5.4.6 Severe Weather

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 weather hazard in Dutchess County.

5.4.6.1 Profile

Hazard Description

For the purpose of this HMP and as deemed appropriated by the Dutchess County Steering and Planning Committees, the severe storm hazard includes: hail, high winds, thunderstorms and tornadoes, 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 (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 (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 Dutchess County. High winds are often associated by other severe weather 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 5.4.6-1. NWS Wind Descriptions

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

Source: NWS 2010
mph miles per hour

Tornadoes

Tornadoes are nature's most violent storms and can cause fatalities and devastate neighborhoods in seconds. A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 300 mph. Damage paths can be greater than one mile in width and 50 miles in length. Tornadoes typically develop from either a severe thunderstorm or hurricane as cool air rapidly overrides a layer of warm air. The average speed of a tornado is 30 mph but may vary from nearly stationary to 70 mph. The lifespan of a tornado rarely is longer than 30 minutes (FEMA 1997; NWS 2010).

Thunderstorms

A thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS 2009d). A thunderstorm forms from a combination of moisture, rapidly rising warm air, and a force capable of lifting air such as a warm and cold front, a sea breeze, or a mountain. Thunderstorms form from the equator to as far north as Alaska. 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 80 people are killed by lightning each year. Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes. An estimated 100,000 thunderstorms occur each year in the U.S., with approximately 10% of them classified as severe. During the warm season, thunderstorms are responsible for most of the rainfall.

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.

High Winds

All of Dutchess County is subject to high winds from thunderstorms, hurricanes/tropical storms, tornadoes, and other severe weather events. According to the FEMA Winds Zones of the United States map, Dutchess 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.

Tornadoes

Tornadoes have been documented in every state in the United States, and on every continent with the exception of Antarctica. Approximately 1,200 tornadoes occur in the United States each year, with the central portion of the country experiencing the most. Tornadoes can occur at any time of the year, with peak seasons at different times for different states (NSSL 2014). New York State has a definite vulnerability to tornadoes. Since 1952, over 350 tornadoes ranging from F0 to F4 have occurred throughout the State (NYS DHSES 2014). Based on statistics from 1991 to 2010, New York State has experienced an average of 10 tornadoes annually (NOAA 2013). For Dutchess County, between 1950 and 2014, the County experienced 11 tornadoes, which averages approximately 0.2 tornadoes each year (SPC 2014).

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, Dutchess County can experience between 20 and 30 thunderstorms each year (NOAA 2012).

Extent

High Winds

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

Table 5.4.6-2. 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).

Tornadoes

The magnitude or severity of a tornado was originally categorized using the Fujita Scale (F-Scale) or Pearson Fujita Scale introduced in 1971. This used to be the standard measurement for rating the strength of a tornado. The F-Scale categorized tornadoes by intensity and area and was divided into six categories, F0 (gale) to F5 (incredible). Table 5.4.6-3 explains each of the six F-Scale categories.

Table 5.4.6-3. Fujita Damage Scale

Scale	Wind Estimate (mph)	Typical Damage
F0	< 73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73-112	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113-157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158-206	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207-260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261-318	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yards); trees debarked; incredible phenomena occur.

Source: Storm Prediction Center (SPC) Date Unknown
mph miles per hour

The Enhanced Fujita Scale (EF-Scale) is now the standard used to measure the strength of a tornado. 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 (DI) and Degree of Damage (DOD), which help better estimate the range of wind speeds produced by the tornado. From that, a rating is assigned, similar to that of the F-Scale, with six categories from EF0 to EF5, representing increasing degrees of damage. The EF-Scale was revised from the original F-Scale to reflect better examinations of tornado damage surveys. This new scale considers how most structures are designed (NOAA 2008). Table 5.4.6-4 displays the EF-Scale and each of its six categories.

Table 5.4.6-4. Enhanced Fujita Damage Scale

EF-Scale Number	Intensity Phrase	Wind Speed (mph)	Type of Damage Done
EF0	Light tornado	65–85	**Light damage**. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over.
EF1	Moderate tornado	86-110	**Moderate damage**. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	Significant tornado	111-135	**Considerable damage**. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.

EF-Scale Number	Intensity Phrase	Wind Speed (mph)	Type of Damage Done
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 meters (109 yards); high-rise buildings have significant structural deformation; incredible phenomena occur.

Source: SPC Date Unknown
EF-Scale Enhanced Fujita Scale
mph miles per hour

Tornado watches and warning are issued by the local NWS office. A tornado watch is released when tornadoes are possible in an area. A tornado warning means a tornado has been sighted or indicated by weather radar. The current average lead time for tornado warnings is 13 minutes. Occasionally, tornadoes develop so rapidly, that little, if any, advance warning is possible (NOAA 2013; FEMA 2013).

Thunderstorms

Severe thunderstorm watches and warnings are issued by the local NWS office and 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 State 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).

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 5.4.6-5 shows the different sizes of hail and the comparison to real-world objects.

Table 5.4.6-5. 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: NOAA 2012; NYS DHSES 2014

Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with severe storm events throughout Dutchess 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, Dutchess County has been included in nine declarations (FEMA 2015).

For this 2015 Plan, known severe storm events, including FEMA disaster declarations, which have impacted Dutchess County between 1990 and 2015 are identified in Table 5.4.6-6. 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 Dutchess 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 5.4.6-6. Severe Storm Events in Dutchess County, 1990 to 2015

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
July 31, 1992	Tornado (F1)	N/A	N/A	Severe thunderstorms produced tornadoes in Cortland County and in northern and central Dutchess County. In Dutchess County, a fairly large tornado cut a swatch of destruction over 20 miles long and 75 yards wide through northern and central parts of the County. The tornado began in the Town of Poughkeepsie and ended in the Town of Northeast. It destroyed thousands of trees and downed hundreds of power lines. There was also damage to homes and barns. The hardest hit areas in the County were Salt Point Turnpike in the Town of Poughkeepsie, West and Whiteford Roads in Pleasant Valley, and the Valley Farm and Stanford Road in the Town of Washington. The County had approximately $2.5 million in property damage from this event.
May 11, 1993	Thunderstorms and Wind	N/A	N/A	Severe thunderstorms impacted eastern New York State with some of the hardest hit areas located in Dutchess County. The County had downed trees, power lines and utility poles that left over 3,000 customers without power. Property damage in the County was estimated at $10,000.
August 1, 1994	Thunderstorms and Wind	N/A	N/A	Severe thunderstorms damaged parts of eastern New York State. In the Township of Poughkeepsie and Hopewell Junction in Dutchess County, the storms downed numerous trees and powerlines and caused extensive damage to a golf course. The County had approximately $50,000 in property damage.
July 26, 1995	Thunderstorms and Flash Flood	N/A	N/A	Severe thunderstorms brought heavy rain and flash flooding to Dutchess County. The Stony Creek in the Village of Tivoli overflowed its banks and caused flooding. Property damages in the County from this event was approximately $50,000.
January 19-30, 1996	Severe Storms and Flooding	DR-1095	Yes	Unseasonably warm temperatures resulted in the rapid melting of one to three feet of snow. In addition to the snow melt, one to three inches of rain fell, resulting in widespread flooding across Dutchess County. Small streams flooded and many roads were washed out. Extensive flooding occurred along the Hudson River and Wappingers Creek. In the higher elevations, there were numerous road washouts. In the Town of Pawling, 50% of the roads in the town were washed out. In the Towns of North East and Amenia, widespread and severe damage also occurred. In the Town of East Fishkill, an ice jam occurred on Fishkill Creek in Hopewell Junction, which caused the gaging station to reach a maximum height of 11.71 feet. On January 27th, strong winds blew across eastern New York State, downing trees, limbs and power lines across the area. Southern Dutchess County saw some of the worst damage with over 6,000 customers without power. Overall, there was $160 million in damages in New York State, of which, $7 million of damages in Dutchess County.
June 30, 1998	Severe Thunderstorms and Flash Flooding	N/A	N/A	Severe thunderstorms and flash flooding impacted Dutchess and Ulster Counties. The storms downed trees and wires and brought large hail across several locations in the counties. Torrential rains from the storms produced flash flooding across Ulster and southern Dutchess County. In Dutchess County, there were several

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
				flooded basements in the Village of Wappingers Falls and they had to be pumped out. There was also flooding of roadways in Hopewell Junction (Town of East Fishkill) and Wingdale (Town of Dover). The County had approximately $12,000 in property damages from this event.
January 18-19, 1999	Heavy Rain, Flooding and Ice Jam	N/A	N/A	Heavy rain and an ice jam in Dutchess County resulted in Wassaic Creek overflowing its banks and flooding County Route 81 in the Town of Amenia. Several homes were evacuated in this area due to the flooding. The County had approximately $10,000 in property damages.
September 16-17, 1999	Remnants of Hurricane Floyd	DR-1296	Yes	The remnants of Hurricane Floyd moved up the east coast of the United States; it brought high winds and heavy rain to eastern New York State. Rainfall totals ranged from three to six inches. Some areas received up to a foot of rain. The rain produced widespread flooding across the region, leading to severe damage and one fatality (in Dutchess County). Significant flooding was noted on many smaller tributaries including the Esopus, Catskill and Schoharie Creeks. Wind gusts from Floyd ranged from 49 mph to over 60 mph. The rain and strong winds produced massive power outages. Damages to Dutchess County were approximately $1 million.
May 18, 2000	Tornado (F0)	N/A	N/A	This was the largest outbreak of severe weather across eastern New York State in nearly two years. This system brought a series of thunderstorms and strong winds. In addition to the thunderstorms, there were two confirmed tornadoes in the area as well. The winds from the thunderstorms downed large trees and power lines in Albany, Columbia, Greene, Montgomery, Saratoga, Schoharie, and Ulster Counties. Dutchess County was especially hit hard. A series of microbursts entered Dutchess County, moving over the southern portion of Hyde Park and the Poughkeepsie Yacht Club in the northern part of the Town. This microburst overturned several boats and a trailer was overturned. The roof was blown off the Yacht Club. A F0 tornado touched down in the Fairview section of the Town of Poughkeepsie. Damage from the tornado was marginal and was confined to downed trees and some minor structural damage to several homes. Wind from the thunderstorms damaged other portions of Dutchess County. There was another microburst that produced damage between County Route 83, east of the Village of Leedsville. This event also downed trees and even uprooted trees in Clinton Corners. Powerlines were knocked down in Rhinebeck. Utility poles were knocked down in the Village of Fishkill. Overall, the County had over $1 million in property damage from this series of events.
July 14-17, 2000	Severe Storms	DR-1335	Yes	Widespread and heavy rainfall impacted eastern New York State, bringing a two-day rain total of over 11 inches in some parts of the area (Ulster County). The excessive rain resulted in flooding and flash flooding. Overall, New York State had $35 million in property damage as a result of this storm series. Between July 14th

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
				and 17th, Dutchess County's rainfall totals ranged from 1.1 inches in Clinton Corners (Town of Clinton) to 1.61 inches in the Town of Red Hook.
December 17, 2000	Heavy Rain and Flooding	N/A	N/A	A record breaking rainstorm struck eastern New York State with rainfall totals ranging between two and four inches with some locally higher amounts. Nearly four inches of rain fell in Dutchess County, causing over $100,000 in property damage.
May 31, 2002	Tornado (F1)	N/A	N/A	This was identified as the largest widespread severe event in eastern New York State in exactly four years. A line of thunderstorms first entered Herkimer County. The first of two tornadoes (F1) briefly touched down in Fulton County. The tornado damaged an old movie theater and threw debris up to a third of a mile away. The line of storms moved east and brought minor to moderate wind damage in Albany, Washington, Warren, Saratoga, Schenectady, Schoharie, Columbia, Montgomery, and Rensselaer Counties. In Dutchess County, there were downed trees and wires countywide. A car was crushed by a tree near Poughkeepsie. The second tornado touched down at Whaley Lake in southeast Dutchess County. It had wind speeds of around 75 mph. Damage from the tornado was mainly confined to downed and twisted trees. Dime size hail fell at Salt Point. The County had approximately $67,000 in property damage.
June 16, 2002	Tornado (F1)	N/A	N/A	Thunderstorms moved over the Hudson Valley of eastern New York State, with some becoming sever. Most of the reports showed hail damage; however, there were two confirmed tornado touchdowns as well as one non-tornadic destructive wind report. The first tornado touched down in Montgomery County. The second tornado had wind speeds around 100 mph and touched down near Pawling in Dutchess County. Damage from this event was mostly confined to downed and twisted trees. Damages in Dutchess County were approximately $20,000.
September 28, 2003	Tornado (F1)	N/A	N/A	A line of thunderstorms developed over eastern New York State during the early morning. A cell broke loose from the line and spawned a tornado across the Town of Fishkill in Dutchess County. The length was just over one mile and the width ranged between 25 and 100 yards. Most of the damage was to trees and some power lines were knocked down. A transformer blew and debris shattered a window of a home. This event caused approximately $10,000 in damages to the County.
October 15, 2003	Strong Winds	N/A	N/A	Strong winds across eastern New York State downed trees and power lines. In Dutchess County, the Towns of Poughkeepsie, Millbrook, Hyde Park, Fishkill and East Fishkill reported a concentrated area of downed trees. One tree fell onto a car in Poughkeepsie. Power lines were also knocked down in the County. This storm caused approximately $10,000 in damages in Dutchess County.
May 13 – June 17, 2004	Severe Storms and Flooding	DR-1534	Yes	May 13th – a cold front moving through New York State brought a line of strong to severe thunderstorms in the eastern part of the State. Numerous roadside culverts were washed out, and roads were closed due to heavy amounts of rain that fell in a

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
				short period of time. In Dutchess and Columbia Counties, there were several reports of hail and downed trees and power lines. June 9th – a series of strong to locally severe thunderstorms brought damage to numerous counties in eastern New York State. Most of the damage were downed trees and power lines which led to power outages.
October 2005	Heavy Rain and Flooding	N/A	N/A	Two rain events in October brought a total of one to two feet of rain across eastern New York State. The first event occurred October 7th and 8th which was due to the remnants of Tropical Storm Tammy. The second event occurred from October 12th through 14th. The worst flooding in New York State occurred in Dutchess County. The first event in Dutchess County caused the Wappingers Creek to crest at 8.33 feet. The second event caused the Wappingers Creek to crest at 11.16 feet at the Village of Wappingers Falls.
October 19, 2005	Heavy Rain and Flooding	N/A	N/A	Heavy rains caused flooding of the Ten Mile River which affected the Towns of Dover, Pawling, and Beekman. There was also flooding in the Town of Milan. This event resulted in $500,000 in property damage in Dutchess County.
June 25, 2006	Tornado (F1)	N/A	N/A	A tornado was reported at Lagrangeville. It was on the ground between 15 and 30 seconds traveling half a mile and cutting a path 150 yards wide.
April 16-18, 2007	Severe Storms and Inland and Coastal Flooding	DR-1692	Yes	An intense coastal storm brought heavy precipitation across the lower Hudson Valley of New York State. At first, the precipitation fell as wet snow, sleet and rain and then changed to all rain. Precipitation totals ranged from three to eight inches and led to widespread flooding across the lower and mid-Hudson Valley region. In Dutchess County, small streams and creeks flooded throughout the County. Record flooding occurred on the Wappingers Creek at Wappingers Falls which crested at 7.06 feet above its flood stage of eight feet. Moderate flooding was recorded along Tenmile River at Webatuck which crested at 11.23 feet. The flooding led to numerous road closures which included large stretches of the Taconic State Parkway in both directions. Additionally, numerous home foundations collapsed near Stormville (Town of East Fishkill). The County had approximately $5.7 million in damages.
October 7, 2009	Strong Wind	N/A	N/A	Strong gusty winds in Dutchess County led to downed trees and power lines in several municipalities. In the Town of East Fishkill, a tree downed wires on Route 52 and the Taconic State Parkway. In the Town of Red Hook, a tree downed wires on Kelly Road. In Wappingers Falls, a tree fell onto a care at Route 9 and Alpine Drive. The County had approximately $13,000 in property damage from this event.
August 26 – September 5, 2011	Hurricane Irene	DR-4020	Yes	As Hurricane Irene moved north along the Atlantic coast, it weakened and made its second landfall as a Tropical Storm near Little Egg Inlet along the southeast New Jersey coast. The storm made its third landfall in New York City on August 28th. This storm brought sustained winds, heavy rain, destructive storm surge and two confirmed tornadoes. Heavy rainfall resulted in widespread moderate flooding across the area. Seven deaths resulted from Irene. At least 600,000 people were

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
				ordered to evacuate their homes from storm surge and inland flooding. Widespread power outages of up to one week followed the storm. The strong winds from Irene pushed a three to five foot storm surge of water along western Long Island South, New York Harbor, the southern and eastern bays of Long Island, and southern bays of New York City. This resulted in moderate to major coastal flooding, wave damage and erosion along the coast, with heavy damage to public beaches and other public and private facilities. In Dutchess County, flash flooding was reported in several locations. Numerous roads and bridges were closed or damaged due to flooding and downed trees. There were mandatory evacuations in the County as well. Record flooding was recorded on the Hudson River at Poughkeepsie and major flooding occurred on the Hoosic River at Eagle Bridge, Hudson River at Troy and on Wappingers Creek at Wappingers Falls. Moderate flooding was reported on Tenmile River at Webatuck (Town of Amenia) and minor flooding on the Hudson River at Waterford. Flooding occurred in the Town of Rhinebeck along Route 9G. Power outages in Dutchess County impacted 25,000 customers.
October 27 – November 8, 2012	Hurricane Sandy	DR-4085 / EM-3351	No / 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 Dutchess County, wind speeds reached 47 mph. Flooding in Dutchess County occurred along the Hudson River throughout the County. In Lake Carmel (Town of Kent), Route 292 was closed due to downed trees and wires between Bundy Hills Road and Sanita Road. There were numerous debris lines along the Poughkeepsie Waterfront on the Hudson River due to tidal flooding. Record flooding occurred on the Hudson River at Poughkeepsie as the River reached 9.54 feet. The surge of water moved all the way to the City of Albany. Water reached the deck of the Icehouse Restaurant (City of Poughkeepsie). Two to four feet of water reached inside the restaurant, based on water marks.
June 25, 2014	Thunderstorms and Lightning	N/A	N/A	Heavy rain and thunderstorms developed in the region of Dutchess County. The heavy rainfall led to significant runoff which caused flash flooding in some areas. Many roads were closed due to flooding and some homes were impacted by flooding as well. A few of the storms produced strong winds and damaging lightning strikes. In Dutchess County, lightning struck a home in the Town of Rhinebeck which caused a fire. There was approximately $5,000 in damages.

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
July 23, 2014	Thunderstorms and Lightning	N/A	N/A	Thunderstorms produced damaging winds and large hail in the region of Dutchess County. In Wiccopee (Town of East Fishkill), a house was struck by lightning and caught fire, causing $25,000 in property damage.

Source(s): FEMA 2015; NOAA-NCDC 2015; NWS 2015; NYS HMP 2014

FEMA Federal Emergency Management Agency
HMP Hazard Mitigation Plan
NCDC National Climatic Data Center
NOAA National Oceanic and Atmospheric Administration
NWS National Weather Service
NYS New York State

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 Dutchess 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 5.4.6-7. Probability of Occurrence of Severe Storm Events

Hazard Type	Number of Occurrences Between 1950 and 2015	Probability
Hail	139	2.2
Wind	75	1.2
Thunderstorm	384	5.9
Tornado	11	0.2
Lightning	12	0.2
Total	621	9.5

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

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

Temperatures in New York State are warming, with an average rate of warming over the past century of 0.25° F per decade. Average annual temperatures are projected to increase across New York State by 2° F to 3.4° F

by the 2020s, 4.1° F to 6.8° F by the 2050s, and 5.3° F to 10.1° F by the 2080s. By the end of the century, the greatest warming is projected to be in the northern section of the State (NYSERDA 2014).

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

In Region 5, it is estimated that temperatures will increase by 3.5ºF to 7.1ºF by the 2050s and 4.1ºF to 11.4ºF by the 2080s (baseline of 47.6ºF). Precipitation totals will increase between 2 and 15% by the 2050s and 3 to 17% by the 2080s (baseline of 38.6 inches). Table 5.4.6-8 displays the projected seasonal precipitation change for the East Hudson and Mohawk River Valleys ClimAID Region (NYSERDA 2011).

Table 5.4.6-8. Projected Seasonal Precipitation Change in Region 5, 2050s (% change)

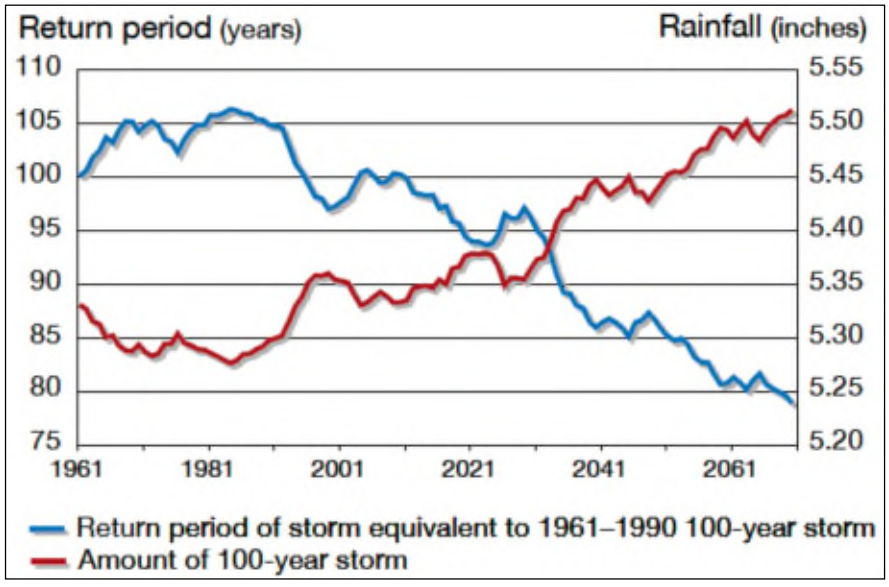
Winter	Spring	Summer	Fall
5 to +15	-5 to +10	-5 to +5	-5 to +10

Source: NYSERDA 2011

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

Figure 5.4.6-1 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 5.4.6-1. Projected Rainfall and Frequency of Extreme Storms



Source: NYSERDA 2011

5.4.6.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the severe weather hazard, all of Dutchess 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 weathers 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 2006 Dutchess County Hazard Mitigation Plan and 2010 Eastern Dutchess All-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 hurricane/tropical storm discussion in Section 5.4.1 [Coastal Hazards] and flooding discussion in Section 5.4.3 [Flood]). Secondary flooding associated with the torrential downpours during severe storms is also a primary concern in Dutchess County. The County has experienced flooding in association with numerous severe storms in the past.

The entire inventory of Dutchess 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 Dutchess County for two probabilistic hurricane events, the 100-year and 500-year MRP wind events. The impacts on population, existing structures and critical facilities on the County are presented below, following a summary of the data and methodology used.

Data and Methodology

The 2010 U.S. Census population and general building stock data were used to support an evaluation of assets exposed to this hazard and the potential impacts associated with this hazard. Refer to Section 5.4.1 (Coastal Hazards) for additional information on the methodology pertaining to the wind and storm surge impacts.

Impact on Life, Health and Safety

For the purposes of this HMP, the entire population of Dutchess County (297,488 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 weather 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 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

Damage to buildings is dependent upon several factors including wind speed and duration, and building construction. Refer to Section 5.4.1 (Coastal Hazards) for a presentation on potential wind losses associated with 100- and 500-year mean return period events. Damage will result from hail stones themselves and will have a specific impact on roofs. The extent of damage will depend on the size of the hailstorm.

Impact on Critical Facilities

Overall, all critical facilities are exposed to the wind hazard associated with severe storms. Refer to Section 5.4.1 (Coastal Hazards) for a presentation on estimated impacts to critical facilities associated with 100- and 500-year mean return period events.

Impact on Economy

As discussed, severe storm events can impact structures and the economy. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting and goods transport) transportation needs. Utility infrastructure (power lines, gas lines, electrical systems) could suffer damage and impacts can result in the loss of power, which can impact business operations and can impact heating or cooling provision to the population. Refer to Section 5.4.1 (Coastal Hazards) for a presentation on estimated economic losses associated with 100- and 500-year mean return period events.

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 events like hurricanes. While predicting changes to the prevalence or intensity of hurricanes and the events affects 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 Dutchess 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.