5.4.6 Severe Storms

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 Rockland County.

5.4.6.1 Profile

Hazard Description

For the purpose of this HMP and as deemed appropriated by the Rockland County Steering and Planning Committees, the severe storm hazard includes: hail, high winds, thunderstorms, tornadoes, Nor'Easters, and hurricanes/tropical storms, 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 Rockland 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.

Nor'Easters

A Nor'Easter is a cyclonic storm that moves along the East Coast of North America. It is called a Nor'Easter because the damaging winds over coastal areas blow from a northeasterly direction. Nor'Easters can occur any time of the year, but are most frequent and strongest between September and April. These storms usually develop between Georgia and New Jersey within 100 miles of the coastline and typically move from southwest to northeast along the Atlantic Coast of the United States (NOAA 2013).

In order to be called a Nor'Easter, a storm must have the following conditions, as per the Northeast Regional Climate Center (NRCC):

- Must persist for at least a 12-hour period
- Have a closed circulation
- Be located within the quadrilateral bounded at 45°N by 65° and 70°W and at 30°N by 85°W and 75°W
- Show general movement from the south-southwest to the north-northeast
- Contain wind speeds greater than 23 miles per hour (mph)

A Nor'Easter event can cause storm surges, waves, heavy rain, heavy snow, wind, and coastal flooding. Nor'Easters have diameters that can span 1,200 miles, impacting large areas of coastline. The forward speed of a Nor'Easter is usually much slower than a hurricane, so with the slower speed, a Nor'Easter can linger for days and cause tremendous damage to those areas impacted. Approximately 20 to 40 Nor'Easters occur in the northeastern United States every year, with at least two considered severe (Storm Solution 2014). The intensity of a Nor'Easter can rival that of a tropical cyclone in that, on occasion, it may flow or stall off the mid-Atlantic coast resulting in prolonged episodes of precipitation, coastal flooding, and high winds.

Hurricanes/Tropical Storms

A hurricane is a tropical storm that attains hurricane status when its wind speed reaches 74 or more miles an hour. Tropical systems may develop in the Atlantic between the Lesser Antilles and the African coast, or may develop in the warm tropical waters of the Caribbean and Gulf of Mexico. These storms may move up the Atlantic coast of the United States and impact the eastern seaboard, or move into the United States through the states along the Gulf Coast, bringing wind and rain as far north as New England before moving offshore and heading east.

A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds and heavy rain (winds are at a lower speed than hurricane-force winds, thus gaining its status as tropical storm versus hurricane). Tropical storms strengthen when water evaporated from the ocean is released as the saturated air rises, resulting in condensation of water vapor contained in the moist air. They are fueled by a different heat mechanism than other cyclonic windstorms such as Nor'Easters and polar lows. The characteristic that separates tropical cyclones from other cyclonic systems is that at any height in the atmosphere, the center of a tropical cyclone will be warmer than its surroundings; a phenomenon called "warm core" storm systems (NOAA 1999).

The National Weather Service (NWS) issues hurricane and tropical storm watches and warnings. These watches and warnings are issued or will remain in effect after a tropical cyclone becomes post-tropical, when such a storm poses a significant threat to life and property. The NWS allows the National Hurricane Center (NHC) to issue advisories during the post-tropical stage. The following are the definitions of the watches and warnings:

- *Hurricane/Typhoon Warning* is issued when sustained winds of 74 mph or higher are expected somewhere within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the warning is issued 36 hours in advance of the anticipated onset of tropical storm force winds. The warning can remain in effect when dangerously high water or combination of dangerously high water and waves continue, even though winds may be less than hurricane force.
- *Hurricane Watch* is issued when sustained winds of 74 mph or higher are possible within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the hurricane watch is issued 48 hours prior to the anticipated onset of tropical storm force winds.

- *Tropical Storm Warning* is issued when sustained winds of 39 to 73 mph are expected somewhere within the specified area within 36 hours (24 hours for the western north Pacific) in association with a tropical, subtropical, or post-tropical storm.
- *Tropical Storm Watch* is issued when sustained winds of 39 to 73 mph are possible within the specified area within 48 hours in association with a tropical, sub-tropical, or post-tropical storm (NWS 2013).

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 Rockland 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, Rockland 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 Rockland County, between 1950 and 2015, the County experienced one tornado, which averages approximately 0.1 tornadoes each year (SPC 2016).

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

Nor'Easters

Nor'Easters threaten the entire east coast of the United States, where the coastal ears are the most susceptible because these areas are directly exposed; however, the impacts of these storms are often felt far inland as well. According to the New York State Hazard Mitigation Plan, the coastal region of New York State is extremely vulnerable to Nor'Easters; however, these storms can impact the entire state.

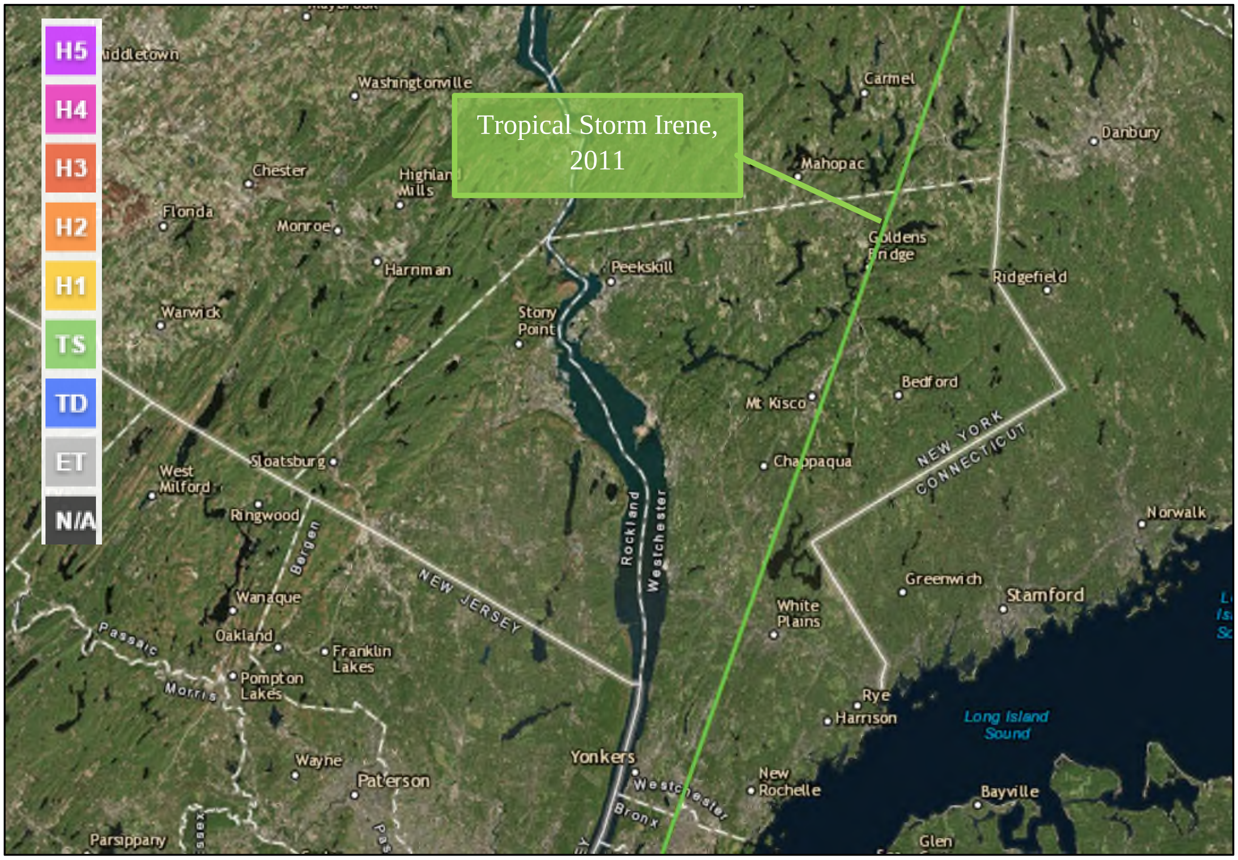
Hurricanes/Tropical Storms

Hurricanes and tropical storms can impact New York State from June to November, the official eastern United States hurricane season. However, late July to early October is the period hurricanes and tropical storms are most likely to impact New York State, due to the coolness of the North Atlantic Ocean waters (NYS DHSES 2014).

Rockland County is vulnerable to the impacts of hurricanes and tropical storms. However, it depends on the storm's track. Inland areas, like western Rockland County, are at risk for flooding due to the heavy rain and winds produced by hurricanes and tropical storms. The majority of damage from these events often results from residual wind damage and inland flooding, most recently experienced during Hurricane Irene in August 2011. Additionally, areas of Rockland County bordered by the Hudson River are susceptible to flooding from tidal-influenced storm surge associated with hurricanes and tropical storms.

NOAA's 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 catalogs tropical cyclones that have occurred from 1842 to 2015 (latest date available from data source). Between 1950 and 2015, 15 tropical cyclones tracked within 65 nautical miles of Rockland County. Figure 5.4.6-1 displays the tropical cyclone track for Rockland County that tracked with 65 nautical miles between 2010 and 2015. Please note that the figure does not show Hurricane Sandy passing within 65 nautical miles of the County.

Figure 5.4.6-1. Historical Tropical Storm and Hurricane Tracks 1990 to 2014



Source: NOAA NHC 2016

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 5.4.6-2 shows the different sizes of hail and the comparison to real-world objects.

Table 5.4.6-2. 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: NOAA 2012; NYS DHSES 2014

High Winds

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

Table 5.4.6-3. NWS Wind Descriptions

Descriptive Term	Sustained Wind Speed (mph)
Strong, dangerous, or damaging	$\geq$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 5.4.6-4 explains each of the six F-Scale categories.

Table 5.4.6-4. 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 5.4.6-5 displays the EF-Scale and each of its six categories.

Table 5.4.6-5. Enhanced Fujita Damage Scale

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

EF-Scale Number	Intensity Phrase	Wind Speed (mph)	Type of Damage Done
			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).

Nor'Easters

The extent of a Nor'Easter can be classified by meteorological measurements and by evaluating its societal impacts. NOAA's NCDC is currently producing the Regional Snowfall Index (RSI) for significant snowstorms that impact the eastern two-thirds of the U.S. The RSI ranks snowstorm impacts on a scale from 1 to 5. It is based on the spatial extent of the storm, the amount of snowfall, and the interaction of the extent and snowfall totals with population (based on the 2000 U.S. Census). The NCDC has analyzed and assigned RSI values to over 500 storms since 1900 (NOAA-NCDC 2011). Table 5.4.5-5 lists the five categories.

Table 5.4.6-6. RSI Ranking Categories

Category	Description	RSI Value
1	Notable	1-3
2	Significant	3-6
3	Major	6-10

Category	Description	RSI Value
4	Crippling	10-18
5	Extreme	18+

Source: NOAA-NCDC 2011
RSI Regional Snowfall Index

Nor'Easters have the potential to impact society to a greater extent than hurricanes and tornadoes. These storms often have a diameter three to four times larger than a hurricane and therefore, impact much larger areas. More homes and properties become susceptible to damage as the size and strength of a Nor'Easter intensifies (Storm Solution 2013). The severity of a Nor'Easter depends on several factors including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, time of occurrence during the day (e.g., weekday versus weekend), and season.

Hurricanes/Tropical Storms

The extent of a hurricane is categorized in accordance with the Saffir-Simpson Hurricane Scale. The Saffir-Simpson Hurricane Wind Scale is a 1-to-5 rating based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. Category 1 and 2 storms are still dangerous and require preventative measures (NOAA 2013). Table 5.4.6-7 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

Table 5.4.6-7. The Saffir-Simpson Scale

Category	Wind Speed (mph)	Expected Damage
1	74-95 mph	Very dangerous winds will produce some damage: Homes with well-constructed frames could have damage to roof, shingles, vinyl siding, and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph	Extremely dangerous winds will cause extensive damage: Homes with well-constructed frames could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph	Devastating damage will occur: Homes with well-built frames may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph	Catastrophic damage will occur: Homes with well-built frames can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	>157 mph	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

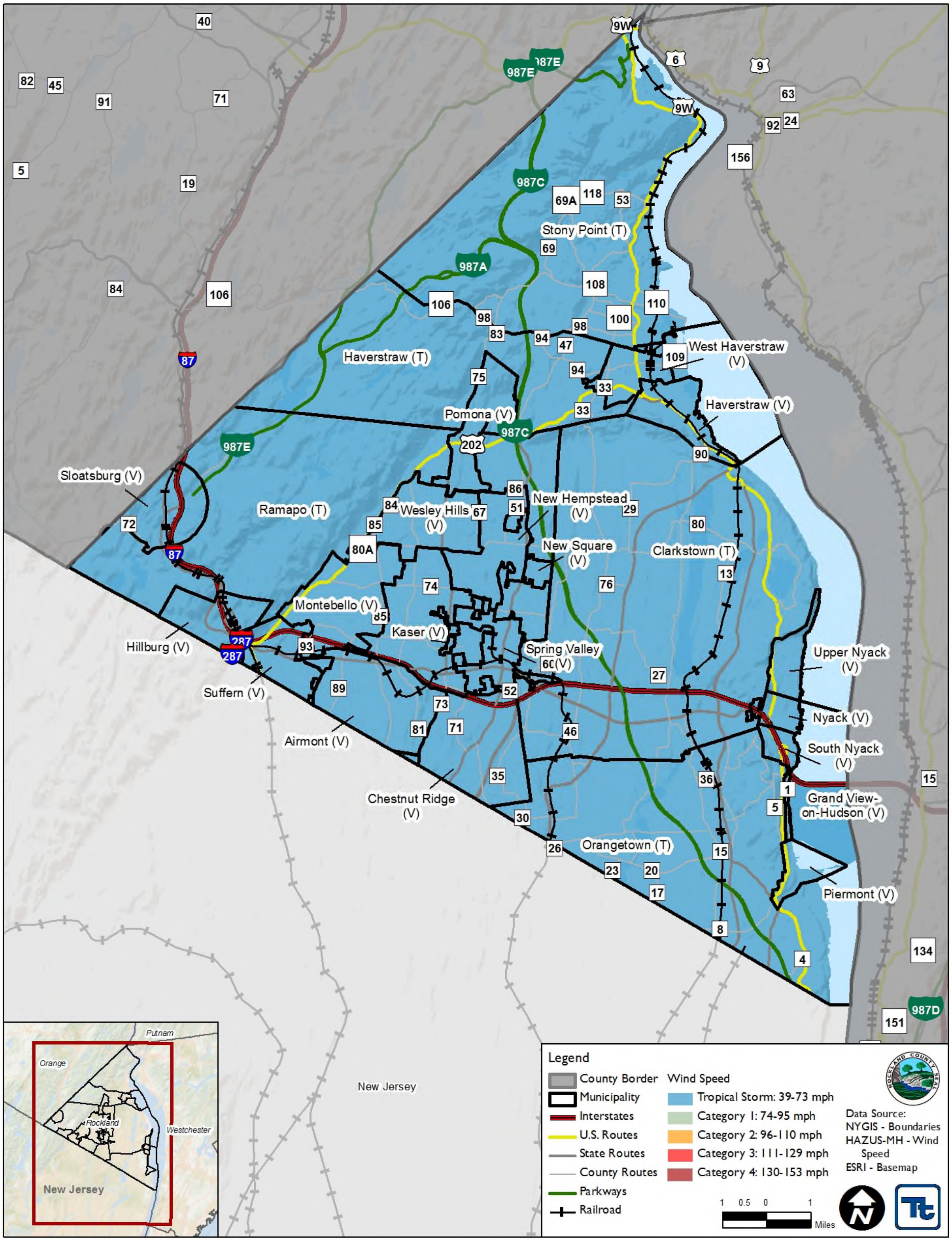
Source: NOAA 2013
Notes: mph = Miles per hour
> = Greater than

Mean Return Period

In evaluating the potential for hazard events of a given magnitude, a mean return period (MRP) is often used. The MRP provides an estimate of the magnitude of an event that may occur within any given year based on past recorded events. MRP is the average period of time, in years, between occurrences of a particular hazard event, equal to the inverse of the annual frequency of exceedance (Dinicola 2009).

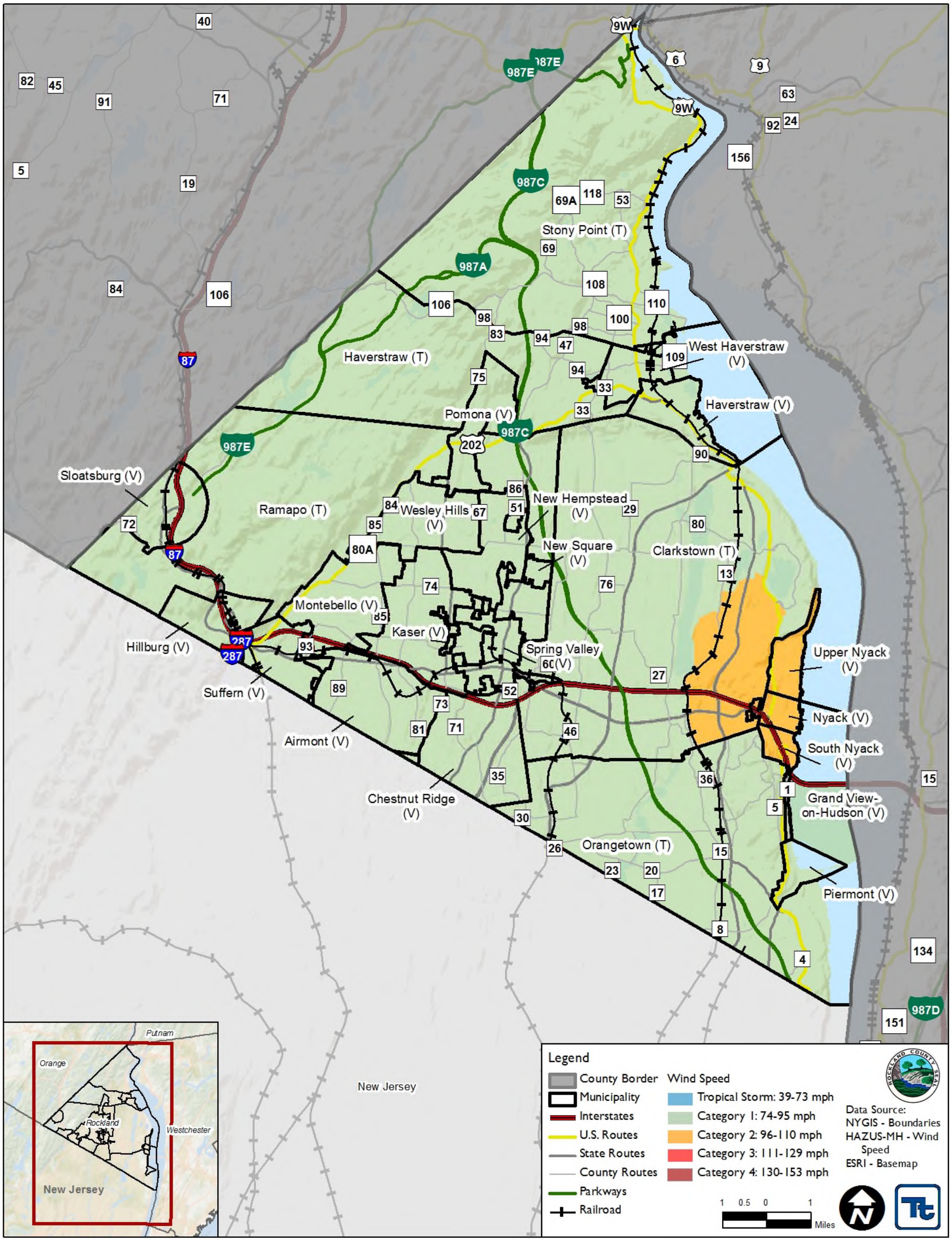
Figure 5.4.6-2 and Figure 5.4.6-3 show the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP events. These peak wind speed projections were generated using Hazards U.S. Multi-Hazard (HAZUS-MH) model runs. HAZUS-MH 3.1 did not generate the hurricane track for the 100- and 500-year event. The maximum 3-second gust wind speeds for Rockland County range from 39 to 73 mph for the 100-year MRP event. The maximum 3-second gust wind speeds for Rockland County range from 74 to 110 mph for the 500-year MRP event. The associated impacts and losses from these 100-year and 500-year MRP hurricane event model runs are reported in the Vulnerability Assessment.

Figure 5.4.6-2. Wind Speeds for the 100-Year Mean Return Period Event



Source: *HAZUS-MH 3.2*

Figure 5.4.6-3. Wind Speeds for the 500-Year Mean Return Period Event



Source: *HAZUS-MH 3.2*

Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with severe storm events throughout Rockland 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 2016, 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, Rockland County has been included in 11 declarations (FEMA 2016). Additionally, Rockland County included in two declarations identified as a snowstorm and/or severe winter storm. However, these events were also identified as Nor'Easters and are included in the table below.

For this Plan update, known severe storm events, including FEMA disaster declarations, which have impacted Rockland County between 2009 and 2016 are identified in Table 5.4.6-6. For events prior to 2009, refer to the 2010 Rockland County Multi-Jurisdictional Hazard Mitigation Plan. 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 Rockland 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 5.4.6-8. Severe Storm Events in Rockland County, 2009 to 2016

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
August 10, 2009	Severe Thunderstorms	N/A	N/A	A series of severe thunderstorms moved across the Lower Hudson Valley. In Rockland County, numerous trees were reported down in the Town of Stony Point. Some homes were damaged as a result of the downed trees. Numerous wires were reported down as well. In Garnerville (Town of Haverstraw), a large tree fell into a pool. In New City (Town of Clarkstown), a tree snapped in half on Ember Drive. Damages in the County were estimated at $27,500.
November 27-28, 2009	Strong Winds	N/A	N/A	Strong winds developed bringing peak wind gusts of 40 to 50 mph. They downed tree limbs and caused scattered power outages across southeast New York State. In Rockland County, strong winds combined with heavy rain downed trees and power lines across the county. This led to power outages impacting thousands of residents. The County had approximately $7,500 in damages from this event.
January 25, 2010	High Wind	N/A	N/A	Strong winds knocked down numerous trees and power lines in Rockland County. In the Village of Nyack, a tree knocked down a utility pole. A tractor trailer was overturned on the Tappan Zee Bridge due to the high winds. The County had approximately $100,000 in damages from this event.
March 13-31, 2010	Severe Storms and Flooding	DR-1899	Yes	March 13 – A Nor'Easter developed producing heavy rainfall as it moved slowly across the northeast. This storm caused widespread flooding across portions of southeast New York State. In Rockland County, the Mahwah River at Suffern (village) exceeded bankful and crested at 7.06 feet on March 14th. The Ramapo River at Ramapo (town) also rose out of its banks causing Route 17 to be closed due to flooding in the Villages of Sloatsburg and Hillburn. Several other rivers and small streams in the county also rose out of their banks and caused flooding. The New York State Thruway was closed from exit 15A to the Orange County line. March 23 – A low pressure system produced heavy rainfall which caused isolated small stream flooding in Rockland County. The Mahwah River in Suffern (village) exceeded bankful and crested at 4.88 feet. March 29 – A Nor'Easter produced heavy rain across the area as it moved to the northeast. This caused widespread flooding across portions of the Lower Hudson Valley, New York City and Long Island. In Rockland County, Route 59 eastbound at Route 303 south in West Nyack (Town of Clarkstown) was closed due to flooding. Rainfall totals ranged from 2.91 inches in the Village of Suffern to 3.82 inches in the Village of Spring Valley.
June 6, 2010	Thunderstorms	N/A	N/A	Numerous thunderstorms moved across the Lower Hudson Valley. In Rockland County, a tree fell onto a car at Exit 16 of the Palisades Parkway in the Town of Stony Point. A downed tree was also reported on US 9 near Buckberg Mountain Road in the Town and US 9 was closed for two hours. Wires were reported down in

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
				the Town of Stony Point and Garnerville (Town of Haverstraw). The County had approximately $12,000 in damages from this event.
July 19, 2010	Severe Thunderstorms and Lightning	N/A	N/A	Severe thunderstorms moved across southeast New York State, impacting Rockland County. In the Town of Orangetown, lightning struck a garage and caused a fire in Pearl River. A downed tree was reported across a southbound lane on the Palisades Parkway between exits 6E and 5S. Another downed tree across a car was reported at Kings Highway. In Tappan, multiple trees and power lines were reported down. In the Village of Suffern, penny size hail was reported at exit 15 on the New York State Thruway. Overall, the County had approximately $30,000 in property damage from this event.
December 26-27, 2010	Severe Winter Storm and Snowstorm (Nor'Easter)	DR-1957	Yes	A major Nor'Easter brought significant snow and blizzard conditions to much of the northeast United States, including the New York City area. Bands of heavy snow with snowfall rates of one to three inches an hour occurred across the region. Strong, gusty winds were also associated with this storm. Wind gusts across the region ranged from 35 to 45 mph with gusts of 50 to 70 mph reported across southeastern New York State, Connecticut and eastern Massachusetts. In the New York City area, strong winds pushed the falling snow into drifts of up to four feet. There were major transportation delays as airports and rail shut down across the city and Long Island. This was one of the worst blizzards in history for New York City and its surrounding areas. Snowfall totals in Rockland County exceeded 18 inches.
July 8, 2011	Thunderstorms	N/A	N/A	Severe thunderstorms brought damaging winds and large hail to Orange and Rockland Counties. In Rockland County, a large tree fell onto a house in New City (Town of Clarkstown). Lightning struck a substation in Sparkill (Town of Orangetown), knocking power out to over 2,500 customers. Overall, the County had approximately $15,000 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 28^{th}. 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 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.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
				In Rockland County, prior to the start of the storm, a countywide state of emergency was declared. The New York State Thruway was closed from the Tappan Zee Bridge to the Rockland/Orange County line. The Montebello Road Bridge was destroyed. All county transportation services, along with Metro North, NJ Transit, Amtrak, and New York City subway service were suspended. Over 11,000 customers were without power. Rainfall totals ranged from 7.52 inches in Tappan (Town of Orangetown) to 9.22 inches in the Village of Hillburn. Multiple municipalities experienced flooding as a result of the rain from Irene. There were deaths in Rockland County attributed to the storm. Overall, Rockland County received over $13 million in reimbursements from FEMA.
October 29-30, 2011	Nor'Easter / Snowstorm	N/A	N/A	A historic October Nor'Easter brought snow, heavy rain and strong winds from the Mid-Atlantic Region to New England on October 29th. In New York State, snowfall rates were as high as two to four inches per hour. Power outages occurred due to downed trees and wires. New York State governor declared a state of emergency for 13 counties. More than 400,000 customers lost power across the State, with the greatest damage in Westchester, Putnam, Rockland and Orange Counties. In Rockland County, there was widespread tree damage and power outages. Between four and eight inches of snow fell, with greater amounts in the higher elevations. In New City (Town of Clarkstown), downed trees blocked lanes on Route 304. Numerous trees and tree limbs were downed in Tallman (Town of Ramapo) and the Village of Pomona as well.
October 27 – November 8, 2012	Hurricane Sandy	DR-4085	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. Additionally, the low lying areas along the Hudson River experienced moderate coastal flooding as storm surge moved north along the river as the storm made landfall in southern New Jersey. In Rockland County, Hurricane Sandy brought high winds and record storm surge. Numerous residents and businesses were damaged tens of thousands were without power. Residents living near the Hudson River were the hardest hit in the County. Shelters and heating stations were opened. Up to two to five feet of inundation occurred in the low lying areas of the Hudson River causing moderate to major flooding. The Town of Stony Point and the Village of Piermont sustained the most widespread major damage. In Stony Point, storm surge and waves up to 12 feet in height struck the Town's Hudson River shoreline. Waterfront homes and businesses were damaged. In the Town of Clarkstown, wind gusts ranged from 60

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
				to 70 mph, downing trees and power lines and causing severe power outages and damaging buildings and infrastructure. Due to the inundation, mandatory evacuations were ordered in the Grassy Point section of the Town of Stony Point. Approximately 400 people were evacuated from their homes. In the Village of Piermont, approximately 300 people were directed to evacuate their homes and businesses. In the Town of Haverstraw, River Road was closed due to tidal flooding during high tide. The largest shelter in the county was at Rockland Community College. A State of Emergency was declared in the County. Overall, Rockland County received over $24 million in reimbursements from FEMA.
November 24, 2013	Strong Wind	N/A	N/A	Strong and gusty winds impacted Rockland County. In Blauvelt (Town of Orangetown), several power lines were knocked down due to the strong winds. Wind gusts of 50 mph were reported in the hamlet. This event caused approximately $10,000 in property damage.
November 26-27, 2014	Nor'Easter / Snowstorm	DR-4204	No	An early season winter storm impacted eastern New York State during Thanksgiving. The storm began the morning of the 26th and once the snow began, it increased in intensity, falling at rates at or greater than one inch per hour. Temperatures dropped to or below freezing across the entire region. There were heavy bands of snow occurring in some locations, especially across the Taconics, Mohawk Valley and southeastern Adirondacks. Snowfall totals ranged from six to 12 inches, with up to 15 inches in the southeastern Adirondacks. Snowfall totals in Rockland County ranged from three to five inches along and north of Interstate 287.
February 16, 2016	Strong Winds	N/A	N/A	Strong to isolated high winds impacted Rockland County. The winds downed power lines in West Nyack (Town of Clarkstown). The County had approximately $50,000 in property damage from this event.

Source(s): FEMA 2016; NOAA-NCDC 2016; NWS 2016; 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).

According to the NOAA National Centers for Environmental Information (NCEI) Storm Events Database and the National Hurricane Center Historical (NHC) Hurricane Tracks mapping tool, Rockland County experienced 204 severe storm events between 1950 and 2015. The table below shows these statistics, as well as the annual average number of events and the percent chance of these individual severe storm hazards occurring in Rockland County in future years (NOAA NCEI 2016; NHC 2016).

Table 5.4.6-9. Probability of Future 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
Funnel Cloud	1	0.02	66.00	0.02	1.52
Hail	28	0.43	2.36	0.42	42.42
Heavy Rain	33	0.51	2.00	0.50	50.00
High Wind	13	0.20	5.08	0.20	19.70
Hurricane*	2	0.03	33.00	0.03	3.03
Lightning	9	0.14	7.33	0.14	13.64
Strong Wind	5	0.08	13.20	0.08	7.58
Thunderstorm Wind	98	1.51	0.67	1	100
Tornado	2	0.03	33.00	0.03	3.03
Tropical Depression*	2	0.03	33.00	0.03	3.03
Tropical Storm*	11	0.17	6.00	0.17	16.67
TOTAL	**204**	**3.14**	**0.32**	**1**	**100**

Source: NOAA-NCEI 2016; NHC 2016
* *Number of events were collected from NHC and includes events that occurred within 65 nautical miles of Rockland County.*

In Section 5.3, the identified hazards of concern for Rockland County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for severe storms in the County is considered 'frequent' (event that occurs within 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).

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).

Each region in New York State, as defined by ClimAID, has attributes that will be affected by climate change. Rockland County is part of Region 2, Catskill Mountains and West Hudson River Valley. In Region 2, it is estimated that temperatures will increase by 3.1ºF to 6.9ºF by the 2050s and 4.0ºF to 10.7ºF by the 2080s (baseline of 50.0ºF). Precipitation totals will increase between 1 and 14% by the 2050s and 2 to 18% by the 2080s (baseline of 46.0 inches). Table 5.4.6-10 displays the projected seasonal precipitation change for the Catskill Mountains and West Hudson River Valley ClimAID Region (NYSERDA 2014).

Table 5.4.6-10. Projected Seasonal Precipitation Change in Region 2, 2050s (% change)

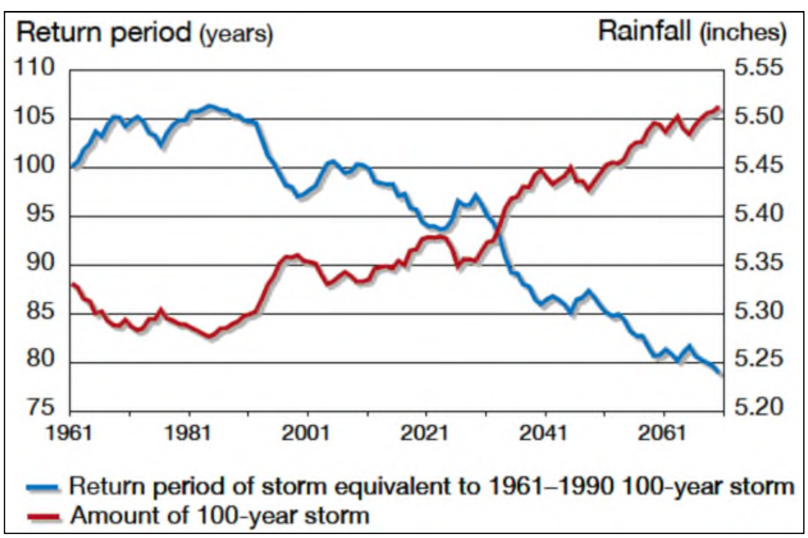
Winter	Spring	Summer	Fall
0 to +15	0 to +10	-5 to +10	-5 to +10

Source: NYSERDA 2011

The projected increase in precipitation is expected to fall in heavy downpours and less in light rains. Downpours are very likely to increase in frequency and intensity, a change which has the potential to affect drinking water; heighten the risk of riverine flooding; flood key rail lines, roadways and transportation hubs; 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 5.4.6-4 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 5.4.6-4. 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 Rockland 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 storms 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 2010 Rockland 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 a hurricane or any severe storm often result in power outages, disruptions to transportation corridors and equipment, loss of workplace access, significant property damage, injuries and loss of life, and the need to shelter and care for individuals impacted by the events. A large amount of damage can be inflicted by trees, branches, and other objects that fall onto power lines, buildings, roads, vehicles, and, in some cases, people. The risk assessment for severe storm evaluates available data for a range of storms included in this hazard category.

Losses from wind are primarily associated with severe thunderstorm or tropical depression/storm-related winds and rain (see flooding discussion in Section 5.4.4 Flood). Secondary flooding associated with the torrential downpours during severe storms is also a primary concern in Rockland County. The County has experienced flooding in association with numerous severe storms in the past.

The entire inventory of Rockland County is at risk of being damaged or destroyed 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 Rockland County for two probabilistic hurricane events, the 100-year and 500-year MRP wind events. In addition, the coastal areas are vulnerable to hurricane storm surge. The impacts on population, existing structures and critical facilities on the County are presented below, following a summary of the data and methodology used.

Data and Methodology

After reviewing historic data, the HAZUS-MH methodology and model were used to analyze the severe storm hazard for Rockland County. Data used to assess this hazard include data available in the HAZUS-MH 3.2 hurricane model, professional knowledge, information provided by the Steering and Planning Committees and input from public citizens.

A probabilistic scenario was run for Rockland County for annualized losses and the 100- and 500-year MRPs were examined for the wind/severe storm hazard. Figure 5.4.6-2 and Figure 5.4.6-3, shown earlier in this section, show the HAZUS-MH maximum peak gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP hurricane events. The estimated hurricane track for the 100- and 500-year events is also shown.

HAZUS-MH contains data on historic hurricane events and wind speeds. It also includes surface roughness and vegetation (tree coverage) maps for the area. Surface roughness and vegetation data support the modeling of wind force across various types of land surfaces. Impacts to life, health, and safety and structures are discussed below using the methodology described above. HAZUS-MH 3.2 default general building stock data and updated critical facility inventories were used in the evaluation of this hazard.

Impact on Life, Health and Safety

For the purposes of this HMP, the entire population of Rockland County (331,687 people) is exposed to hurricane and tropical storm events (U.S. Census, 2010). Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. HAZUS-MH estimates there will be 0 displaced households and 0 people will require temporary shelter as a result of the 100-year MRP event, and for the 500-year MRP event, 3 households will be displaced in Clarkstown (T), Nyack (V), and Spring Valley (V).

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.

Impact on General Building Stock

After considering the population exposed to the hurricane hazard, the value of general building stock exposed to and damaged by 100- and 500-year MRP hurricane wind events was considered. Potential damage is the modeled loss that could occur to the exposed inventory, including damage to structural and content value based on the wind-only impacts associated with a tropical storm or hurricane.

The entire study area is considered at risk to the hurricane wind hazard. Please refer to Section 4 (County Profile) which presents the total exposure value for general building stock by occupancy class for Rockland County. Expected building damage was evaluated by HAZUS-MH across the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 5.4.6-4 summarizes the definition of the damage categories.

Table 5.4.6-4. 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 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
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

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
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
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
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

Table 5.4.6-4 summarizes the building value (structure only) damage estimated for the 100- and 500-year MRP wind-only events. Damage estimates are reported for the county's probabilistic HAZUS-MH model scenarios. The data shown indicates estimated potential losses associated with wind damage to building structure.

Table 5.4.6-5. Estimated Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Wind Events

Municipality	Total Replacement Cost Value (Structure Only)	Estimated Total Damages*			Percent of Total Building Replacement Value		
		Annualized Loss	100-Year	500-Year	Annualized Loss	100-Year	500-Year
Airmont, Village of	$1,147,606,000	$34,649	$743,889	$2,329,973	<1%	<1%	<1%
Chestnut Ridge, Village of	$1,208,912,000	$38,750	$744,705	$2,442,702	<1%	<1%	<1%
Clarkstown, Town of	$10,790,548,000	$424,818	$6,859,263	$57,694,554	<1%	<1%	<1%
Grand View on Hudson, Village of	$57,017,000	$3,948	$46,985	$433,678	<1%	<1%	<1%
Haverstraw, Town of	$1,306,045,000	$38,980	$634,737	$2,502,211	<1%	<1%	<1%
Haverstraw, Village of	$864,560,000	$31,599	$391,360	$2,498,787	<1%	<1%	<1%
Hillburn, Village of	$154,749,000	$2,693	$57,888	$168,839	<1%	<1%	<1%
Kaser, Village of	$540,123,000	$9,148	$135,921	$1,042,096	<1%	<1%	<1%
Montebello, Village of	$637,968,000	$16,982	$368,947	$1,349,840	<1%	<1%	<1%
New Hempstead, Village of	$481,082,000	$18,276	$395,674	$1,839,421	<1%	<1%	<1%
New Square, Village of	$283,711,000	$7,888	$93,392	$1,073,469	<1%	<1%	<1%
Nyack, Village of	$1,195,804,000	$42,220	$359,523	$9,804,322	<1%	<1%	<1%
Orangetown, Town of	$5,765,568,000	$244,527	$3,406,868	$19,231,034	<1%	<1%	<1%
Piermont, Village of	$375,058,000	$22,383	$193,357	$1,578,556	<1%	<1%	<1%
Pomona, Village of	$476,410,000	$13,046	$290,525	$921,897	<1%	<1%	<1%
Ramapo, Town of	$2,994,808,000	$84,261	$1,554,331	$9,091,890	<1%	<1%	<1%
Sloatsburg, Village of	$355,185,000	$8,678	$213,162	$423,952	<1%	<1%	<1%
South Nyack, Village of	$520,705,000	$21,052	$217,807	$4,320,252	<1%	<1%	<1%
Spring Valley, Village of	$2,021,793,000	$63,927	$880,223	$8,101,712	<1%	<1%	<1%
Stony Point, Town of	$1,970,843,000	$67,592	$1,255,721	$6,252,962	<1%	<1%	<1%
Suffern, Village of	$1,219,838,000	$37,405	$767,490	$2,328,670	<1%	<1%	<1%
Upper Nyack, Village of	$267,094,000	$11,973	$149,183	$2,100,601	<1%	<1%	<1%
Wesley Hills, Village of	$651,564,000	$19,440	$441,035	$1,695,803	<1%	<1%	<1%
West Haverstraw, Village of	$985,445,000	$28,665	$425,880	$1,647,222	<1%	<1%	<1%
Rockland County	**$36,272,436,000**	**$1,292,899**	**$20,627,867**	**$140,874,443**	**<1%**	**<1%**	**<1%**

Source: HAZUS-MH 3.2

**The Total Damages column represents the sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious and government) based on estimated replacement cost value.*

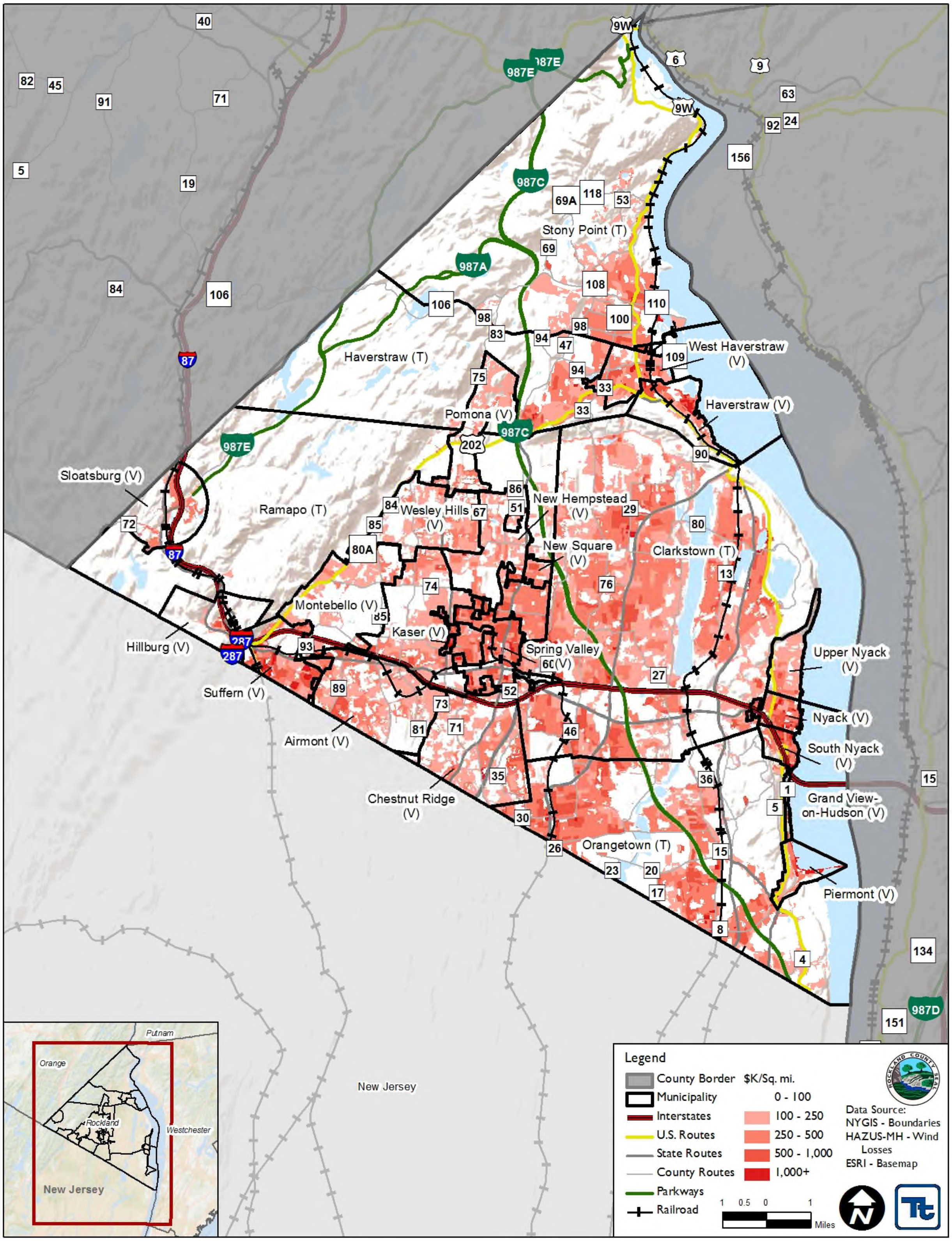
Table 5.4.6-6. Estimated Residential and Commercial Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Wind Events

Municipality	Total Replacement Value (Structure Only)	Estimated Residential Damage		Estimated Commercial Damage	
		100-Year	500-Year	100-Year	500-Year
Airmont, Village of	$1,147,606,000	$712,447	$2,233,796	$23,464	$71,562
Chestnut Ridge, Village of	$1,208,912,000	$710,520	$2,339,897	$23,117	$74,452
Clarkstown, Town of	$10,790,548,000	$6,593,675	$54,662,024	$189,082	$2,048,753
Grand View on Hudson, Village of	$57,017,000	$46,209	$420,807	$761	$12,689
Haverstraw, Town of	$1,306,045,000	$612,178	$2,445,992	$14,863	$37,580
Haverstraw, Village of	$864,560,000	$376,072	$2,423,534	$9,266	$43,380
Hillburn, Village of	$154,749,000	$51,043	$155,371	$4,123	$7,942
Kaser, Village of	$540,123,000	$115,960	$862,333	$14,852	$146,025
Montebello, Village of	$637,968,000	$346,456	$1,265,998	$18,186	$69,102
New Hempstead, Village of	$481,082,000	$388,583	$1,808,205	$4,620	$20,414
New Square, Village of	$283,711,000	$85,318	$1,014,403	$5,254	$39,980
Nyack, Village of	$1,195,804,000	$302,296	$8,186,450	$43,641	$1,227,940
Orangetown, Town of	$5,765,568,000	$3,237,339	$18,219,121	$99,947	$595,362
Piermont, Village of	$375,058,000	$185,160	$1,508,758	$5,853	$51,170
Pomona, Village of	$476,410,000	$283,924	$905,742	$5,493	$12,938
Ramapo, Town of	$2,994,808,000	$1,474,714	$8,654,954	$50,834	$278,751
Sloatsburg, Village of	$355,185,000	$208,223	$418,803	$3,484	$3,578
South Nyack, Village of	$520,705,000	$202,541	$4,016,600	$4,016	$136,883
Spring Valley, Village of	$2,021,793,000	$837,961	$7,802,685	$30,072	$215,776
Stony Point, Town of	$1,970,843,000	$1,219,837	$6,101,478	$18,400	$82,672
Suffern, Village of	$1,219,838,000	$740,436	$2,266,995	$14,876	$34,715
Upper Nyack, Village of	$267,094,000	$145,343	$2,007,713	$2,744	$70,561
Wesley Hills, Village of	$651,564,000	$429,572	$1,658,905	$8,794	$28,097
West Haverstraw, Village of	$985,445,000	$402,589	$1,596,736	$16,124	$34,992
Rockland County	**$36,272,436,000**	**$19,708,395**	**$132,977,297**	**$611,866**	**$5,345,313**

Source: HAZUS-MH 3.2

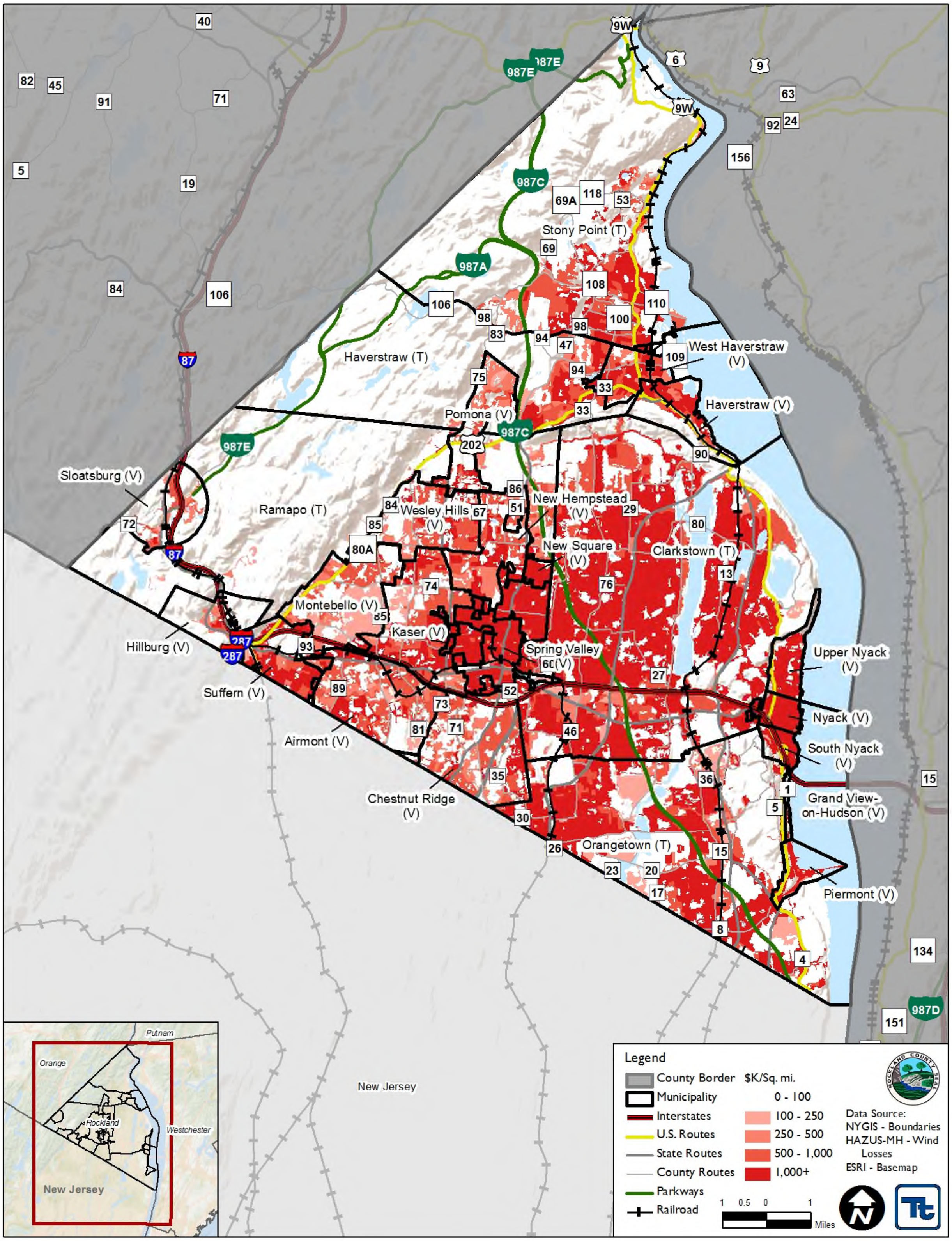
The total damage to buildings (structure only) for all occupancy types across the county is estimated to be $20.6 million for the 100-year MRP wind-only event, and approximately $140.9 million for the 500-year MRP wind-only event. The majority of these losses are to the residential building category. Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. 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 5.4.6-7. Density of Losses for Structures (All Occupancies) for the 100-Year MRP Wind Event



Source: HAZUS-MH 3.2

Table 5.4.6-8. Density of Losses for Structures (All Occupancies) for the 500-Year MRP Wind Event



Source: HAZUS-MH 3.2

Impact on Critical Facilities

Overall, all critical facilities are exposed to the wind hazard. HAZUS-MH estimates the probability that critical facilities (i.e., medical facilities, fire/EMS, police, EOC, schools, and user-defined facilities such as shelters and municipal buildings) may sustain damage as a result of 100- and 500-year MRP wind-only events. Additionally, HAZUS-MH estimates the loss of use for each facility in number of days. Due to the sensitive nature of the critical facility dataset, individual facility estimated loss is not provided. Overall, HAZUS-MH estimates no damage to the critical facilities as a result of the 100-year event.

Table 5.4.6-7 summarizes the potential damages to the critical facilities in Rockland County as a result of the 500-year MRP wind event. The percent probability that each facility type may experience damage by category is indicated below.

Table 5.4.6-7. Estimated Impacts to Critical Facilities for the 500-Year Mean Return Period Hurricane-Related Winds

Facility Type	500-Year Event				
		Percent-Probability of Sustaining Damage			
	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	2	0	0	0
Medical	0	0-5	0	0	0
Police	0	1-5	0-2	0	0
Fire	0	0-2	0-1	0	0
Schools	0	0-6	0-4	0	0

Source: HAZUS-MH 3.2

Impact on Economy

Hurricanes and tropical 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" subsection 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.

For the 100-year MRP wind event, HAZUS-MH estimates less than $500 in business interruption costs (income loss, relocation costs, rental costs and lost wages) and no inventory losses. For the 500-year MRP wind only event, HAZUS-MH estimates approximately $8,000,000 in business interruption losses for the county, which includes loss of income, relocation costs, rental costs and lost wages, in addition to approximately $5,750 in inventory losses.

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.

HAZUS-MH 3.2 also estimates the amount of debris that may be produced a result of the 100- and 500-year MRP wind events. Table 5.4.6-8 summarizes the estimated debris by municipality. 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 5.4.6-8. Debris Production for 100- and 500-Year Mean Return Period Wind Events

Municipality	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year
Airmont, Village of	13	126	0	0	116	455	810	3,116
Chestnut Ridge, Village of	13	125	0	0	93	478	745	3,375
Clarkstown, Town of	146	5,059	0	0	1,153	12,991	7,732	79,215
Grand View on Hudson, Village of	2	34	0	0	3	65	38	643
Haverstraw, Town of	20	235	0	0	119	724	555	2,534
Haverstraw, Village of	43	373	0	0	54	411	492	2,250
Hillburn, Village of	2	13	0	0	10	98	56	251
Kaser, Village of	17	185	0	0	8	51	100	539
Montebello, Village of	10	98	0	0	147	777	516	2,445
New Hempstead, Village of	2	100	0	0	102	686	546	3,774
New Square, Village of	20	218	0	0	11	99	126	998
Nyack, Village of	41	1,524	0	0	12	420	191	3,842
Orangetown, Town of	66	1,318	0	0	737	6,271	4,084	27,503
Piermont, Village of	12	181	0	0	14	178	112	1,429
Pomona, Village of	1	38	0	0	26	210	128	1,200
Ramapo, Town of	63	1,060	0	0	210	3,052	904	13,832
Sloatsburg, Village of	3	12	0	0	45	74	335	539
South Nyack, Village of	10	516	0	0	6	281	75	2,374
Spring Valley, Village of	95	1,287	0	0	72	606	765	5,238
Stony Point, Town of	18	418	0	0	174	7,255	1,229	11,281
Suffern, Village of	62	287	0	0	85	251	631	1,710
Upper Nyack, Village of	3	222	0	0	0	399	1	2,447
Wesley Hills, Village of	1	75	0	0	47	442	349	3,149
West Haverstraw, Village of	21	159	0	0	29	188	363	1,658
Rockland County	**684**	**13,663**	**0**	**0**	**3,273**	**36,462**	**20,882**	**175,339**

Source: HAZUS-MH 3.2

Effect of Climate Change on Vulnerability

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

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

Change of Vulnerability

Rockland County continues to be vulnerable to the severe storm hazard. The HAZUS-MH model was not used to estimate potential losses for the 2010 HMP. The best available data were used for the 2015 HMP update; probabilistic scenarios were evaluated using HAZUS-MH and updated building stock and critical facility inventories were developed and utilized. Overall, this vulnerability assessment provides more accurate estimated exposure and potential losses for Rockland County.

Future Growth and Development

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

Additional Data and Next Steps

Over time, Rockland 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, custom building stock based on tax assessor data, building footprints and specific building information such as details on protective features (for example, hurricane straps).