5.4.6 Severe Storms

The following section provides the hazard profile and vulnerability assessment for the severe storm hazard in Broome County.

5.4.6.1 Profile

This section presents information regarding the description, extent, location, previous occurrences and losses, climate change projections and probability of future occurrences for the severe storm hazard.

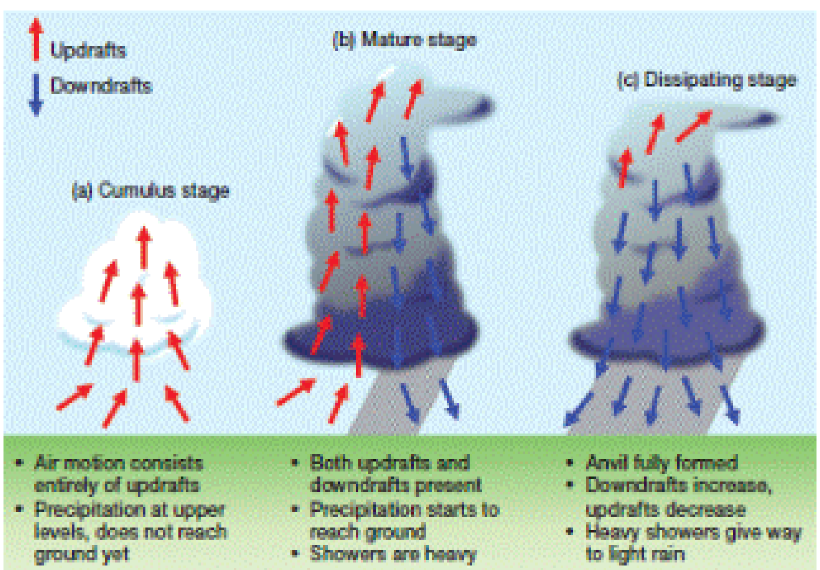
Hazard Description

For this HMP the severe storm hazard includes: thunderstorms, lightning, hail, tornadoes, high winds, and hurricanes/tropical storms, which are defined below.

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 2009d). Figure 5.4.6-1 illustrates the stages of thunderstorm development.

Figure 5.4.6-1. Thunderstorm Development Stages.



Source: weather.gov

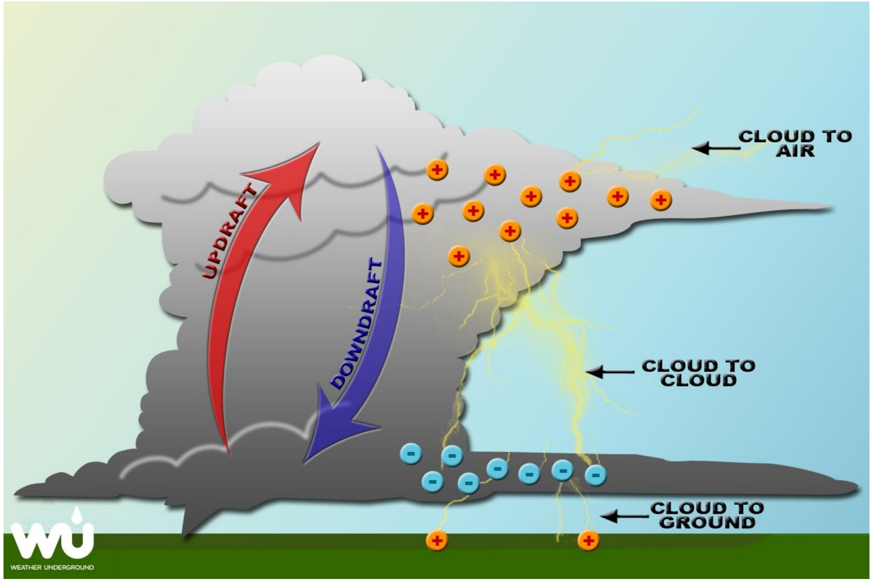
Thunderstorms can lead to flooding, landslides, strong winds, and lightning. Roads could become impassable from flooding, downed trees or power lines, or a landslide. Downed utility poles can lead to utility losses, such as electricity, phone, and water (from loss of pumping and filtering capabilities). Lightning can damage homes and injure people. In the United States, 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 United States, with approximately 10 percent of them classified as severe. During the warm season, thunderstorms are responsible for most of the rainfall.

Lightning

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. Lightning ranks as one of the top weather killers in the United States, killing approximately 50 people and injuring hundreds each year. Lightning can occur anywhere there is a thunderstorm. Lightning can be cloud to air, cloud to cloud, and cloud to ground. Figure 5.4.6-2 demonstrates the variety of lightning types.

Figure 5.4.6-2. Types of Lightning

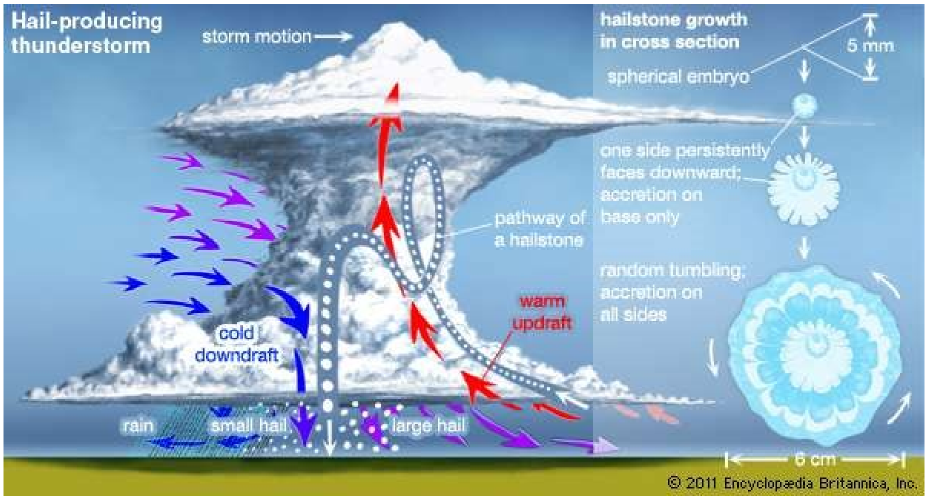


Source: Weather Underground, n.d.

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 might thaw as it moves into warmer air toward the bottom of the thunderstorm, or the droplet might be picked up again by another updraft and carried back into the cold air to 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. Figure 5.4.6-3 shows the hail formation process. Most hail is small and typically less than two inches in diameter (NWS 2009c).

Figure 5.4.6-3. Hail Formation



Source: Encyclopedia Britannica 2011

High Winds

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 (Rosenstiel School of Marine & Atmospheric Science 2005). High winds are often associated by other severe weather events such as thunderstorms, tornadoes, hurricanes, and tropical storms.

Tornadoes

A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 250 miles per hour (mph). Damage paths can be greater than 1 mile wide and 50 miles long. Tornadoes typically develop from either a severe thunderstorm or hurricane as cool air rapidly overrides a layer of warm air. Tornadoes typically move at speeds between 30 and 125 mph and can generate combined wind speeds (forward motion and speed of the whirling winds) exceeding 300 mph. The lifespan of a tornado rarely is longer than 30 minutes (FEMA 1997). Tornadoes can occur at any time of the year, with peak seasons at different times for different states (NSSL 2013).

Hurricanes/Tropical Storms

Tropical cyclones are fueled by a different heat mechanism than other cyclonic windstorms, such as Nor'easters and polar lows. The characteristic that separates tropical storms from other cyclonic systems is that at any height in the atmosphere, the center of a tropical storm will be warmer than its surroundings, a phenomenon called *warm core* storm systems (NOAA 2013). Tropical cyclones 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. Tropical cyclones begin as disturbed areas of weather, often referred to as tropical waves. As the storm organizes, it is designated as a tropical depression.

A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds of 39 to 73 mph and heavy rain. A hurricane is a tropical storm that attains hurricane status when its wind speed reaches 74 mph or higher. Tropical systems can develop in the Atlantic between the Lesser Antilles and the African coast or in the warm tropical waters of the Caribbean Sea and Gulf of Mexico. These storms can move up the Atlantic coast of the United States, impacting the eastern seaboard, or move into the

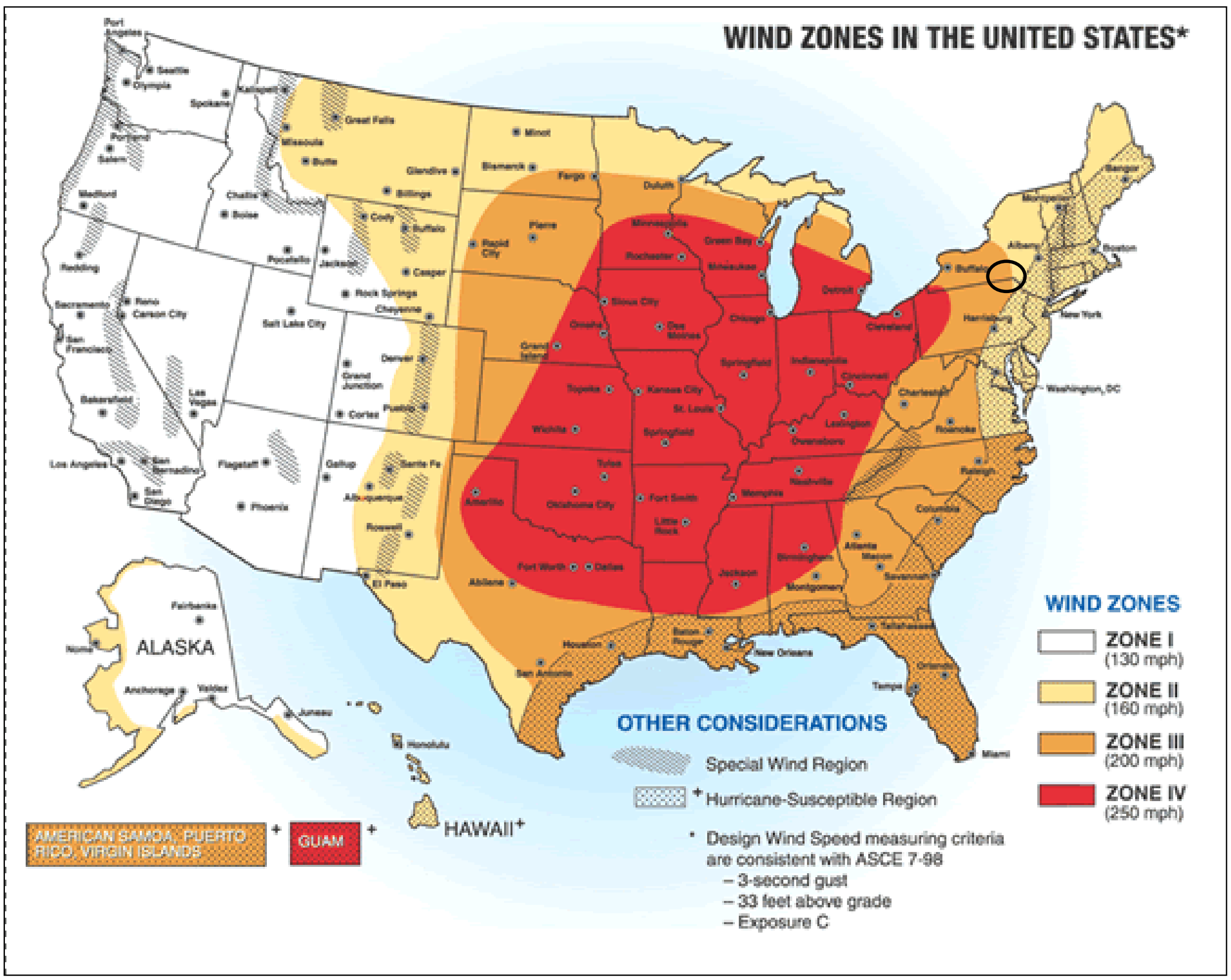
United States through the states along the Gulf Coast, bringing wind and rain as far north as New England before moving eastward offshore.

Despite that Broome County is an inland county, coastal storms, such as hurricanes and tropical storms, can impact the county (NYS DHSES 2014). Hurricanes and tropical storms can impact Broome County from June to November, the official eastern U.S. hurricane season; however, late July to early October is the most likely period for hurricanes and tropical storms to impact Broome County, due to the cooling of the North Atlantic Ocean waters (NYS DHSES 2014).

Location

All of Broome County is exposed to hail, lightning, windstorms, high wind, thunderstorms, tornadoes, hurricanes, and tropical storms, and all of the county is subject to high winds from severe weather events. According to the FEMA Winds Zones of the United States map, Broome County is located in Wind Zones II and III, where wind speeds can reach up to 200 mph. Figure 5.4.6-4 illustrates wind zones across the United States, which indicate the impacts of the strength and frequency of wind activity per region. The information on the figure is based on 40 years of tornado data and 100 years of hurricane data collected by FEMA.

Figure 5.4.6-4. Wind Zones in the United States



Note: The black oval indicates the approximate location of Broome County.

Extent

The extent (severity or magnitude) of a severe storm is largely dependent upon the most damaging aspects of each type of severe weather. This section describes the extent of thunderstorms, lighting, hail, windstorms, tornadoes, hurricanes, and tropical storms in Broome County. Historical data presented in Table 5.4.6-1 lists the maximum extent of severe weather in Broome County.

Table 5.4.6-1. Severe Storm Extent in Broome County (1950 to 2017)

Extent of Severe Storms in Broome County	
Largest Hailstone on Record	2 inches
Strongest Tornado on Record	F3
Highest Wind Speed on Record	70 knots
Strongest Tropical System on Record	Tropical Storm

Source: NCEI 2018, NOAA Historical Hurricane Tracks 2018

Thunderstorms

Severe thunderstorm watches and warnings are issued by the local NWS office and the Storm Prediction Center (SPC). The NWS and SPC will update the watches and warnings and 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, 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 that contain updated information on the severe thunderstorm and advise the public when the warning is no longer in effect (NWS 2009d, NWS 2010c).
- 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 can 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 advise public 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 might 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).

Figure 5.4.6-55 presents the severe thunderstorm risk categories, as provided by the SPC.

Figure 5.4.6-5 Severe Thunderstorm Risk Categories.

Understanding Severe Thunderstorm Risk Categories

THUNDERSTORMS (no label)	1 - MARGINAL (MRGL)	2 - SLIGHT (SLGT)	3 - ENHANCED (ENH)	4 - MODERATE (MDT)	5 - HIGH (HIGH)
No severe* thunderstorms expected	**Isolated severe thunderstorms possible**	**Scattered severe storms possible**	**Numerous severe storms possible**	**Widespread severe storms likely**	**Widespread severe storms expected**
Lightning/flooding threats exist with all thunderstorms	Limited in duration and/or coverage and/or intensity	Short-lived and/or not widespread, isolated intense storms possible	More persistent and/or widespread, a few intense	Long-lived, widespread and intense	Long-lived, very widespread and particularly intense
• Winds to 40 mph • Small hail	• Winds 40-60 mph • Hail up to 1" • Low tornado risk	• One or two tornadoes • Reports of strong winds/wind damage • Hail ~1", isolated 2"	• A few tornadoes • Several reports of wind damage • Damaging hail, 1 - 2"	• Strong tornadoes • Widespread wind damage • Destructive hail, 2" +	• Tornado outbreak • Derecho

* NWS defines a severe thunderstorm as measured wind gusts to at least 58 mph, and/or hail to at least one inch in diameter, and/or a tornado. All thunderstorm categories imply lightning and the potential for flooding. Categories are also tied to the probability of a severe weather event within 25 miles of your location.

Source: NOAA SPC 2017

Lightning

Lightning is most often associated with moderate to severe thunderstorms. The severity of lightning refers to the frequency of lightning strikes during a storm. The New York City Office of Emergency Management notes that lightning strikes occur with moderate frequency in the State of New York, with 3.8 strikes occurring per square mile each year. Multiple devices are available to track and monitor the frequency of lightning (NYSDHSES 2014).

Hailstorms

The severity of hail is measured by duration, hail size, and geographic extent. Most hail stones from hail storms are made up of variety of sizes. Only the very largest hail stones pose serious risk to people, if exposed (NYS DHSES 2014). The size of hail is estimated by comparing it to a known object. 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

The Tornado and Storm Research Organization (TORRO) Hailstorm Intensity Scale (H0 to H10) relates typical damage and hail sizes.

Table 5.4.6-3. TORRO Hailstorm Intensity Scale

TORRO Hailstorm Intensity Scale	Intensity Category	Typical Hail Diameter (mm)	Typical Damage Impacts
H0	Hard Hail	5	No damage
H1	Potentially Damaging	5-15	Slight general damage to plants, crops
H2	Significant	10-20	Significant damage to fruit, crops, vegetation
H3	Severe	20-30	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored
H4	Severe	25-40	Widespread glass damage, vehicle bodywork damage
H5	Destructive	30-50	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
H6	Destructive	40-60	Bodywork of grounded aircraft dented, brick walls pitted
H7	Destructive	50-75	Severe roof damage, risk of serious injuries
H8	Destructive	60-90	(Severest recorded in the British Isles) Severe damage to aircraft bodywork
H9	Super Hailstorms	75-100	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
H10	Super Hailstorms	>100	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open

Source: TORRO 2018

High Winds

The following table provides the descriptions of winds and their associated sustained wind speed used by the NWS during wind-producing events.

Table 5.4.6-4. 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

Table 5.4.6-5. Beaufort Wind Scale

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects on Land
0	Less than 1	Calm	Calm, smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-6	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	7-10	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	11-16	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	17-21	Fresh Breeze	Small trees in leaf begin to sway
6	22-27	Strong Breeze	Larger tree branches moving, whistling in wires
7	28-33	Near Gale	Whole trees moving, resistance felt walking against wind
8	34-40	Gale	Twigs breaking off trees, generally impedes progress
9	41-47	Strong Gale	Slight structural damage occurs, slate blows off roofs
10	48-55	Storm	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"
11	56-63	Violent Storm	
12	64+	Hurricane	

Source: SPC, n.d.

The Beaufort wind scale, developed in 1805, is also used today to classify wind conditions, and is provided in Appendix E (Supplementary Data). 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 can pose a hazard or are life threatening. The criterion for each of these varies from state to state. According to the NWS (2018), 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.

Tornadoes

The magnitude or severity of a tornado is categorized using the Enhanced Fujita Tornado Intensity Scale (EF Scale). This is the scale now used exclusively for determining tornado ratings by comparing wind speed and actual damage. Figure 5.4.6-6 illustrates the relationship between EF ratings, wind speed, and expected tornado damage.

Figure 5.4.6-6. Explanation of EF-Scale Ratings

EF Rating	Wind Speeds	Expected Damage
EF-0	65-85 mph	'Minor' damage: shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled.
EF-1	86-110 mph	'Moderate' damage: more significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged.
EF-2	111-135 mph	'Considerable' damage: roofs torn off well constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed.
EF-3	136-165 mph	'Severe' damage: entire stories of well constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark.
EF-4	166-200 mph	'Extreme' damage: Well constructed homes are leveled, cars are thrown significant distances, top story exterior walls of masonry buildings would likely collapse.
EF-5	> 200 mph	'Massive/incredible' damage: Well constructed homes are swept away, steel-reinforced concrete structures are critically damaged, high-rise buildings sustain severe structural damage, trees are usually completely debarked, stripped of branches and snapped.

Source: Cornell University 2018

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 (FEMA 1997).

Hurricanes/Tropical Storms

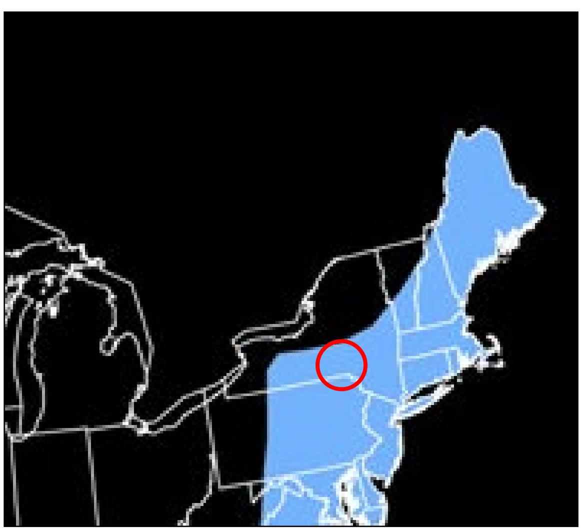
The extent of a hurricane or tropical storm is commonly categorized in accordance with the Saffir-Simpson Hurricane Wind Scale, which assigns a designation of tropical storm for storms with sustained wind speeds below 74 mph and a hurricane category rating of 1–5 based on a hurricane's increasing sustained 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. Tropical Storms and Category 1 and 2 storms are still dangerous and require preventative measures (NOAA 2013). 5.4.6-7 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

Figure 5.4.6.7. The Saffir-Simpson Scale

Source: Disaster Readiness Portal 2017

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 might occur within any given year based on past recorded events. The MRP is the average period, in years, between occurrences of a particular hazard event, equal to the inverse of the annual frequency of exceedance (Dinicola 2009). 5.4.6-8 shows the number of hurricanes expected for the 100-year MRP in the northeast region. Broome County is on the edge of the area that could expect 20 hurricanes in a 100-year period.

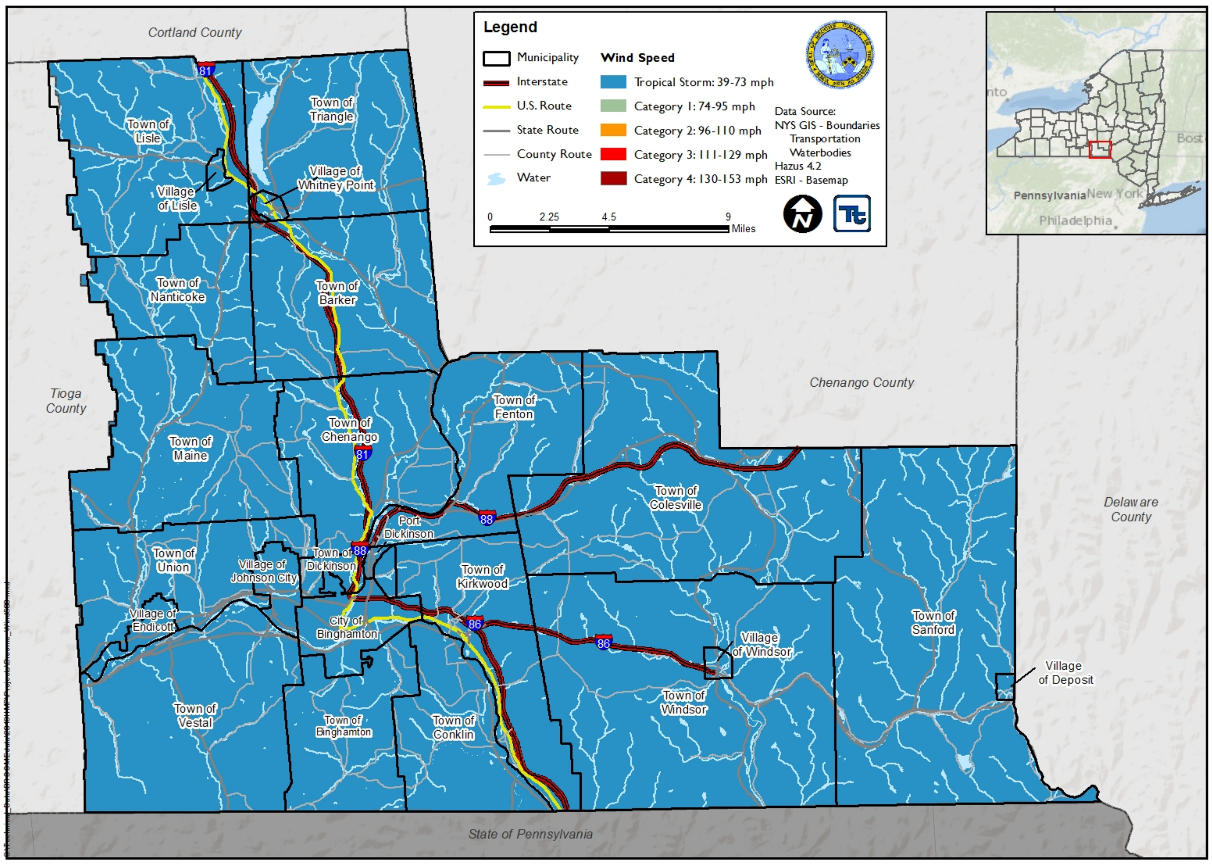
Figure 5.4.6.8. Number of Hurricanes for a 100-year MRP



Source: U.S. Geological Survey (USGS) 2005
Note: Red circle indicates Broome County's approximate location within the region;
Light blue area: 20 to 40 hurricanes expected in a 100-year period.

Peak wind speed projections were generated using HAZUS-MH v4.2. HAZUS-MH v4.2 estimated the maximum 3-second gust wind speeds for Broome County to be below 39 mph for the 100-year MRP event and not strong enough to be considered a tropical storm. The maximum 3-second gust wind speeds for Broome County range from 54 to 60 mph for the 500-year MRP event (tropical storm). HAZUS-MH v4.2 did not generate the hurricane track for the 100- and 500-year probabilistic events. The associated impacts and losses from these 100-year and 500-year MRP hurricane event model runs are reported in the Vulnerability Assessment. Figure 5.4.6-9 shows the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 500-year MRP events.

Figure 5.4.6-9. Wind Speeds for the 500-Year MRP Event



Previous Occurrences and Losses

Many sources have provided historical information regarding previous occurrences and losses associated with severe storm events in Broome County. According to NOAA-NCEI Storm Events Database, Broome County has been impacted by 307 severe storm events that caused no fatalities, 20 injuries, $6.973 million in property damage, and $2,000 in crop damage.

Table 5.4.6-6. Severe Storm Events 1950-2018

Hazard Type	Number of Occurrences Between 1950 and 2018	Total Fatalities	Total Injuries	Total Property Damage ($)	Total Crop Damage ($)
Funnel Cloud	2	0	0	$0	$0
Hail	80	0	0	$332,000	$0
Heavy Rain	3	0	0	$2,000	$0
High Wind	13	0	0	$652,340	$0
Hurricane*	0	0	0	$0	$0
Lightning	12	0	1	$88,000	$0
Strong Wind	3	0	0	$11,000	$0
Thunderstorm Wind	186	0	1	$1.796 million	$2,000
Tornado	8	0	18	$4.092 million	$0
Tropical Depression**	0	0	0	$0	$0
Tropical Storm*	2	0	0	$0	$0
TOTAL	**309**	**0**	**20**	**$6.973 million**	**$2,000**

Source: NOAA-NCEI 2018; NHC 2018
** Number of events were collected from NHC and includes events that occurred within 65 nautical miles of Broome County.*
*** Tropical Storm includes one extra-tropical storm*
M: Million, K: Thousand

Between 1954 and 2018, New York State was included in 43 FEMA declared severe storm-related major disaster declarations (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. Of those declarations, Broome County was included in 17 declarations (FEMA 2018). Table 5.4.6-7 lists FEMA DR and EM declarations for Broome County.

Table 5.4.6-7. Severe Storm-Related FEMA Declarations for Broome County, 1954 to 2018

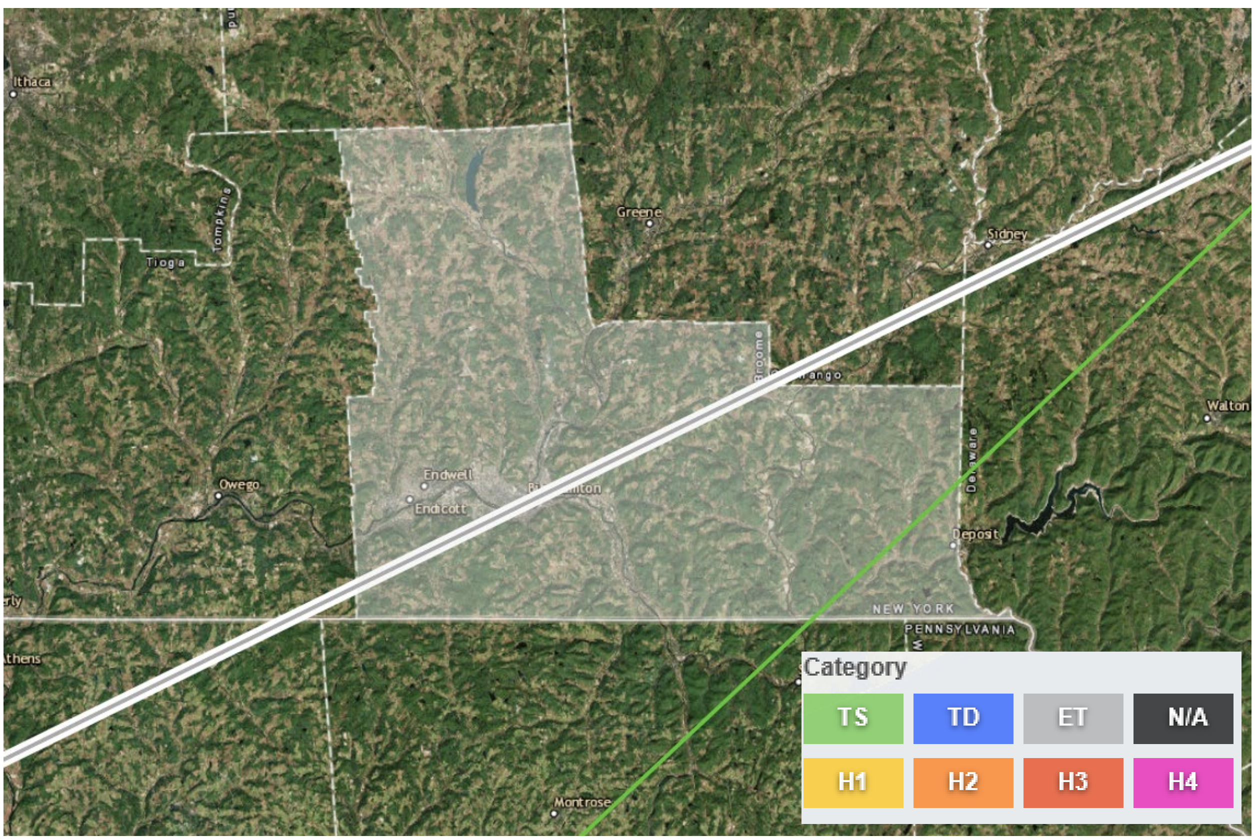
FEMA Declaration Number	Date(s) of Event	Event Type	Details
DR-290	July 22, 1970	Flood	Heavy Rains and Flooding
DR-338	June 23, 1972	Flood	Tropical Storm Agnes
DR-487	October 2, 1975	Flood	Storms, Rains, Landslides, and Flooding
DR-515	July 21, 1976	Flood	Severe Storms and Flooding
DR-1095	January 19–30, 1996	Flood	Severe Storms and Flooding
DR-1222	May 31–June 2, 1998	Severe Storm	Severe Storms and Tornadoes
DR-1534	May 13–June 17, 2004	Severe Storm	Severe Storms and Flooding
DR-1564	August 13–September 16, 2004	Severe Storm	Severe Storms and Flooding
DR-1565	September 16–24, 2004	Severe Storm	Tropical Depression Ivan
DR-1589	April 2–4, 2005	Severe Storm	Severe Storms and Flooding
DR-1650	June 26–July 10, 2006	Severe Storm	Severe Storms and Flooding

FEMA Declaration Number	Date(s) of Event	Event Type	Details
DR-1670	November 16–17, 2006	Severe Storm	Severe Storms and Flooding
DR-1993	April 26–May 8, 2011	Flood	Severe Storms, Flooding, Tornadoes, and Straight-Line Winds
EM-3341	September 7–11, 2011	Severe Storms and Flooding	Remnants of Tropical Storm Lee
DR-4031	September 7–11, 2011	Severe Storms and Flooding	Remnants of Tropical Storm Lee
EM-3351	October 27–November 8, 2012	Hurricane	Hurricane Sandy
DR-4129	June 26–July 10, 2013	Flood	Severe Storms and Flooding
DR-4397	August 13–15, 2018	Flood	Severe Storms and Flooding

Source: FEMA 2018

Figure 5.4.6-10 from the NOAA Historical Hurricane Tracker illustrates the tracks of storms between 1842 and 2018 within 65 miles of Broome County. Broome County is not frequently impacted by hurricanes, tropical storms, or tropical depressions but has recently experienced the direct and indirect landward effects associated with hurricanes and tropical storms, including Hurricane Irene and Tropical Storm Lee in 2011 and Superstorm Sandy in 2012. Please note that the figure does not show Hurricane Sandy passing within 65 nautical miles of the county.

Figure 5.4.6-10. Historical Hurricane Tracks within 65 miles of Broom County, 1878 to 2018



Source: NOAA Historical Hurricane Tracks 2018 (names of storms will be added when available)

Note: Category refers to tropical cyclone strength. TS: Tropical Storm, TD: Tropical Depression, ET: Extra-tropical Storm, H1: Category 1 Hurricane, H2: Category 2 Hurricane, H3: Category 3 Hurricane, H4: Category 4 Hurricane.

The NOAA National Centers for Environmental Information (NCEI) Storm Events database records severe storm events. For this HMP update, known severe storm events that have impacted Broome County between 2012 and 2018 are identified in Table 5.4.6-8. With severe storm documentation for New York State and Broome County being so extensive, not all sources have been identified or researched. Therefore, Table 5.4.6-8 might not include all events that have occurred in the county. For events prior to 2012, refer to Appendix E (Supplementary Data). For detailed information on damages and impacts to each municipality, refer to Section 9 (Jurisdictional Annexes).

Table 5.4.6-8. Severe Storm Events in Broome County, 2012 to 2017

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
May 29, 2012	Hail	N/A	No	With a warm front draped across northern New York and a cold front to the west, New York State was entrenched in the warm and moist warm sector, as temperatures rose well into the 80s with dewpoints in the 60s during the afternoon. Showers and thunderstorms developed out ahead of the approaching cold front, with many storms becoming severe and producing large hail and damaging winds.
July 23, 2012	Hail, Thunderstorm Wind	N/A	No	During the afternoon of July 23rd, an upper level disturbance moved east toward central New York from southern Ontario, Canada. Daytime heating and instability combined with favorable wind parameters in the atmosphere to produce severe thunderstorms. Many reports were received of wind damage and very large hail. In Harpursville, around 100 trees were blown down. Utility poles fell on several roads. $10K in property damage was reported.
September 26, 2012	Hail	N/A	No	Showers and thunderstorms developed along and ahead of a cold front that pushed through central New York during the afternoon. Several storms reached severe levels, producing isolated damaging wind reports and many reports of large hail. Some of the hail was as large as golf balls.
April 19, 2013	Thunderstorm Wind	N/A	No	A strong cold front crossed central New York State during the late afternoon and early evening hours of Friday April 19th. This front was accompanied by a squall line which produced locally damaging wind including a confirmed EF1 Tornado in Chenango and Delaware counties. Most areas saw brief heavy rain and wind gusts to 50 mph with a few locations seeing intense straight-line winds gusting 80–110 mph. In West Endicott, a line of thunderstorms blew down a tree onto a house on Airport Road resulting in $10K in property damage.
May 22, 2013	Hail	N/A	No	A warm front lifted north of New York State during the late morning into the evening hours of Wednesday, May 22nd. This front resulted in a cluster of storms that produced large hail and wind damage.
June 24, 2013	Hail	N/A	No	An upper level disturbance combined with an unstable airmass contributed to the development of severe thunderstorms across central New York. Chenango Bridge reported $5K in property damage.
May 22, 2014	Hail	N/A	No	Central New York was well into warm, moist, and unstable air as a warm front was located across the Hudson Valley and a cold front was located over western New York. This led to the development of severe thunderstorms on Thursday, May 22nd.
July 7, 2014	Thunderstorm Wind	DR-4129	No	A weak warm front that moved from the Great Lakes region allowed for severe thunderstorms to develop across portions of central New York. Strong and organized low level wind shear resulted in damaging winds from all severe storms during the afternoon hours. Many trees were blown down, including on top of cars, power lines, and a storage shed. Trees fell in the Town of Lisle. Killawog reported $15K in property damage.
July 13, 2014	Funnel Cloud, Thunderstorm Wind	N/A	No	A weak frontal boundary and strong upper level disturbance helped develop numerous severe thunderstorms. Favorable and strong wind shear in the lower and middle layers of the

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
				atmosphere resulted in damaging winds and tornadoes across central New York. In Kattleville, trees fell near Route 12 resulting in $10K in property damage. In Stella, trees fell around Floral and Grand Avenues. Stella reported $30K in property damage. In Kirkwood, trees fell, closing part of Ostrum Road resulting in $10K in property damage. In Damascus, trees fell around Highway 79 and Piper Hill Road. A possible tornado was sighted near a golf course. Damascus reported $10K in property damage. In West Windsor, trees fell, resulting in $10K in property damage. A portion of the plexiglass facade was blown from above JCPenney's door, while water was coming into the store, at the Oakdale Mall.
August 21, 2014	Hail, Thunderstorm Wind	N/A	No	A low-pressure system located over southern Ontario along with surface boundaries near central New York resulted in thunderstorms during the afternoon hours. These storms developed in an unstable airmass with a severe thunderstorm occurring over Tompkins County producing large hail. In Glen Aubrey, thirty trees fell in one location, including two uprooted hemlock trees. Lawn furniture was blown over 200 feet. Glen Aubrey reported $10K in property damage.
September 2, 2014	Thunderstorm Wind	N/A	No	A cold front moved through central New York during the afternoon and evening hours of Tuesday, September 2nd. This front acted on a moist and unstable air mass, resulting in the development of numerous severe thunderstorms over New York State. Straight-line winds estimated near 60 mph snapped trees and branches, with trees snapped off at mid to high trunk level. One tree fell on a trailer. Chenango Bridge reported $20K in property damage.
September 11, 2014	Hail	N/A	No	A warm and humid airmass, combined with the passage of an upper level wave, resulted in the development of severe thunderstorms across central New York.
May 18, 2015	Hail, Thunderstorm Wind	DR 4180	No	A warm front lifted northward across the area Monday morning the 18th, then stalled across central New York and northeast Pennsylvania. Showers and thunderstorms developed along this stationary front by midafternoon. A few of these storms became severe and produced strong winds and large hail. State official reported thunderstorm winds caused trees to uproot and wires knocked down. Multiple power outages were reported from this storm. Castle Creek reported $30K in property damage.
June 12, 2015	Hail	N/A	No	A very unstable air mass was present Friday afternoon and evening, as a warm front lifted north that morning across Pennsylvania and New York. A shortwave aloft, which was embedded within the cyclonic flow, interacted with this front, and showers and thunderstorms developed over central New York. Late Friday afternoon, the front shifted slowly southward as a cold front. Showers and thunderstorms continued to develop along the front into the late evening hours as it moved southward into Pennsylvania. These storms produced damaging winds and large hail. A severe thunderstorm developed over the area and produced golf ball sized hail resulting in $5K in property damages in West Endicott.
July 26, 2015	Hail	N/A	No	Weak northwest flow aloft was present over the northeast Sunday, July 16th. A cold front was slowly moving southward over central New York Sunday morning and stalled over central New York and northeast Pennsylvania Sunday evening. Showers and thunderstorms

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
				developed along this boundary. A few of these storms became severe and produced damaging winds and large hail. Maine reported $5K in property damage.
June 28, 2016	Hail	N/A	No	A cold front was centered over central New York and northeast Pennsylvania Thursday morning. By late morning, thunderstorms developed ahead of and along this front in a very unstable air mass. The thunderstorms slowly moved east during the afternoon with some of the storms becoming severe. West Endicott reported $1K in property damage.
May 1, 2017	Thunderstorm Wind	N/A	No	A warm front lifted north across the region Monday morning, which created an unstable air mass across the state of New York and Pennsylvania. By late Monday afternoon, a cold front moved into western New York and Pennsylvania, which produced a line of thunderstorms. As the thunderstorms moved east, coverage became widespread and a major severe weather outbreak ensued for central New York and northeast Pennsylvania. Some of the thunderstorms produced winds gusting 70–100 mph. Numerous trees fell, and there were widespread power outages, some of which lasted for several days. West Endicott reported $12K in property damage.
May 14, 2017	Hail	N/A	No	Showers and thunderstorms developed ahead of and along an advancing cold front across the states of New York and Pennsylvania Sunday afternoon. As the storms moved to the east, an isolated storm produced nickel-sized hail in the Binghamton area.
June 19, 2017	Thunderstorm Wind	N/A	No	A cold front extended from north to south across western New York and Pennsylvania Monday morning and showers and thunderstorms were organized ahead and along the front. The front quickly moved east into a very unstable air mass, and additional showers and thunderstorms developed across central New York and northeast Pennsylvania. Some of these storms became severe and produced strong winds. In West Endicott, a thunderstorm produced severe winds and knocked over power line poles and wires resulting in $10K in property damage.
June 25, 2017	Thunderstorm Wind	N/A	No	A thunderstorm moved across the region and became severe. This thunderstorm produced severe winds and removed a portion of a roof from a house on Caldwell Hill Road resulting in $10K in property damage in Lisle.
July 1, 2017	Hail	N/A	No	Showers and thunderstorms moved across the region during the early morning leaving copious amounts of low-level moisture across the state of New York. During the afternoon, breaks in the cloud coverage allowed the atmosphere to become unstable ahead of an approaching cold front. A cold front moved across the region late Saturday afternoon, and showers and thunderstorms developed ahead and along the advancing cold front. As the front moved east, some of these storms became severe and produced damaging winds and large hail. Chenango Bridge reported $2K in property damage.
July 17, 2017	Lightning, Thunderstorm Wind	N/A	No	A cold front advanced east across western New York Monday morning and became stalled and aligned north to south over central New York and Pennsylvania shortly after noon. Showers and thunderstorms developed along this boundary in a very unstable environment and quickly moved east. Some of these storms became severe and produced damaging winds and large hail. In Glen Castle, a thunderstorm developed over the area and produced lightning which struck a tree in the town of Chenango on Susan Street causing $1K in

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
				property damage. In Windsor, a thunderstorm produced severe winds which uprooted or snapped more than 10 trees on Ouaquaga Road resulting in $10K in property damage.
August 4, 2017	Lightning	N/A	No	A strong cold front moved across the northeast, as a surface low-pressure system moved toward Quebec Friday morning. By Friday afternoon, a pre-frontal trough developed across New York and Pennsylvania, leading to thunderstorms in a very unstable atmosphere. As these storms propagated eastward, some became severe, producing damaging winds. In the Town of Vestal, lightning struck the side of a house near 341 2nd Ave causing $5K in property damage.
August 13-15, 2018	Severe Storms and Flooding	DR-4397	Yes	Heavy rains on August 15th caused flash flooding, road closures, and damages across Broome County. A state of emergency was issued for Broome County due to this event, and the emergency operations center was activated. In the City of Binghamton, homes and streets on the East Side and parts of the South Side were flooded, mostly in basements and about 18 homes had water pumped out. Side streets in the city experienced significant flash flooding and authorities were going door-to-door to survey damage and check on residents. The American Red Cross opened an emergency shelter in Vestal, which was moved to Conklin.

Source(s): FEMA 2018; NOAA-NCDC 2018; NYS HMP 2014

** Many sources were consulted to provide an update of previous occurrences and losses; event details and loss/impact information may vary and has been summarized in the above table*

*** Only thunderstorm wind events with property damages of $10K or greater are listed. There were 26 days of thunderstorm winds with 59 individual reports and a total of $359,000 in property damages.*

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
K =$1,000

Climate Change Projections

Table 5.4.6-9 provides the projected seasonal precipitation changes for Southern Tier ClimAID Region (NYSERDA 2014).

Table 5.4.6-9. Projected Seasonal Precipitation Change in Region 3, 2050s (% change)

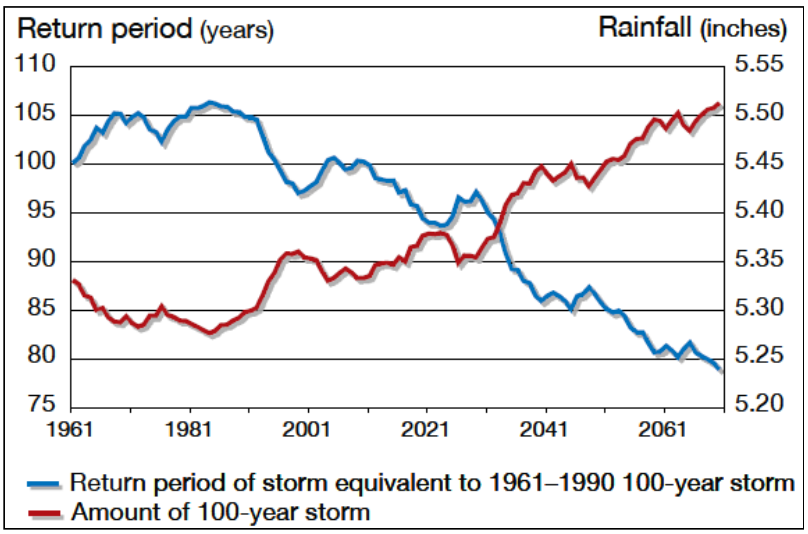
Winter	Spring	Summer	Fall
+5 to +15	0 to +15	-10 to +10	-5 to +10

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 that has the potential to affect drinking water through flooding contaminating wells; 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 can the ability of water supply systems to provide water. Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent wastewater treatment plants and industrial discharges (NYSERDA 2011).

Figure 5.4.6-11 displays the projected rainfall and frequency of extreme storms in New York State. The amount of rainfall 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 5.4.6-11. Projected Rainfall and Frequency of Extreme Storms



Source: NYSERDA 2011

Probability of Future Occurrences

Table 5.4.6-10 summarizes data regarding the probability of occurrences of severe storm events in Broome County based on the historic record. Thunderstorm events are the most common in Broome County, followed by hail events. The information used to calculate the probability of occurrences is based solely on NOAA-NCEI storm events database results.

Table 5.4.6-10. 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	2	0.03	34.50	0.03	2.90
Hail	80	1.18	0.86	1.16	115.94
Heavy Rain	3	0.04	23.00	0.04	4.35
High Wind	13	0.19	5.31	0.19	18.84
Hurricane*	0	0	0	0	0
Lightning	12	0.18	5.75	0.17	17.39
Strong Wind	3	0.04	23.00	0.04	4.35
Thunderstorm Wind	186	2.74	0.37	2.70	269.57
Tornado	8	0.12	8.63	0.12	11.59
Tropical Depression*	0	0	0	0	0
Tropical Storm*	2	0.03	34.50	0.03	2.90
TOTAL	**309**	**4.54**	**0.22**	**4.48**	**447.83**

Source: NOAA-NCEI 2018; NHC 2018
** Number of events were collected from NHC and includes events that occurred within 65 nautical miles of Broome County.*

Broome County is expected to continue experiencing direct and indirect impacts of severe storms annually. These storms may induce secondary hazards such as flooding and utility failure. In Section 5.3 (Hazard Ranking), the identified hazards of concern for Broome 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 has 100 percent annual probability and might occur multiple times per year).

5.4.6.2 Vulnerability Assessment

Wind-related vulnerability data was generated using a HAZUS-MH analysis for the severe storm hazard. A probabilistic assessment was conducted for the 100- and 500-year MRPs to analyze the severe storm hazard and provide a range of loss estimates. The other severe storm hazards profiled above were assessed qualitatively.

Impact on Life, Health and Safety

The impact of a severe storms on life, health, and safety is dependent upon several factors including the severity of the event and whether adequate warning time was provided to residents. The entire population of Broome County (197,381) is assumed to be exposed to this hazard (U.S. Census 2016 ACS 5-Year Population Estimate).

Lightning can be responsible for deaths, injuries, and property damage. Lightning-based deaths and injuries typically involve heart damage, inflated lungs, or brain damage, as well as loss of consciousness, amnesia, paralysis, and burns, depending on the severity of the strike. Additionally, most people struck by lightning survive, although they may have severe burns and internal damage. People located outdoors (i.e., recreational activities and farming) are considered most vulnerable to hailstorms, thunderstorms, and tornadoes because there is little to no warning, and shelter might not be available. Moving to a lower risk location will decrease a person's vulnerability.

As a result of severe storm events, residents can be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings, and debris carried by high winds from hurricanes, tropical storms, or tornadoes 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 v4.2 currently estimates that no residents will be displaced or require temporary shelter due to either a 100-year or a 500-year MRP event.

Economically disadvantaged populations are more vulnerable because they often evaluate evacuation needs and make decisions based on the economic impact to their family. The population over the age of 65 (34,712) is also vulnerable, can physically have difficulty evacuating, and are more likely to seek or need medical attention, which may not be available due to isolation during a storm event (U.S. Census 2016 ACS 5-Year Population Estimate). Section 4 (County Profile) provides for the statistics for these populations for Broome County.

Impact on General Building Stock

Damage to buildings depends on several factors, including wind speed, storm duration, path of the storm track or tornado, and distance from the tornado funnel. Depending on the size of the hail and severity of the storm, the county could see damage from hail impacting structures. Lightning can spark wildfires or building fires, especially if structures are not protected by surge protectors on critical electronic, lighting, or information technology systems. While damage to the building stock is possible as a result of lightning and hail, they are difficult to estimate and would not have as wide of an impact as a high wind or tornado event.

Building construction plays a major role in the extent of damage resulting from a severe storm event. Due to differences in construction, residential structures generally are more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings, in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. High-rise buildings are very vulnerable structures. HAZUS-MH v4.2 Hurricane User Manual defines a high-rise building as a one being six stories or greater in height. Per HAZUS v4.2, there are 887 high-rise buildings in the county. The City of Binghamton, Villages of Endicott and Johnson City, and the Towns of Union and Vestal have high-rise buildings per this definition, with the City of Binghamton having the greatest total of buildings (722). Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside.

The U.S. Census Bureau defines manufactured homes as "movable dwellings, 8 feet or wider and 40 feet or more long, designed to be towed on its own chassis, with transportation gear integral to the unit when it leaves the factory, and without need of a permanent foundation (U.S. Census 2010)." Manufactured homes include multi-wide and expandable manufactured homes but exclude travel trailers, motor homes, and modular housing. Due to their light-weight and often unanchored design, manufactured housing is extremely vulnerable to high winds and will generally sustain the most damage.

Table 5.4.6-11 displays the number of manufactured housing units per municipality in Broome County. Total counts were obtained from the custom general building stock. Manufactured housing occupancy class was determined using the property class descriptions from the Broome County tax assessor data. As noted below, Fenton Town contains the greatest number of manufactured homes, followed closely by the Towns of Conklin, Maine, Lisle, and Windsor.

Table 5.4.6-11. Manufactured Housing Units per Municipality in Broome County

Municipality	Number of Manufactured Homes		Municipality	Number of Manufactured Homes
Barker (T)	178		Lisle (T)	402
Binghamton (C)	1		Lisle (V)	14
Binghamton (T)	9		Maine (T)	420
Chenango (T)	289		Nanticoke (T)	289

Municipality	Number of Manufactured Homes	Municipality	Number of Manufactured Homes
Colesville (T)	431	Port Dickinson (V)	0
Conklin (T)	395	Sanford (T)	136
Deposit (V)	0	Triangle (T)	282
Dickinson (T)	3	Union (T)	34
Endicott (V)	1	Vestal (T)	101
Fenton (T)	613	Whitney Point (V)	63
Johnson City (V)	2	Windsor (T)	329
Kirkwood (T)	128	Windsor (V)	0
		Broome County:	**4,120**

Source: Broome County GIS & Mapping Services
Note: (C) - City, (T) – Town, (V) – Village

The entire county's general building stock is exposed to the severe storm wind hazard (greater than $124 billion in structural replacement cost). Expected estimated building damage was estimated by HAZUS-MH v4.2 and at the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction

As noted earlier in the profile, HAZUS-MH v4.2 estimates the 100-year MRP peak gust wind speeds for Broome County to be less than 39 mph and estimates $0 in structure damage. Although damage to buildings was not estimated by the wind model, damage could still occur at these wind speeds.

HAZUS-MH v4.2 estimates $5.3 million in building damages (less than 1 percent of the county's total building inventory) as a result of the 500-year MRP event's tropical storm peak gust wind speeds (54 to 60 mph). Residential buildings account for 100 percent of the total damage. Table 5.4.6-12 summarizes the building damage (structure only) estimated for the 500-year MRP wind event by municipality. Total dollar damage reflects the overall impact to buildings at an aggregate level.

Table 5.4.6-12. Estimated Annualized Loss and Building Value (Structure Only) Damaged by the 500-Year MRP Wind Events

Municipality	Total Replacement Cost Value (Structure Only)	Estimated Total Damages*		Percent of Total Building Replacement Value	
		Annualized Loss	500-Year	Annualized Loss	500-Year
Barker (T)	$439,118,041	$802	$98,766	<1%	<1%
Binghamton (C)	$49,423,441,320	$31,930	$1,455,272	<1%	<1%
Binghamton (T)	$801,903,100	$1,932	$199,001	<1%	<1%
Chenango (T)	$2,777,071,417	$3,557	$396,399	<1%	<1%
Colesville (T)	$1,931,209,372	$1,964	$195,345	<1%	<1%
Conklin (T)	$1,078,006,795	$1,829	$176,173	<1%	<1%
Deposit (V)	$283,738,889	$499	$37,531	<1%	<1%
Dickinson (T)	$854,122,423	$820	$81,242	<1%	<1%
Endicott (V)	$7,583,787,954	$4,498	$111,441	<1%	<1%
Fenton (T)	$1,091,318,949	$1,834	$218,883	<1%	<1%
Johnson City (V)	$19,160,306,045	$8,236	$274,257	<1%	<1%
Kirkwood (T)	$2,177,958,481	$2,346	$189,740	<1%	<1%

Municipality	Total Replacement Cost Value (Structure Only)	Estimated Total Damages*		Percent of Total Building Replacement Value	
		Annualized Loss	500-Year	Annualized Loss	500-Year
Lisle (T)	$355,429,066	$494	$13,396	<1%	<1%
Lisle (V)	$66,995,607	$72	$408	<1%	<1%
Maine (T)	$1,041,084,855	$1,598	$85,213	<1%	<1%
Nanticoke (T)	$252,368,984	$333	$11,658	<1%	<1%
Port Dickinson (V)	$337,529,316	$390	$43,243	<1%	<1%
Sanford (T)	$502,854,072	$1,130	$96,606	<1%	<1%
Triangle (T)	$351,139,869	$469	$27,494	<1%	<1%
Union (T)	$19,350,826,249	$11,838	$620,384	<1%	<1%
Vestal (T)	$12,811,547,132	$10,162	$665,995	<1%	<1%
Whitney Point (V)	$325,046,761	$245	$13,088	<1%	<1%
Windsor (T)	$910,644,121	$2,168	$215,383	<1%	<1%
Windsor (V)	$466,200,435	$562	$31,645	<1%	<1%
Broome County:	**$124,373,649,253**	**$89,705**	**$5,258,563**	**<1%**	**<1%**

Source: HAZUS-MH v4.2

**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.*

Note: (C) – City, (T) – Town, (V) – Village

Impact on Critical Facilities

Utility infrastructure could suffer damage from high winds associated with falling tree limbs or other debris, resulting in the loss of power or other utility service. Loss of service can impact residents, critical facilities, and business operations alike. Interruptions in heating or cooling utilities can affect populations, such the young and elderly, who are particularly vulnerable to temperature-related health impacts. Loss of power can impact other public utilities, including potable water, wastewater treatment, and communications. In addition to public water services, property owners with private wells might not have access to potable water until power is restored. Lack of power to emergency facilities, including police, fire, EMS, and hospitals, will inhibit a community's ability to effective respond to an event and maintain the safety of its citizens.

HAZUS-MH v4.2 estimates the probability that critical facilities, such as medical facilities, fire and emergency medical services, police, emergency operations centers (EOC), schools, and user-defined facilities, such as shelters and municipal buildings, might sustain damage as a result of 100-year and 500-year MRP wind-only events. Additionally, HAZUS-MH v4.2 estimates the loss of use for each facility in number of days. HAZUS-MH v4.2 estimates there is a 0 percent chance that critical facilities in Broome County will experience at least minor damage; and continuity of operations at these facilities will not be interrupted (no loss of use is estimated) as a result of the 100- or 500-year MRP events, with the exception of medical facilities. HAZUS-MH v4.2 estimates there is less than a 1 percent chance that medical facilities might experience moderate to severe damage as a result of the 500-year MRP event.

At this time, HAZUS-MH v4.2 does not estimate losses to transportation lifelines and utilities as part of the wind model. Transportation lifelines, including roadways, rail lines, and bridges, are not considered particularly vulnerable to the wind hazard; they are more vulnerable to cascading effects, such as flooding and falling debris, which could block corridors until the hazard is removed. Impacts to transportation lifelines affect both short-term (for example, evacuation activities) and long-term (for example, day-to-day commuting) transportation needs.

Impact on Economy

Severe storms impact the economy; impacts include loss of business function, damage to inventory, relocation costs, wage loss, and rental loss due to the repair or replacement of buildings. HAZUS-MH v4.2 estimates the total economic loss associated with each probabilistic event (direct building losses and business interruption losses). Business interruption losses include losses associated with the inability to operate a business because of the wind damage sustained during a storm or the temporary living expenses for those displaced from their home because of an event.

For the 100- and 500-year MRP wind events, HAZUS-MH v4.2 does not estimate any inventory loss to businesses and reports an estimated $4,000 in business interruption costs for the 500-year MRP event. Direct building losses, the estimated costs to repair or replace the damage caused to a building, is reported in the *Impact on General Building Stock* section above.

Debris management can be costly and impact the local economy. HAZUS-MH v4.2 estimates the amount of debris that might be produced a result of the 100- and 500-year MRP wind events. HAZUS-MH v4.2 estimates that no debris will be generated as a result of the 100-year MRP wind events. Because the estimated debris production does not include flooding, this is likely a low estimate and could be higher if multiple events occur. According to the HAZUS-MH Hurricane User Manual, estimates of weight and volume of eligible tree debris consist of downed trees that would likely be collected and disposed at public expense. Refer to the User Manual for additional details regarding these estimates. Table 5.4.6-13 summarizes debris production estimates for 500-year MRP wind events.

Table 5.4.6-13. Debris Production for the 500-Year MRP Wind Events

Debris Type	Quantity		Debris Type	Quantity
Brick and Wood	91 tons		Trees	15,984 tons
Concrete and Steel	0 tons		Eligible Tree Volume	15,812 cubic yards

Source: HAZUS-MH v4.2

Future Changes that May Impact Vulnerability

Understanding future changes that effect vulnerability in the county can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The county considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development.
- Projected changes in population.
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Projected Development

Any areas of growth could be potentially impacted by the severe storm hazard because the entire county is exposed and vulnerable; however, due to increased standards and codes, new development can be less vulnerable to the severe storm hazard compared with the aging building stock in the county.

Projected Changes in Population

According to population projections from the Cornell Program on Applied Demographics (2018), Broome County will experience a continual population decrease through 2040 (an estimated 17,400 people in total by

2040). This decrease will reduce the overall vulnerability of the county's population over time. Section 4.4.2 (Population Trends) in the County Profile provides additional discussion on population trends.

Climate Change

The entire State of New York is projected to experience an increase in the frequency and severity of extreme storms and rainfall. Major clusters of summertime thunderstorms in North America will grow larger, more intense, and more frequent later this century in a changing climate, unleashing far more rain and posing a greater threat of flooding across wide areas (UCAR 2017). Section 5.4.4 (Flood) provides a discussion related to the impact of climate change due to increases in rainfall. An increase in storms will produce more wind events and can increase tornado activity. Additionally, an increase in temperature provides more energy to produce storms that generate tornadoes (Climate Central 2016). With an increased likelihood of strong winds and tornado events, all of the county's assets will experience additional risk for losses as a result of extreme wind events.

Changes in Vulnerability Since the 2013 HMP

Broome County and its municipalities continue to be vulnerable to severe storms. However, there are several differences between the loss estimates between this HMP update and the results in the 2013 HMP. For the 2013 plan, the HAZUS-MH v2.1 hurricane model was run, while for the 2019 HMP update HAZUS-MH v4.2 was used. The HAZUS-MH v4.2 model estimated less building impacts than the previous HAZUS-MH v2.1 model, even with an increase in the number of buildings and total replacement cost value of the building stock in the updated HMP's custom-general building stock inventory. HAZUS-MH v4.2 estimated no losses for the 100-year MRP event, while HAZUS-MH v2.1 estimated approximately $52,000 in structural losses. For the 500-year MRP event, HAZUS-MH v4.2 estimated approximately $5.2 million in structural losses, while HAZUS-MH v2.1 estimated approximately $5.5 million. The decrease in losses could be the result of changes in the loss parameters between HAZUS-MH versions.

Overall, the vulnerability assessment presented in this update uses a more accurate and updated building inventory, which provides more accurate estimated exposure and potential losses for Broome County.

Issues Identified

Important issues associated with severe storm events in Broome County include the following:

- Older building stock in Broome County could be more vulnerable to severe storm events, such as windstorms, as they may have been built to low or no code standards.
- Many critical facilities do not have a source of backup power; during power outages, these facilities might not function properly or provide the necessary needs to the county.
- The impacts of drought and invasive species might lead to dead or dying trees. These trees are more susceptible to falling during severe storm events. This can cause power outages, close roadways, and damage buildings and property.
- Not all municipalities have debris management or tree maintenance plan in place. Debris from downed trees must be addressed, as it can impact the severity of severe storm events, requires coordination efforts, and could require additional funding.
- Severe storms may put additional pressure on wastewater treatment plants where there are combined sewers. While the municipalities are continuously working on separation, there are still some that go to the Binghamton-Johnson City Joint Sewage Treatment Plant.