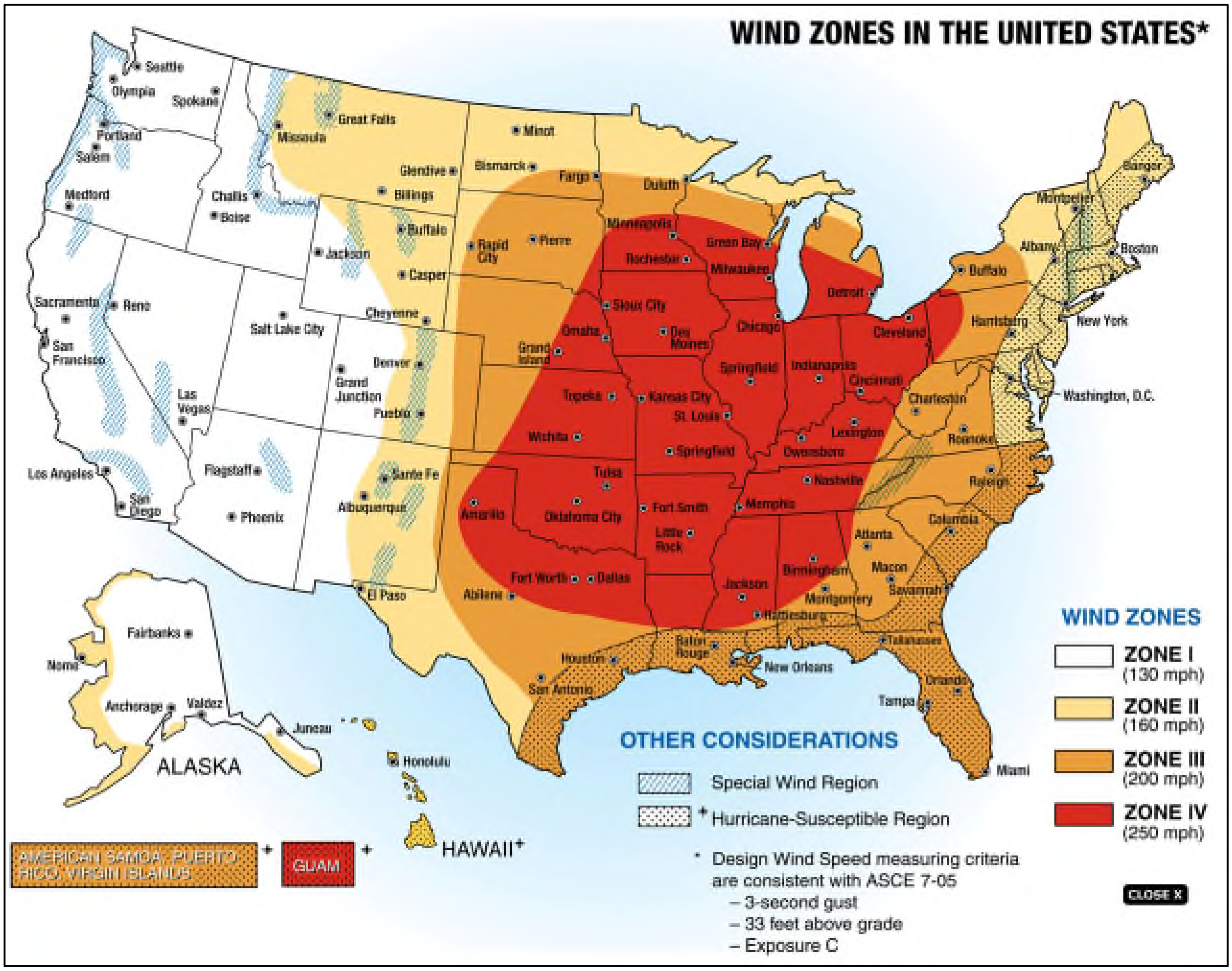


Source: NOAA Storm Events Database

High Winds

All of Warren County is subject to high winds from thunderstorms, hurricanes/tropical storms, tornadoes, and other severe storm events. According to Figure 5.4.5-2, the FEMA Winds Zones of the United States map, Warren County is located in Wind Zone II, where wind speeds can reach up to 160 mph. The County is also located in the Hurricane Susceptible Region, which extends along the entire east coast from Maine to Florida, the Gulf Coast, and Hawaii. This figure indicates how the frequency and strength of windstorms impacts the United States and the general location of the most wind activity. This is based on 40 years of tornado data and 100 years of hurricane data, collected by FEMA.

Figure 5.4.5-2. Wind Zones in the United States



Source: FEMA, 2001

Thunderstorms

Thunderstorms affect relatively small localized areas, rather than large regions like winter storms and hurricane events. Thunderstorms can strike in all regions of the United States; however, they are most common in the central and southern states. The atmospheric conditions in these regions of the country are ideal for generating these powerful storms. It is estimated that there are as many as 40,000 thunderstorms each day worldwide. The most thunderstorms are seen in the southeast United States, with Florida having the highest incidences (80 to over 100 thunderstorm days each year). According to NOAA, Warren County can experience between 20 and 30 thunderstorms each year (NWS 2010).

Extent

Hailstorms

The severity of hail is measured by duration, hail size, and geographic extent. All of these factors are directly related to thunderstorms, which creates hail. There is wide potential variation in these severity components. The most significant impact of hail is damage to crops. Hail also has the potential to damage structures and vehicles during hailstorms.

Hail can be produced from many different types of storms. Typically, hail occurs with thunderstorm events. The size of hail is estimated by comparing it to a known object. Most hailstorms are made up of a variety of sizes, and only the very largest hail stones pose serious risk to people, when exposed. Table 5.4.5-2 shows the different sizes of hail and the comparison to real-world objects.

Table 5.4.5-2. Hail Size

Size	Inches in Diameter
Pea	0.25 inch
Marble/mothball	0.50 inch
Dime/Penny	0.75 inch
Nickel	0.875 inch
Quarter	1.0 inch
Ping-Pong Ball	1.5 inches
Golf Ball	1.75 inches
Tennis Ball	2.5 inches
Baseball	2.75 inches
Tea Cup	3.0 inches
Grapefruit	4.0 inches
Softball	4.5 inches

Source: NWS 2015; NYS DHSES 2014

High Winds

The following table provides the descriptions of winds used by the NWS during wind-producing events.

Table 5.4.5-3. NWS Wind Descriptions

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

Source: NWS 2010
mph miles per hour

The NWS issues advisories and warnings for winds. Issuance is normally site-specific. High wind advisories, watches and warnings are products issued by the NWS when wind speeds may pose a hazard or is life threatening. The criterion for each of these varies from state to state. Wind warnings and advisories for New York State are as follows:

- High Wind Warnings are issued when sustained wind speeds of 40 mph or greater lasting for one hour or longer or for winds of 58 mph or greater for any duration or widespread damage are possible.
- Wind Advisories are issues when sustained winds of 30 to 39 mph are forecast for one hour or longer, or wind gusts of 46 to 57 mph for any duration (NWS 2015).

Thunderstorms

Severe thunderstorm watches and warnings are issued by the local NWS office and Storm Prediction Center (SPC). The NWS and SPC will update the watches and warnings and will notify the public when they are no longer in effect. Watches and warnings for tornadoes in New York State are as follows:

- Severe Thunderstorm Warnings are issued when there is evidence based on radar or a reliable spotter report that a thunderstorm is producing, or forecast to produce, wind gusts of 58 mph or greater, structural wind damage, and/or hail one-inch in diameter or greater. A warning will include where the storm was located, what municipalities will be impacted, and the primary threat associated with the severe thunderstorm warning. After it has been issued, the NWS office will follow up periodically with Severe Weather Statements which contain updated information on the severe thunderstorm and will let the public know when the warning is no longer in effect (NWS 2009; NWS 2010).
- Severe Thunderstorm Watches are issued by the SPC when conditions are favorable for the development of severe thunderstorms over a larger-scale region for a duration of at least three hours. Tornadoes are not expected in such situations, but isolated tornado development may also occur. Watches are normally issued well in advance of the actual occurrence of severe weather. During the watch, the NWS will keep the public informed on what is happening in the watch area and also let the public know when the watch has expired or been cancelled (NWS 2009; NWS 2010).
- Special Weather Statements for Near Severe Thunderstorms are issued for strong thunderstorms that are below severe levels, but still may have some adverse impacts. Usually, they are issued for the threat of wind gusts of 40 to 58 mph or small hail less than one-inch in diameter (NWS 2010).

Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with severe storm events throughout Warren 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 1954 and 2015, New York State was included in 54 FEMA declared severe storm-related disasters (DR) or emergencies (EM) classified as one or a combination of the following hazards: coastal storm, high tides, heavy rain, flooding, hurricane, ice storm, severe storms, thunderstorms, tornadoes, tropical storm, straight-line winds, and landslides. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. Of those declarations, Warren County has been included in ten declarations (FEMA 2015).

For this 2016 Plan update, known severe storm events, including FEMA disaster declarations, which have impacted Warren County between 2010 and 2015 are identified in Table 5.4.5-4. For detailed information on damages and impacts to each municipal, refer to Section 9 (jurisdictional annexes). Please note that not all events that have occurred in Warren County are included due to the extent of documentation and the fact that not all sources may have been identified or researched. Loss and impact information 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 plan.

Table 5.4.5-4. Severe Storm Events in Warren County between 2010 and 2015

Dates of Event	Event Type	FEMA Declaration Number	Location / County Designated?	Losses / Impacts
March 13 – 31, 2010	Severe Storms and Flooding	DR-1899	Yes	A low pressure system tracked northeast over northeastern United States on March 23rd, bringing a moderate to heavy rainfall to east central New York. The ground was already nearly saturated from recent snow melt, causing rivers and streams to run high. In Warren County, a bridge was reported washed out on Harrington Road in the Town of Johnsburg due to a possible beaver dam break along Johnson Brook. The County reported a total of $25,000 in property damage.
October 1, 2010	Flooding (Remnants of Tropical Storm Nicole)	N/A	N/A	The remnants of Tropical Storm Nicole brought very heavy rains to east-central New York State. Rainfall totals from this storm ranged from three to nine inches, resulting in widespread river and small stream and urban flooding, including water in basements. In Warren County, there was standing water reported in the City of Glens Falls at the intersection of Sherman Avenue and Elm Street due to the heavy rains.
April 28-30, 2011	Severe Storms, Flooding, Tornadoes, and Straight-Line Winds	DR-1993	Yes	Heavy showers and thunderstorms impacted the western and central Mohawk Valley, Adirondack region, and the Upper Hudson River Valley, including the Lake George Region (Warren County). Thunderstorms produced severe weather and very heavy rainfall. The combination of the rainfall and rapid snowmelt due to warm temperatures led to increased runoff and rapid river rises. In Warren County, flooding from this event covered nearly two-thirds of the County. Flooding occurred along the Hudson River in the County from North River southward to the Saratoga County line. Numerous municipalities reported flooding of roadways, houses, and riverside camps. Some properties had several feet of water in them. Many major roadways were closed in the County due to flooding. The North Creek Trailer Park on Route 28 in the Town of Johnsburg was evacuated because water from the Hudson River entered the park. A mudslide in excess of 200 feet occurred on 13th Lake Road in North River/North Creek. In the hamlet of North Creek (Town of Johnsburg), a couple hundred feet of railway tracks were reported under two to five feet of water with several buildings at the train station being flooded as well. In the Town of Stony Creek, the 1,000 Acres Golf Course was flooded with the 9th green under eight feet of water. Flood water receded through April 30th. The County had approximately $676,000 in property damage from this event.
May 27 – June 2, 2011	Flooding, Thunderstorm Wind, Hail (Memorial Day Storm)	N/A	N/A	A combination of individual storms caused severe damage along a thin line through the County and impacted the Towns of Stony Creek, Thurman, Warrensburg, Horicon, and Bolton. A swath of heavy rainfall which fell in just a few hours causing flash flooding, resulting in road closures with significant damage to many roadways, washed-out culverts and a least a couple of washed-out bridges. In addition, a few of the storms were severe producing large hail up to the size of a golf ball and some trees were downed by strong thunderstorm winds.

Dates of Event	Event Type	FEMA Declaration Number	Location / County Designated?	Losses / Impacts
				It was reported that seven area fire departments, three EMS crews, the Warren County Sheriff's Office, State Police, along with state, county and local highway departments all responded to the flooding. Numerous trees were reported down on wires in Chestertown, as well as in Thurman, and Warrensburg. Nickel size hail was reported in Chestertown and Stony Creek, quarter size hail was reported in Hague, ping-pong ball size hail was reported in Thurman, and golf ball size hail was reported in Warrensburg. The County had $13.125 million in damages from this event.
August 28-30, 2011	Hurricane Irene	DR-4020	Yes	The greatest impact of Irene in eastern New York State was heavy to extreme rainfall which resulted in catastrophic flooding across portions of the region. Rainfall amounts averaged between four and eight inches with amounts of up to 12 inches falling in the eastern Catskills and Schoharie Valley. Three to six inches were common across the Lake George and Saratoga regions. The rainfall resulted in widespread flash flooding and river flooding across eastern New York State. Bridges were closed on major roadways in this area of the State. In Warren County, wind and flood damage occurred throughout the county. The most severe was limited to the Lake Champlain Watershed area, located on the eastern side of the County, and in the Lake George and West Mountain areas. In the Town of Lake George, Route 9N was flooded from the Route 9/9N spilt south to the ramp for Exit 21 for the Northway. Route 9L was also flooded between Route 9N and Bay Road. Two of the seven docks in the Village of Lake George floated off and were crushed.
October 27 – November 8, 2012	Hurricane Sandy	EM-3351	Yes	Hurricane Sandy moved up the east coast of the United States during the last week of October 2012. As the storm made landfall in southern New Jersey, bands of rain moved across eastern New York State. Rainfall totals in this part of the State were minimal and did not cause any flooding. The storm did bring strong and gusty winds to the area, bringing down trees and power lines across the region. Wind gusts ranged from 40 to 60 mph. In Warren County, wind gusts of 65 mph pushed down the length of Lake George, creating waves that threatened to spill over the shoreline. Some of the docks along the Lake were damaged but flooding did not occur. Numerous private boats were sunk or damaged. In Glens Falls, trees and wires were knocked down from the winds.
June 28, 2013	Severe Storms and Flooding	DR-4129	Yes	Heavy rain fell across the Mohawk Valley and western Adirondacks with rates of one inch per hour with three to five inches of rain falling in total. This event, with the combination of a previous rainfall event, led to significant flash flooding across both the Mohawk Valley and Adirondacks. Many roads were washed out and closed. Urbanized areas along the Mohawk River experienced flooding as well.

Dates of Event	Event Type	FEMA Declaration Number	Location / County Designated?	Losses / Impacts
				Many communities declared state of emergencies and President Obama signed a major disaster declaration for New York State which included Herkimer, Montgomery and Warren Counties. In Warren County, the Town of Johnsburg experienced severe flooding from this event. Flash flooding occurred in the Bakers Mill section of the Town. Water rescue teams were deployed to several homes that were threatened by flooding. A state of emergency was declared for the Town as a result of flooding.

Sources: FEMA 2015; NYSDEC; Robinson 1999
FEMA Federal Emergency Management Agency
NYSDEC New York State Department of Environmental Conservation

Probability of Future Occurrences

Predicting future severe storm events in a constantly changing climate has proven to be a difficult task. Predicting extremes in New York State is particularly difficult because of the region's geographic location. It is positioned roughly halfway between the equator and the North Pole and is exposed to both cold and dry airstreams from the south. The interaction between these opposing air masses often leads to turbulent weather across the region (Keim, 1997). The following table provides the probability of occurrences of severe storm events. Based on historic occurrences, thunderstorm events are the most common in Warren County, followed by hail events. However, the information used to calculate the probability of occurrences is only based on using NOAA-NCDC storm events database results.

Table 5.4.5-5. Probability of Occurrence of Severe Storm Events

Hazard Type	Number of Occurrences Between 1950 and 2015	Rate of Occurrence or Annual Number of Events (average)	Recurrence Interval (in years) (# Years/Number of Events)	Probability of Event in any given year	% chance of occurrence in any given year
Hail	47	0.72	1.40	0.71	71.21
High or Strong Wind	42	0.65	1.57	0.64	63.64
Thunderstorm	163	2.51	0.40	1	100
Lightning	7	0.11	9.43	0.11	10.61

Source: NOAA-NCDC 2015
Note: Probability was calculated using the available data provided in the NOAA-NCDC storm events database.

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

In Section 5.3, the identified hazards of concern for Warren County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for ranking hazards. Based on historical records and input from the Planning Committee, the probability of occurrence for severe storms in the County is considered 'frequent' (likely to occur more than once every 25 years, as presented in Table 5.3-3).

Climate Change Impacts

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

Each region in New York State, as defined by ClimAID, has attributes that will be affected by climate change. Warren County is part of Region 7 (see Figure 5.4.5-3), Adirondack Mountains. Some of the issues in this region, affected by climate change, include: loss of high elevation plants, animals and ecosystem types; decline in winter recreation; decline in milk production, etc. (NYSERDA 2011).

Figure 5.4.5-3. Climate Regions of New York State

Source: NYSERDA 2011

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

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

In Region 7, it is estimated that temperatures will increase by 3.7ºF to 7.4ºF by the 2050s and 4.2ºF to 11.8ºF by the 2080s (baseline of 39.9ºF). Precipitation totals will increase between 2 and 15% by the 2050s and 3 to 17% by the 2080s (baseline of 40.8 inches). Table 5.4.5-6 displays the projected seasonal precipitation change for the Adirondack Mountains ClimAID Region (NYSERDA, 2011).

Table 5.4.5-6. Projected Seasonal Precipitation Change in Region 7, 2050s (% change)

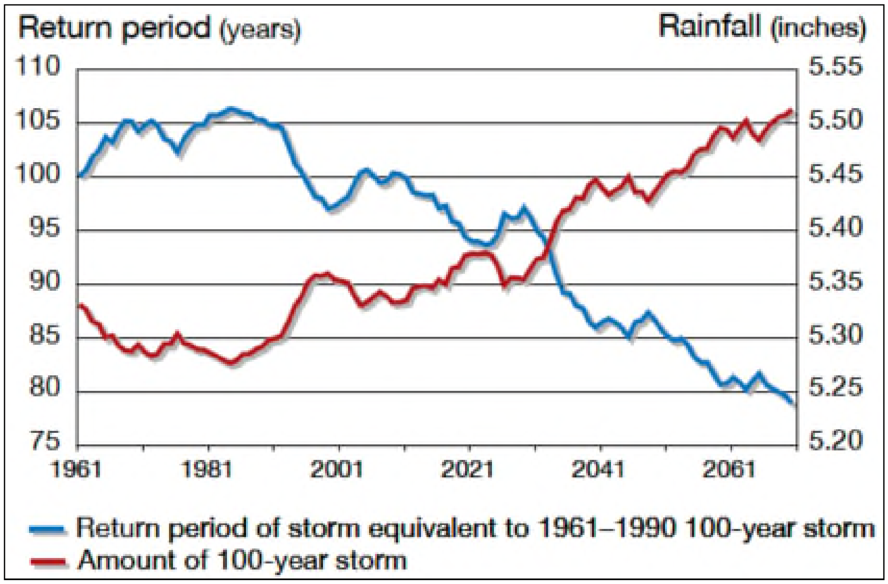
Winter	Spring	Summer	Fall
+5 to +15	-5 to +10	-5 to +5	-5 to +10

Source: NYSERDA 2011

The projected increase in precipitation is expected to fall in heavy downpours and less in light rains. The increase in heavy downpours has the potential to affect drinking water; heighten the risk of riverine flooding; flood key rail lines, roadways and transportation hugs; and increase delays and hazards related to extreme weather events (NYSERDA 2011). Less frequent rainfall during the summer months may impact the ability of water supply systems. Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent wastewater treatment plants (NYSERDA 2011).

Figure 5.4.5-4 displays the project rainfall and frequency of extreme storms in New York State. The amount of rain fall in a 100-year event is projected to increase, while the number of years between such storms (return period) is projected to decrease. Rainstorms will become more severe and more frequent (NYSERDA 2011).

Figure 5.4.5-4. Projected Rainfall and Frequency of Extreme Storms



Source: NYSERDA 2011

5.4.5.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the severe storm hazard, all of Warren County is exposed and vulnerable. Therefore, all assets in the County (population, structures, critical facilities and lifelines), as described in Section 4 (County Profile), are exposed and potentially vulnerable. The following text evaluates and estimates the potential impact of severe storm on the County including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2011 Warren County Hazard Mitigation Plan
- Further data collections that will assist understanding this hazard over time

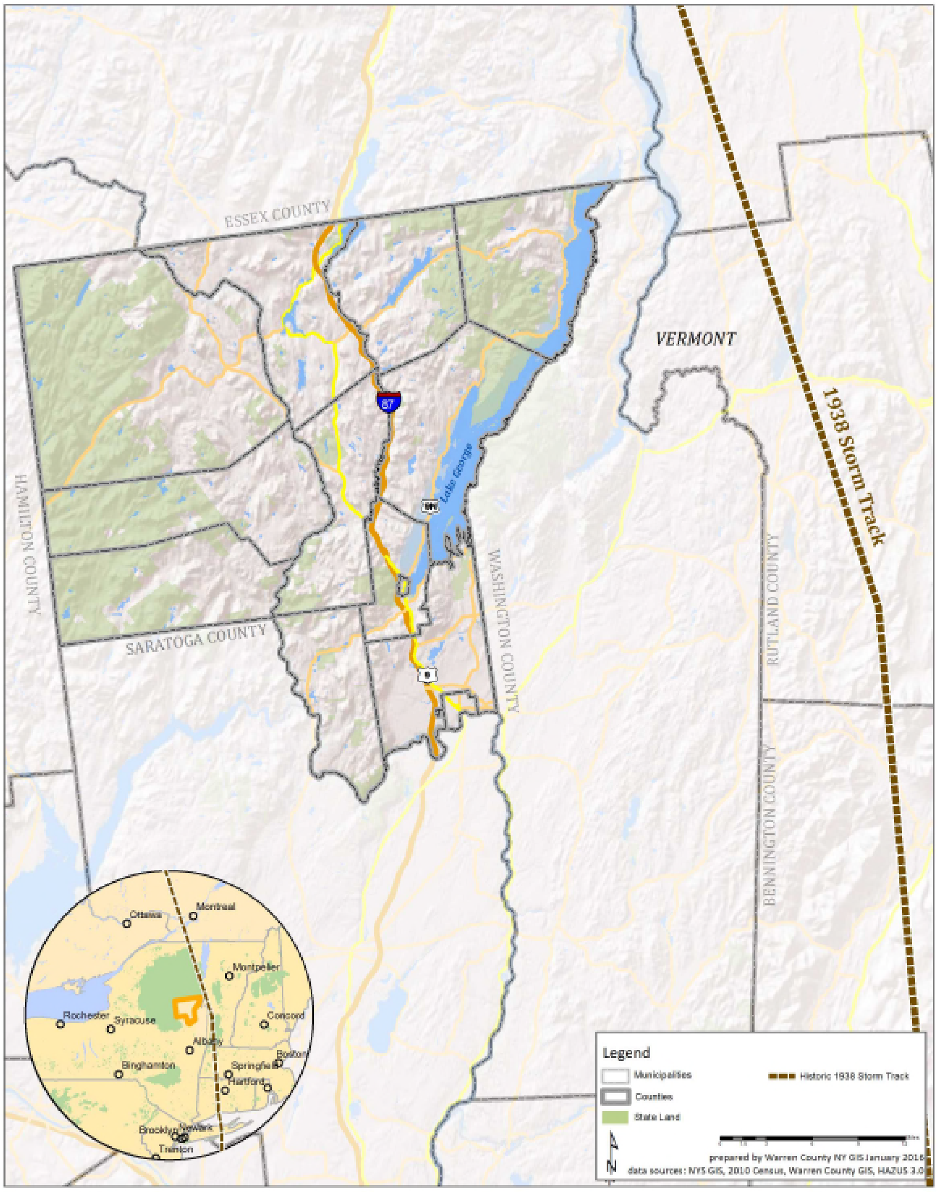
Overview of Vulnerability

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

Losses from wind are primarily associated with severe thunderstorm or tropical depression/storm-related winds and rain (see flooding discussion in Section 5.4.2 [Flood]). Secondary flooding associated with the torrential downpours during severe storms is also a primary concern in Warren County. The County has experienced flooding in association with numerous severe storms in the past.

The entire inventory of Warren County is at risk of being damaged or lost due to impacts of severe storms (severe wind). Certain areas, infrastructure, and types of building are at greater risk than others due to proximity to falling hazards and manner of construction. Potential losses associated with high wind events were calculated for Warren County using a historic scenario, based on the New England Hurricane of 1938 ("Long Island Express"), a strong Category 3 storm that that tracked just to the east of Warren County. Wind gusts reached Category 5 strength as the storm made landfall in southern New England, and the storm is considered to be the worst hurricane to strike New England in modern times. The storm is believed to have entered Vermont as a Category 2 and exited into Quebec as a Category 1. The storm track is shown below in Figure 5.4.5-6.

Figure 5.4.5-6. 1938 Historic Storm Track



Source: Warren County GIS; HAZUS 3.0

HAZUS 3.0 was used to calculate the impacts on current population, existing structures and critical facilities in the County if the 1938 storm were to hit in present times. Results are presented below, following a summary of the data and methodology used.

Data and Methodology

At the recommendation of FEMA HAZUS technical support staff, and with input from the Steering and Planning Committees, the severe storm hazard for Warren County was analyzed using a historic scenario based on the New England Hurricane of 1938, described in the section above. The historic scenario was run using the HAZUS-MH 3.0 methodology and model. The 2010 U.S. Census population and general building stock data available in HAZUS 3.0 were used to support an evaluation of assets exposed to the 1938 storm and the potential impacts associated with this hazard. Figure 5.4.5-6 shows the storm track used in the model.

HAZUS-MH 3.0 contains data on historic wind speeds, surface roughness and vegetation (tree coverage). 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 3.0 were used to evaluate potential losses from a repeat of the 1938 storm in the present day. The default data in HAZUS-MH was determined to be the best available for use in this evaluation.

Impact on Life, Health and Safety

For the purposes of this HMP, the entire population of Warren County (65,707 people) is exposed to severe storm events (U.S. Census 2010). Residents may be displaced or require temporary to long-term sheltering due to severe storm events. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate. The population of individuals with access or functional needs or over the age of 65 is also more vulnerable and, physically, they may have more difficulty evacuating. The elderly are considered most vulnerable because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention which may not be available due to isolation during a storm event. Please refer to Section 4 for the statistics of these populations.

People located outdoors (i.e., recreational activities and farming) are considered most vulnerable to hailstorms, thunderstorms and tornadoes. This is because there is little to no warning and shelter may not be available. Moving to a lower risk location will decrease a person’s vulnerability.

Impact on General Building Stock

After considering the population exposed to the severe storm hazard, the general building stock replacement value exposed to and damaged by a repeat of the historic 1938 storm was examined. Wind-only impacts from the storm are reported based on the model run in HAZUS-MH 3.0. Potential damage is the modeled loss that could occur to the exposed inventory, including damage to structural and content value based on the wind-only impacts associated with the storm.

It is assumed that the entire County’s general building stock is exposed to the severe storm wind hazard (approximately $9.4 billion structure only). Expected building damage was evaluated by HAZUS across the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 5.4.5-7 summarizes the definition of the damage categories.

Table 5.4.5-7. Description of Damage Categories

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
No Damage or Very Minor Damage Little of no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very limited water penetration.	≤ 2%	No	No	No	No	No
Minor Damage Maximum of one broken window, door or garage door. Moderate roof cover loss that can be covered to prevent additional water entering the building. Marks or dents on walls requiring painting or patching for repair.	> 2% and ≤ 15%	One window, door, or garage door failure	No	< 5 Impacts	No	No
Moderate Damage Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water.	> 15% and ≤ 50%	> the larger of 20% & 3 and ≤ 50%	1 to 3 Panels	Typically 5 to 10 Impacts	No	No
Severe Damage Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	> 50%	> one and ≤ the larger of 20% & 3	> 3 and ≤ 25%	Typically 10 to 20 Impacts	No	No
Destruction Complete roof failure 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

HAZUS estimates the 3-second peak wind gusts for Warren County in the 1938 historic storm scenario to range from 57 to 71mph, characteristic of a Tropical Storm. HAZUS estimates $9,124,700 in damages to the general building stock (structure only). This estimated damage total is less than one percent of Warren County's building inventory. The residential buildings are estimated to experience approximately 98% of the total loss. Table 5.4.5-8 summarizes the building value (structure only) damage estimated for the historic event, by occupancy class.

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

Table 5.4.5-8. Estimated Building Replacement Value (Structure Only) Damaged by Historic 1938 Storm Scenario

Municipality	Total Building Replacement Value (Structure Only)	Total Building Damage (All Occupancies)		Residential Buildings	All Other Occupancies
		Loss	% of GBS RCV Total		
Bolton	$617,682,000	$586,152	0.09%	$561,263	$24,889
Chester	$507,248,000	$211,264	0.04%	$211,264	$0
Glens Falls	$1,866,928,000	$1,003,829	0.05%	$930,810	$73,019
Hague	$258,080,000	$222,965	0.09%	$220,750	$2,215
Horicon	$386,333,000	$429,354	0.11%	$427,489	$1,865

Municipality	Total Building Replacement Value (Structure Only)	Total Building Damage (All Occupancies)		Residential Buildings	All Other Occupancies
		Loss	% of GBS RCV Total		
Johnsburg	$349,807,000	$33,985	0.01%	$33,985	$0
Lake George	$459,912,000	$356,068	0.08%	$351,936	$4,132
Lake George Village	$237,788,000	$75,368	0.03%	$67,072	$8,296
Lake Luzerne	$477,064,000	$359,799	0.07%	$354,206	$5,593
Queensbury	$3,602,139,000	$2,605,680	0.07%	$2,520,428	$85,252
Stony Creek	$93,149,000	$30,608	0.03%	$30,608	$0
Thurman	$187,298,000	$33,193	0.02%	$33,193	$0
Warrensburg	$399,760,000	$162,005	0.04%	$152,496	$9,509
Warren County (Total)	**$9,443,188,000**	**$6,110,270**	**0.06%**	**$5,895,500**	**$214,770**

Source: HAZUS – MH 3.0, default (2010 Census) data. "All Other Occupancies" includes commercial, industrial, agricultural, religious, government and education buildings.

Impact on Critical Facilities

The HAZUS-MH 1938 historic storm scenario was used to estimate the probability that critical facilities (i.e., medical facilities, fire/EMS, police, EOC, schools, and user-defined facilities such as shelters and municipal buildings) may sustain damage as a result of a wind-only event. Additionally, HAZUS-MH estimates the loss of use for each facility in number of days. HAZUS does not predict a loss of days for any critical facility, but does predict moderate damage to Glens Falls Hospital based on the 1938 historic storm track.

Table 5.4.5-9. Estimated Impacts to Critical Facilities for the 1938 Historic Storm Scenario (# of facilities)

Facility Type	500-Year Event				
	Loss of Days	Percent-Probability of Sustaining Damage			
		Minor	Moderate	Severe	Complete
EOC	0	0	0	0	0
Medical	0	0	1	0	0
Police	0	0	0	0	0
Fire	0	0	0	0	0
Schools	0	0	0	0	0

Source: HAZUS-MH 3.0

At this time, HAZUS-MH 3.0 does not estimate losses to transportation lifelines and utilities as part of the hurricane model. Transportation lifelines are not considered particularly vulnerable to the wind hazard; they are more vulnerable to cascading effects such as flooding, falling debris etc. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs.

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

Impact on Economy

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

HAZUS-MH estimates a minimal $5,500 in business interruption costs sustained mainly by the residential occupancy class from relocation and rental costs as a result of the historic storm scenario.

HAZUS-MH 3.0 also estimates the amount of debris that may be produced a result of a wind storm scenario. Table 5.4.5-10 estimates the debris produced based on the 1938 historic model. Because the estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur. According to the HAZUS-MH Hurricane User Manual: '*The Eligible Tree Debris columns provide estimates of the weight and volume of downed trees that would likely be collected and disposed at public expense. As discussed in Chapter 12 of the HAZUS-MH Hurricane Model Technical Manual, the eligible tree debris estimates produced by the Hurricane Model tend to underestimate reported volumes of debris brought to landfills for a number of events that have occurred over the past several years. This indicates that that there may be other sources of vegetative and non-vegetative debris that are not currently being modeled in HAZUS. For landfill estimation purposes, it is recommended that the HAZUS debris volume estimate be treated as an approximate lower bound. Based on actual reported debris volumes, it is recommended that the HAZUS results be multiplied by three to obtain an approximate upper bound estimate. It is also important to note that the Hurricane Model assumes a bulking factor of 10 cubic yards per ton of tree debris. If the debris is chipped prior to transport or disposal, a bulking factor of 4 is recommended. Thus, for chipped debris, the eligible tree debris volume should be multiplied by 0.4*'.

Table 5.4.5-10. Debris Production (Tons) for 1938 Historic Storm Scenario

Municipality	Brick and Wood (tons)	Concrete and Steel (tons)	Trees (tons)	Eligible Tree Weight (tons)	Eligible Tree Volume (cubic yards)
Bolton	7	0	5,474	368	3,740
Chester	0	0	2,721	163	1,715
Glens Falls	45	0	288	205	2,065
Hague	4	0	4,776	137	1,377
Horicon	3	0	6,449	294	2,990
Johnsburg	0	0	6,399	114	1,163
Lake George	3	0	1,860	161	1,664
Lake George Village	0	0	18	13	213
Lake Luzerne	0	0	2,606	166	1,744
Queensbury	55	0	4,411	807	8,102
Stony Creek	0	0	2,592	55	564
Thurman	0	0	2,987	77	780
Warrensburg	0	0	2,228	159	1,652
Warren County (Total)	**117**	**0**	**42,809**	**2,720**	**27,771**

Source: HAZUS-MH 3.0

Effect of Climate Change on Vulnerability

Climate is defined not simply as average temperature and precipitation but also by the type, frequency and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of severe storm events. While predicting changes to the prevalence or intensity of severe storm events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society and the environment (U.S. Environmental Protection Agency [EPA], 2006). Refer to 'Climate Change Impacts' which is discussed earlier in this section for information regarding climate change and severe storm events.

Future Growth and Development

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

Change of Vulnerability

Overall, this vulnerability assessment using a more accurate and updated building inventory which provides more accurate estimated exposure and potential losses for Warren County.

Additional Data and Next Steps

The collection of additional/actual valuation data for general building stock, critical infrastructure and economic losses would further support future estimates of potential exposure and damage for these inventories and the economy.