11. SEVERE WEATHER

11.1 HAZARD PROFILE

11.1.1 Hazard Description

For this HMP update and as deemed appropriated by the Passaic County Planning Partnership, the severe weather hazard includes thunderstorms and lightning, high winds, hailstorms, tornadoes, and hurricanes.

Thunderstorms and Lightning

A thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS 2021). 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. Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes.

Although thunderstorms generally affect a small area, they have the potential to become dangerous due to their ability to generate tornadoes, hailstorms, strong winds, and flash flooding. The National Weather Service (NWS) considers a thunderstorm severe if it produces wind gusts of at least 58 miles per hour (mph), hail of at least one-inch diameter, or tornadoes. An estimated 100,000 thunderstorms occur each year in the United States, with approximately 10 percent of them classified as severe (NWS 2016).

Lightning is a 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. 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. Lightning can occur anywhere there is a thunderstorm and can travel cloud-to-air, cloud-to-cloud, intra-cloud, and cloud-to-ground (NOAA 2014).

High Winds

Wind is 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. High winds are often associated with other severe weather events such as thunderstorms, tornadoes, hurricanes, and tropical storms (NWS 2012). This hazard profile focuses on the following three types of high wind events (NOAA 2023):

- **Straight-line wind** is a term used to define any wind that is not associated with rotation and is used mainly to differentiate from tornadic winds.
- A **microburst** is a small, concentrated downburst that produces an outward burst of strong winds at or near the surface. Microbursts are typically less than 2.5 miles across and last 5 to 10 minutes. Maximum windspeeds sometimes exceed 100 mph. There are two kinds of microbursts: wet and dry. A wet microburst is accompanied by heavy precipitation at the surface. Dry microbursts, common in places like the high plains and the intermountain west, occur with little or no precipitation reaching the ground.
- A **derecho** is a widespread, long-lived windstorm that is associated with a band of rapidly moving showers or thunderstorms. A derecho is defined as an event with a wind damage swath extending more than 240 miles that includes wind gusts of at least 58 mph or greater along most of its length. A typical derecho consists of numerous microbursts, downbursts, and downburst clusters.

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 and become frozen. The frozen droplet falls into warmer air toward the bottom of the thunderstorm but might be carried by another updraft 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 droplet with many layers of ice falls to the ground as hail (NSSL 2021).

Tornadoes

A tornado is a violently rotating column of air that extends from a thunderstorm to the ground with an average forward speed of 30 mph. Tornadoes typically develop from either a severe thunderstorm or hurricane as cool air rapidly overrides a layer of warm air. Tornadoes can occur at any time of the year, with peak seasons at different times for different states (NWS 2010).

Hurricanes

A hurricane is a tropical cyclone that reaches wind speed of at least 74 mph. A tropical cyclone is a rotating, organized system of clouds and thunderstorms that originates over tropical or sub-tropical waters and has a closed low-level circulation. Tropical depressions, tropical storms, and hurricanes are all considered tropical cyclones. These storms are accompanied by heavy rain and strong winds. Almost all tropical storms and hurricanes in the Atlantic Basin form between June and November, officially referred to as hurricane season. August and September are peak months for hurricane development in the North Atlantic Basin (NHC 2020).

Tropical cyclones strengthen when water evaporated from the ocean is released as the saturated air rises, resulting in condensation of water vapor. At any height in the atmosphere, the center of a tropical cyclone will be warmer than its surroundings, which is called a “warm core” storm system (NOAA 2023).

11.1.2 Location

All of Passaic County is exposed to all of the types of severe weather addressed in this HMP.

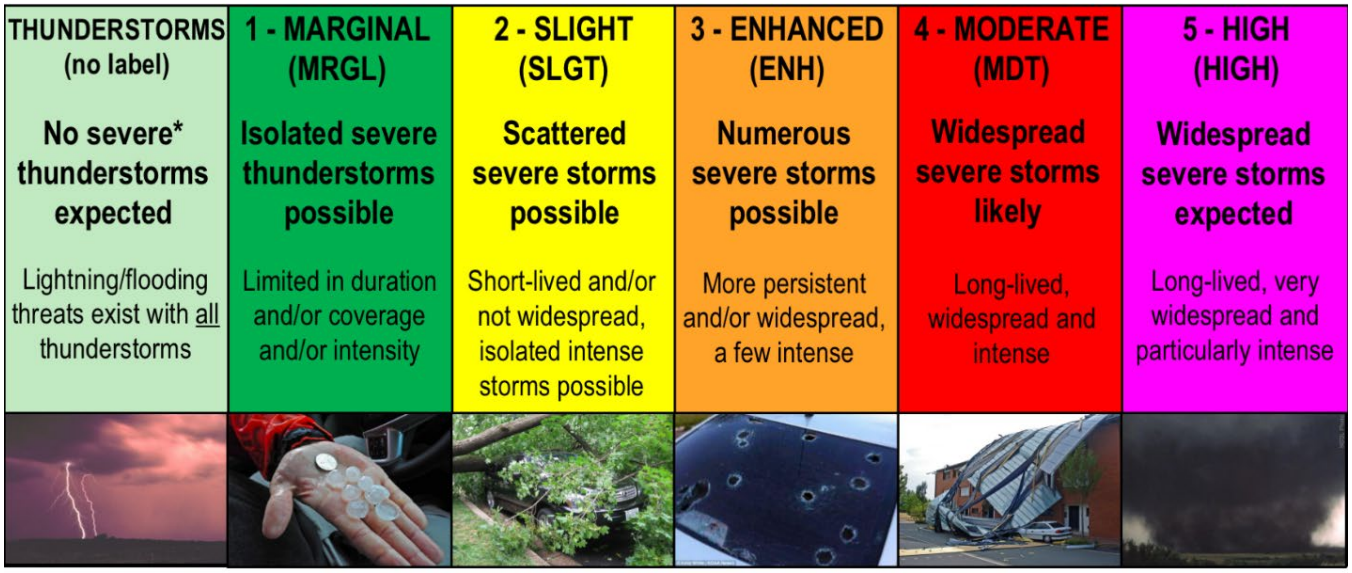
11.1.3 Extent

Thunderstorms and Lightning

As depicted in Figure 11-1, the NWS has five categories for thunderstorm risk: marginal, slight, enhanced, moderate, and high. The probabilistic forecast expresses the best estimate of a severe weather event occurring within 25 miles of a point (NWS 2019). The NWS issues the following statements, watches, and warnings for thunderstorms (NWS 2023):

- **Special Weather Statement**—Issued for strong storms that are below severe levels but may have impacts. It is usually reserved for the threat of wind gust of 40 to 57 mph or hail between a half and one inch in diameter.
- **Severe Thunderstorm Watch**—Issued when severe thunderstorms are possible in or near watch areas.
- **Severe Thunderstorm Warning**—Issued when a severe storm is imminent or occurring that is either detected by weather radar or reported by storm spotters. A severe thunderstorm is one that produces winds 58 mph or stronger or hail that is at least one inch in diameter. A warning means to take shelter.

Figure 11-1. Thunderstorm Risk



Source: NWS 2019

Cloud-to-ground and intra-cloud lightning flashes are detected and mapped in real-time by two networks: National Lightning Detection Network (NLDN) and the Earth Networks Total Lightning Network. These systems work by detecting radio atmospheric signals emitted by fast electric currents in lightning channels (NOAA n.d.).

Hailstorms

The severity of hail is measured by duration, hail size, and geographic extent. Hail can exhibit a variety of sizes, often estimated by comparing the hail to a known object (Table 11-1). Most hailstorms are made up of a mix of different sizes, and only the very largest hail stones pose serious risk to people caught in the open (NSSL 2021).

Table 11-1. Hail Size

Description	Diameter (in inches)	Description	Diameter (in inches)
Pea	0.25	**Golf ball**	1.75
Marble or Mothball	0.50	**Tennis ball**	2.5
Penny or Dime	0.75	**Baseball**	2.75
Nickel	0.88	**Tea cup**	3.00
Quarter	1.00	**Softball**	4.00
Ping Pong Ball	1.25	**Grapefruit**	4.50

Source: (NOAA 2023)

High Winds

Table 11-2 provides the descriptions of wind events and their associated sustained speed used by the NWS. Another scale used to classify wind conditions is the Beaufort wind scale, which is provided in Appendix H (Supplementary Data).

Table 11-2. NWS Wind Descriptions

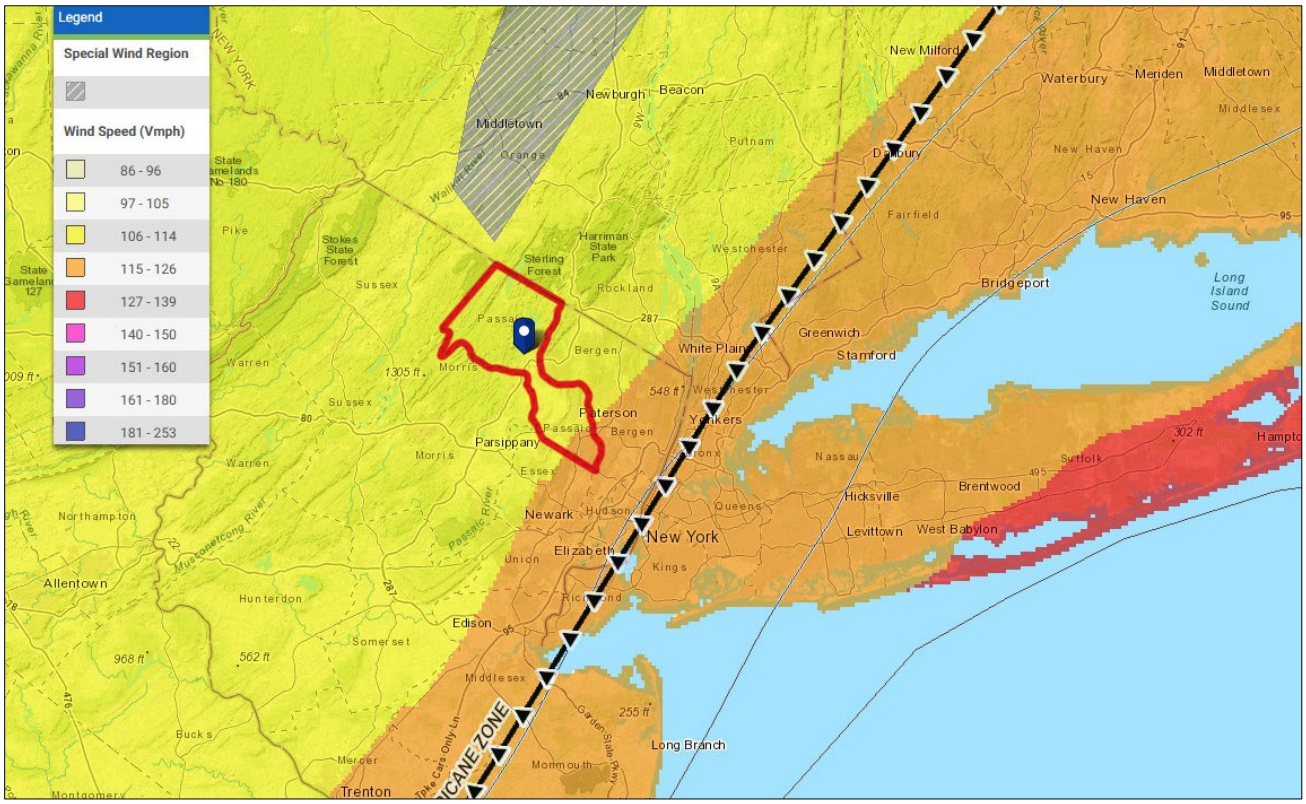
Descriptive Term	Sustained Wind Speed (mph)
Strong, dangerous, or damaging	≥40
Very Windy	30 to 40
Windy	20 to 30
Breezy, brisk, or blustery	15 to 25
None	5 to 15 or 10 to 20
Light or light and variable wind	0 to 5

Source: NWS n.d.

The American Society of Civil Engineers (ASCE) identifies wind speeds to use in building design (ASCE 2024):

- For Risk Category II structures, which include most residential buildings, the ASCE standard calls for a design that can withstand the 3-second gust wind speed that has a 7 percent chance of occurring in a 50-year period. In Passaic County, that speed is 114 mph. Figure 11-2 shows the mapping of ASCE Risk Category II wind speeds in the County and surrounding areas.
- For Risk Category IV structures, defined as buildings that are critical for emergencies and defense (such as shelters and other critical facilities), the ASCE design standard is the 3-second gust wind speed that has a 1.6 percent chance of occurring in a 50-year period. In Passaic County this is 126 mph.

Figure 11-2. ASCE Design Winds for Risk Category II Structures



Source: (ASCE 2024)

The NWS issues the following high wind alerts when wind speeds can pose a hazard or are life threatening (NWS 2012):

- **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.
- **High Wind Watches** are issued when there is the possibility that High Wind Warning Criteria may be met at longer ranges (24 to 48 hours out).
- **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.

Tornadoes

The magnitude of a tornado is categorized using the Enhanced Fujita (EF) Tornado Intensity Scale. This scale determines tornado ratings by comparing wind speed and actual damage. Figure 11-3 describes the relationship between EF ratings, wind speed, and expected tornado damage.

Figure 11-3. EF Scale Rating Descriptions

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: NWS n.d.

Tornado alerts 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 2011).

Hurricanes

Numerical Scale

Hurricane magnitude is measured using the Saffir-Simpson Hurricane Scale. The Saffir-Simpson Hurricane Wind Scale rates storms from Categories 1 to 5 (from least to most severe) 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 2023). Table 11-3 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

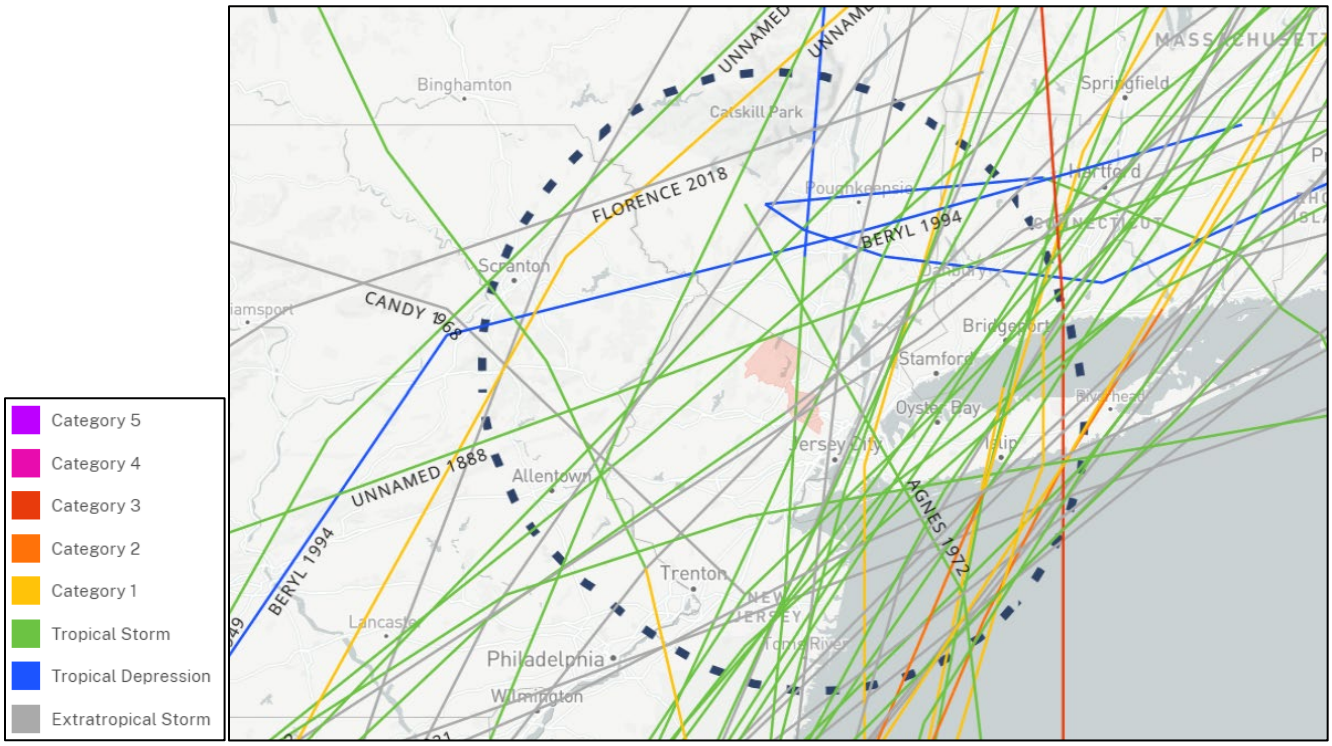
Table 11-3. The Saffir-Simpson Hurricane Scale

Category	Wind Speed (mph)	Expected Damage
1	74 to 95	Very dangerous winds will produce some damage: Homes with well-constructed frames could have damage to roof, shingles, vinyl siding, and gutters. Large tree branches will snap and shallow-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 to 110	Extremely dangerous winds will cause extensive damage: Homes with well-constructed frames could sustain major roof and siding damage. Many shallow-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 to 129	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 to 156	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	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 2023

Figure 11-4 shows the categories of tropical cyclone tracks for events that tracked within 60 nautical miles of Passaic County (an approximate distance from the center of rotation where significant impacts could be felt) between 1861 and 2023.

Figure 11-4. Historical Tropical Storm and Hurricane Tracks 1861 to 2023



Source: NOAA 2023
Note: Passaic County is shaded in red.

Hurricane Alerts

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 (NOAA 2023):

- A **Hurricane 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.
- A **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.
- A **Tropical Storm Warning** is issued when sustained winds of 39 to 73 mph are expected somewhere within the specified area within 36 hours in association with a tropical, subtropical, or post-tropical storm.
- A **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.

Mean Return Period for Hurricane Winds

Hurricane mean return periods (MRPs) are the frequency at which a certain intensity of hurricane can be expected within a given distance of a given location. For example, an MRP of 20 years for a major hurricane means that on average during the previous 100 years, a Category 3 or greater hurricane passed within 58 miles of a specific location approximately 5 times. According to the NHC, the return period of hurricanes for Passaic County was not calculated. However, the return period for surrounding counties is 18 to 19 years for a hurricane (greater than 64 mph winds) and 74 to 76 years for a major hurricane (greater than 110 mph winds) (NHC 2020).

Figure 11-5 and Figure 11-6 show the estimated maximum three-second gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP hurricane wind events. These peak wind speed projections were generated using Hazus. The estimated hurricane track used for the 100- and 500-year event is also shown. For the 100-year MRP event, the maximum three-second gust wind speeds for Passaic County range from tropical storm to Category 1 hurricane speeds. For the 500-year MRP event, the maximum three-second gust wind speeds for Passaic County range from Category 1 to Category 2 hurricane speeds.

11.1.4 Previous Occurrences

FEMA Major Disaster and Emergency Declarations

Passaic County has been included in 16 major disaster (DR) or emergency (EM) declarations for severe weather-related events (FEMA 2024). Table 11-4 lists these declarations.

Table 11-4. FEMA Declarations for Hazard Events in Passaic County (1954 to 2023)

Event Date	Declaration Date	Declaration Number	Description
August 20, 1955	August 20, 1955	DR-41-NJ	Hurricane & Floods
September 16-18, 1999	September 17, 1999	EM-3148-NJ	Hurricane Floyd
September 16-18, 1999	September 18, 1999	DR-1295-NJ	Hurricane Floyd
April 1-3, 2005	April 19, 2005	DR-1588-NJ	Severe Storms and Flooding
August 29-October 1, 2005	September 19, 2005	EM-3257-NJ	Hurricane Katrina Evacuation
April 14-20, 2007	April 26, 2007	DR-1694-NJ	Severe Storms, Inland and Coastal Flooding
March 12-April 15, 2010	April 2, 2010	DR-1897-NJ	Severe Storms and Flooding
August 26-September 5, 2011	August 27, 2011	EM-3332-NJ	Hurricane Irene
August 27-September 5, 2011	August 31, 2011	DR-4021-NJ	Hurricane Irene
September 28-October 6, 2011	October 14, 2011	DR-4039-NJ	Remnants of Tropical Storm Lee
October 29-30, 2011	November 30, 2011	DR-4048-NJ	Severe Storm
October 26-November 8, 2012	October 28, 2012	EM-3354-NJ	Hurricane Sandy
October 26-November 8, 2012	October 30, 2012	DR-4086-NJ	Hurricane Sandy
September 1-3, 2021	September 2, 2021	EM-3573-NJ	Hurricane Ida
September 1-3, 2021	September 5, 2021	DR-4614-NJ	Hurricane Ida

Source: FEMA 2024

Figure 11-5. Wind Speeds for the 100-Year MRP Event

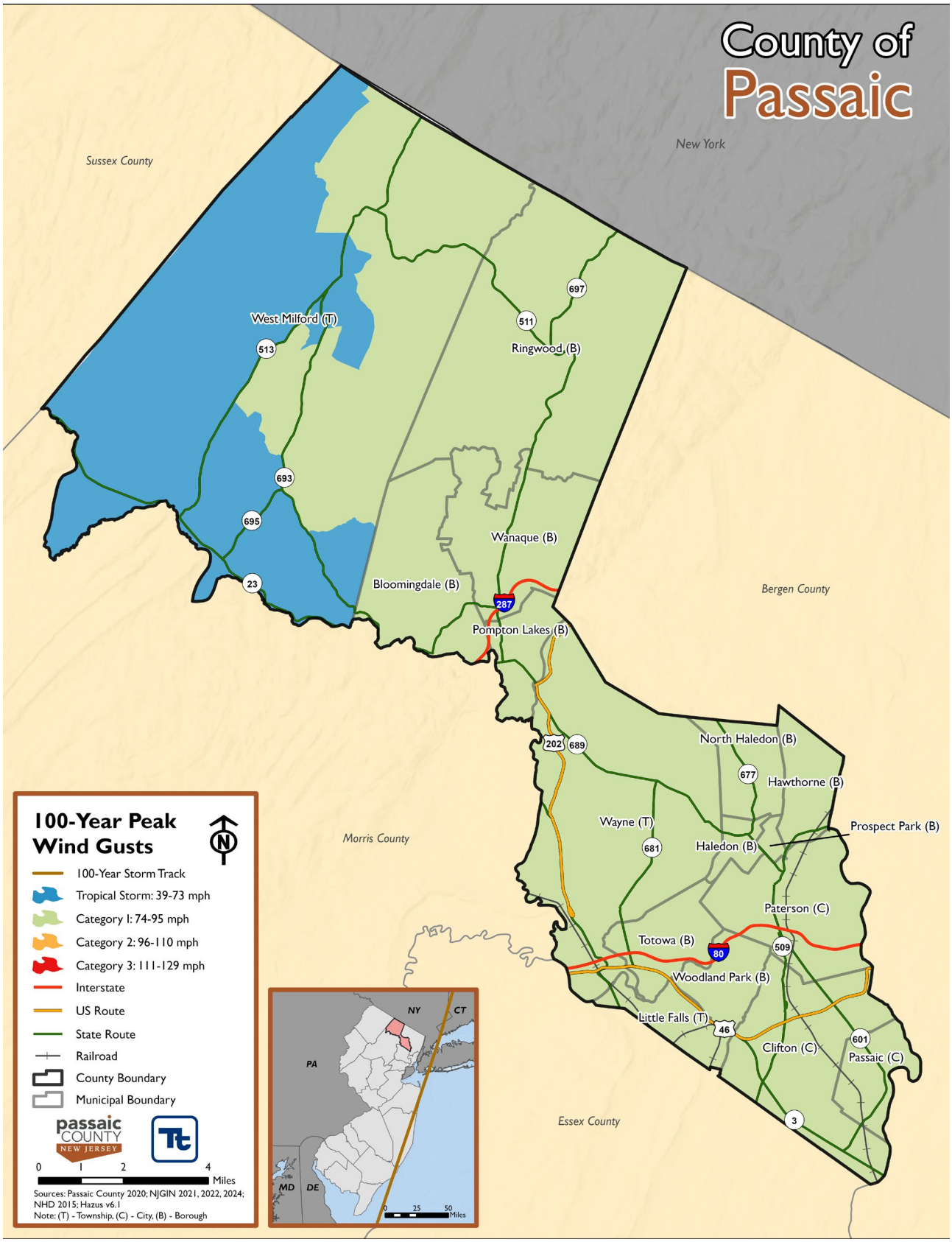
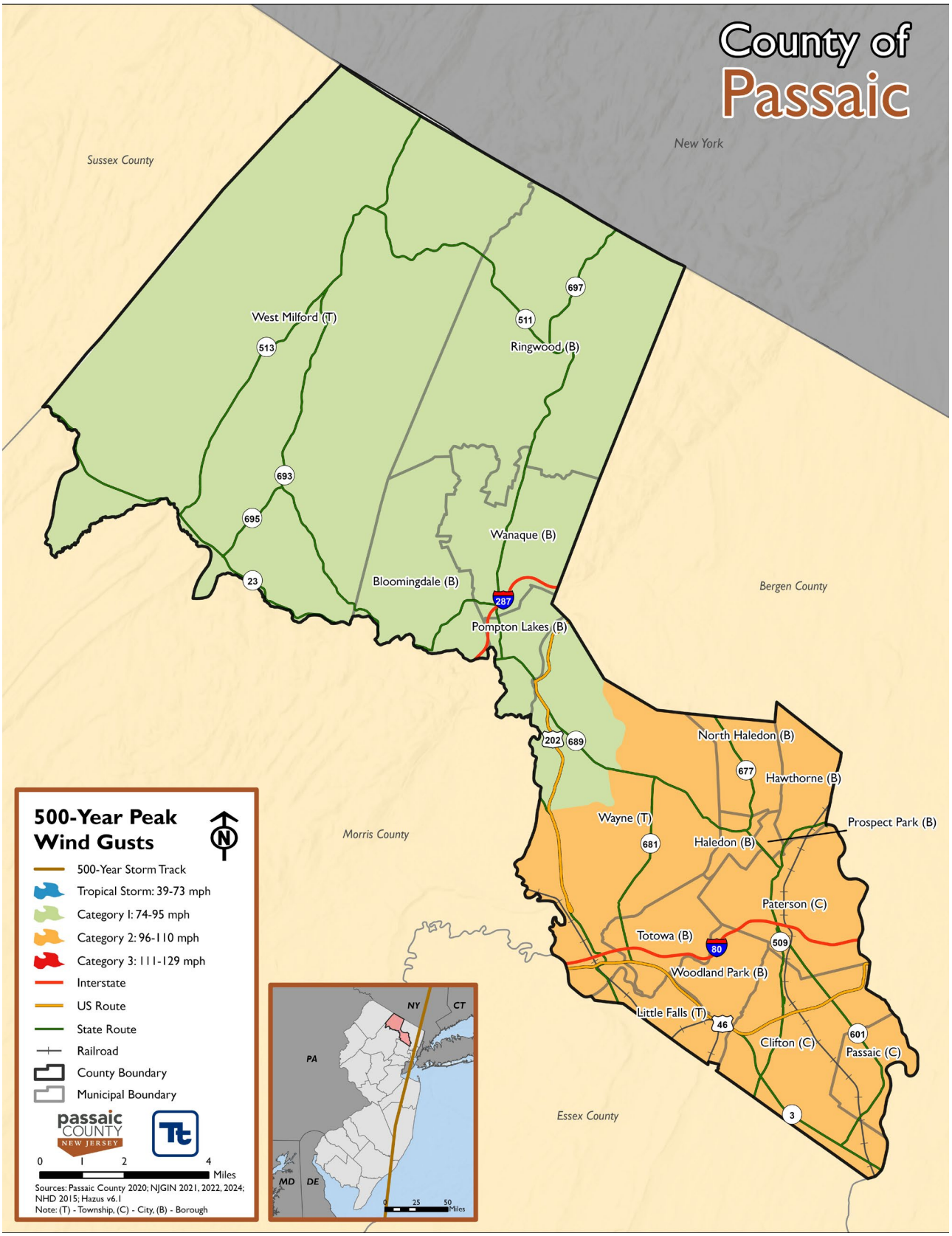


Figure 11-6. Wind Speeds for the 500-Year MRP Event



USDA Declarations

The U.S. Secretary of Agriculture is authorized to designate counties as disaster areas to make emergency loans from the U.S. Department of Agriculture (USDA) to producers suffering losses in those counties and in contiguous counties. Between 2019 and 2023, Passaic County was included two USDA severe weather-related agricultural disaster declarations (USDA 2024). These declarations are summarized in Table 11-5.

Table 11-5. USDA Declarations for Severe Weather Events in Passaic County (2019 to 2023)

Event Date	USDA Declaration Number	Description
August 3, 2020	S4892	High Winds and Heavy Rain from Hurricane Isaias
August 21, 2021	S5092	Excessive Rain

Source: USDA 2024

Previous Events

Known severe weather events that impacted Passaic County between August 2019 and December 2023 are listed in Table 11-6. For events prior to 2019, refer to the 2019 Passaic County HMP.

Table 11-6. Severe Storms Events in Passaic County (August 2019 to December 2023)

Event Date	Event Type	FEMA Declaration Number	Passaic County Included in Declaration?	Location Impacted	Description
November 1, 2019	Strong Wind	N/A	N/A	Western Passaic County	Strong winds occurred behind low pressure and strong cold front. In the town of West Bloomingdale, a 54 mph wind gust was recorded
April 13, 2020	High Wind	N/A	N/A	Eastern Passaic County	A tree down due to high winds brought down wires on Central Avenue in the Town of Hawthorne. Approximately $50,000 in property damage was reported in Passaic County.
April 21, 2020	Hail	N/A	N/A	Clifton	Strong to severe thunderstorms in northeastern New Jersey brought penny-sized hail.
August 4, 2020	Tropical Storm	N/A	N/A	County-wide	Category 1 Hurricane Isaias weakened to a tropical storm by the time it reached the New York region. The highest sustained wind speeds across northeastern New Jersey ranged from 35 to 50 mph. Gusts were between 60 and 70 mph, and rainfall was between 0.5 and 4 inches.
August 25, 2020	Thunderstorm Wind	N/A	N/A	Upper Greenwood Lake	Severe thunderstorms across northern New Jersey downed multiple trees in the Upper Greenwood Lake area near Lake Shore Drive and Riverside Road. $3,000 in property damage was reported in Passaic County.

Event Date	Event Type	FEMA Declaration Number	Passaic County Included in Declaration?	Location Impacted	Description
August 27, 2020	Thunderstorm Wind	N/A	N/A	Haledon	Severe thunderstorm across northern New Jersey downed trees and wires on E 22nd Street. $3,000 in property damage was reported in Passaic County.
December 25, 2020	High Wind	N/A	N/A	Eastern Passaic County	High winds caused a partial roof collapse on Lafayette Avenue in Hawthorne.
July 6, 2021	Thunderstorm Wind	N/A	N/A	Packanack Lake, Prospect Park, Clifton	Severe thunderstorms crossed northeastern New Jersey. In Packanack Lake the public reported trees down and garbage cans littering the street. $3,000 in property damage was reported in Packanack Lake. In Prospect Park a fallen tree on house and $11,000 in property damage was reported. In Clifton a fallen tree on a house and $11,000 in property damage was reported.
July 6, 2021	Lightning	N/A	N/A	South Paterson	Severe thunderstorms crossed northeastern New Jersey. Lightning damage to home at 42 Bloomfield Avenue and $6,000 in property damage was reported.
July 12, 2021	Thunderstorm Wind	N/A	N/A	Pinecrest Lake	A thunderstorm had evidence of rotation via radar signatures across northeastern New Jersey, mainly Passaic County. Downed trees and powerlines and $5,000 in property damage were reported.
August 11-12, 2021	Thunderstorm Wind	N/A	N/A	South Paterson, Midland Park	Severe thunderstorms crossed northeastern New Jersey. County fair tents in Garrett Mountain were damaged and $3,000 in property damage was reported.
September 2-5, 2021	Hurricane	DR-4614-NJ EM-3573-NJ	Yes	County-wide	Extremely heavy rainfall associated with the remnants of Hurricane Ida ranged from 5 to 8 inches. Eight people died as a result of the flash flooding. Canal Street in Passaic was covered with several feet of water.
November 13, 2021	Hail	N/A	N/A	Haskell	Severe thunderstorms crossed northeastern New Jersey. Hail one inch in diameter was reported.
May 22, 2022	Thunderstorm Wind	N/A	N/A	Athenia	Severe thunderstorms in northeastern New Jersey brought damaging wind gusts. A large oak tree was uprooted and $1,500 in property damage was reported.
April 22, 2023	Hail	N/A	N/A	Pinecrest Lake	Severe thunderstorms crossed northeastern New Jersey. Quarter sized hail was observed in West Milford.
July 14, 2023	Thunderstorm Wind	N/A	N/A	Charlotteburg	Multiple rounds of thunderstorms moved through northeastern New Jersey producing damaging wind gusts. Downed pole and wires were reported on NJ 23 northbound south of CR 695/Echo Lake Road.

Event Date	Event Type	FEMA Declaration Number	Passaic County Included in Declaration?	Location Impacted	Description
September 9, 2023	Thunderstorm Wind	N/A	N/A	Prospect Park, Great Notch (Little Falls)	Severe storms produced damaging winds over northeast New Jersey.

Source: NOAA NCEI 2024; FEMA 2023

11.1.5 Probability of Future Occurrences

Probability Based on Previous Occurrences

Information on previous severe weather occurrences in the County was used to calculate the probability of future occurrence of such events, as summarized in Table 11-7. Based on historical records and input from the Steering Committee, the probability of occurrence for severe weather in the County is considered ”frequent.”

Table 11-7. Probability of Future Severe Weather Events in Passaic County

Hazard Type	Number of Occurrences Between 1996 and 2023	Percent Chance of Occurring in Any Given Year
Hail	29	100%
High Wind	40	100%
Hurricane[a]	5	19%
Lightning	15	58%
Strong Wind	10	38%
Thunderstorm Wind	118	100%
Tornado	1	4%
Total	218	100%

Source: NOAA NCEI 2024

a. Hurricane events include tropical storms.

Effect of Climate Change on Future Probability

A warmer atmosphere means storms have the potential to be more intense and occur more often. In New Jersey, extreme storms typically include spring and summer thunderstorms, tropical storms, and on rare occasions hurricanes. Most of these events occur in the warmer months between April and October. Over the last 50 years in New Jersey, storms that resulted in extreme rain increased by 71, percent which is a faster rate than anywhere else in the United States (NJDEP 2020). By 2050, annual precipitation in New Jersey could increase by 4 to 11 percent (NJDEP 2020). By the end of this century, heavy precipitation events are projected to occur two to five times more often and with more intensity than in the last century.

11.1.6 Cascading Impacts on Other Hazards

Rainfall associated with severe weather may exacerbate flooding and dam failures. Strong winds can be destructive to the functionality of utilities by breaching power lines and disconnecting the utility systems, as well as result in falling trees and branches. Fallen vegetation also reduces the soil stability of steep slopes, which can lead to an increased risk of landslides.

11.2 VULNERABILITY AND IMPACT ASSESSMENT

The entire County and all inventoried assets have been identified as exposed to severe storms. All of the weather types included in this hazard were evaluated at a qualitative level only, except for high winds/tropical cyclone. A quantitative assessment was completed to assess wind-related damage from tropical cyclones and other storms, using a probabilistic analysis within the Hazus hurricane model for the 100- and 500-year MRP hurricane wind events.

11.2.1 Life, Health, and Safety

Overall Population

The entire population of Passaic County (461,860) is exposed to severe storm events. Potential impacts include the following:

- Downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life.
- Lightning can be responsible for deaths, injuries, and property damage.
- People located outdoors (i.e., recreational activities and farming) are vulnerable to hailstorms, thunderstorms, and tornadoes because there is little to no warning, and shelter might not be available.
- Construction workers who work in open spaces, at heights, with electrical equipment and metals, in excavation areas and trenches, or with hazardous materials face higher risks related to wet weather and wind (Hazwoper 2020).

Residents may be displaced or require short-term sheltering due to severe weather events. As shown in Table 11-8, Hazus estimates that there will be five displaced households and five persons seeking short-term shelter from the 100-year MRP hurricane wind event. Further, Hazus estimates that there will be 657 households displaced and 795 persons seeking short-term sheltering caused by the 500-year MRP hurricane wind event

Socially Vulnerable Population

Without a quantitative assessment of potential impacts of severe weather on socially vulnerable populations, the Planning Partners can best assess mitigation options through an understanding of the general numbers and locations of such populations across Passaic County. Section 3.6.3 provides detailed data on socially vulnerable populations within the planning area. Table 11-9 summarizes highlights of this information. For planning purposes, it is reasonable to assume that percentages and distribution of socially vulnerable populations affected by severe weather will be similar to the countywide numbers.

Table 11-8. Displaced Households and Persons Seeking Shelter Due to the 100- and 500-Year MRP Wind

Jurisdiction	100-Year MRP Hurricane		500-Year MRP Hurricane	
	Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering
Bloomingdale (B)	0	0	2	1
Clifton (C)	5	5	167	171
Haledon (B)	0	0	10	12
Hawthorne (B)	0	0	28	20
Little Falls (T)	0	0	11	5
North Haledon (B)	0	0	6	3
Passaic (C)	0	0	117	189
Paterson (C)	0	0	234	335
Pompton Lakes (B)	0	0	5	3
Prospect Park (B)	0	0	8	13
Ringwood (B)	0	0	1	1
Totowa (B)	0	0	13	10
Wanaque (B)	0	0	3	2
Wayne (T)	0	0	33	17
West Milford (T)	0	0	1	0
Woodland Park (B)	0	0	18	13
Passaic County (Total)	5	5	657	795

Source: US Census Bureau 2022; Hazus v6.1

Table 11-9. Distribution of Socially Vulnerable Populations by Municipality

Category	Sussex County Total		Municipality Highest in Category		Municipality Lowest in Category	
	Number	Percent	Number	Percent	Number	Percent
			Paterson	North Haledon	Prospect Park	Passaic
Population Over 65	**78,440**	**15.10%**	**18,141**	**24.6%**	**625**	**9.0%**
			Paterson	Passaic, Prospect Park	Bloomingdale	Bloomingdale
Population Under 5	**33,502**	**6.40%**	**12,442**	**8.3%**	**247**	**3.2%**
Non-English-Speaking Population	**68,953**	**13.30%**	Paterson **34,885**	Passaic **22.4%**	Bloomingdale, Ringwood **104**	Ringwood **0.9%**
Population With Disability	**46,707**	**9.00%**	Paterson **12,756**	Prospect Park **14.3%**	Bloomingdale **588**	Pompton Lakes **7.2%**
Population Below Poverty Level	**68,995**	**13.30%**	Paterson **37,143**	Paterson **23.5%**	Ringwood **262**	Ringwood **2.2%**
Households Below ALICE Threshold	**62,752**	**35%**	Paterson **33,284**	Paterson **67%**	North Haledon **745**	Ringwood **22%**

Particular impacts of this hazard on socially vulnerable populations are as follows:

- Individuals who rent their homes often lack control over necessary repairs, which can exacerbate the impact of hazards.
- Some residents depend on medical equipment that requires electricity, making power outages a serious health risk.
- Those without private transportation may face isolation if public transportation services are disrupted.
- Hourly workers may suffer financial losses if they are unable to work due to hazardous conditions, leading to cascading effects on their households, such as difficulties in affording rent or groceries.
- Economically disadvantaged populations may be more vulnerable because they lack the financial resources needed to evacuate.
- The population over age 65 is also more vulnerable because they are more likely to need medical attention that may not be available due to isolation during a severe weather event, and they may have more difficulty evacuating.

11.2.2 General Building Stock

All buildings are exposed to severe weather events. Potential impacts include the following

- Lightning could be a threat to the building stock if it starts a fire. Over 22,000 fires caused by lightning occurred annually throughout the U.S. between 2007 and 2011, which was valued at approximately $450 million of damage per year (National Fire Protection Association 2013).
- While hailstorms are not frequently known to cause major injuries or damage in the State of New Jersey, an extreme event can carry hail stones traveling at speeds greater than 100 miles per hour (National Weather Service 2019). This could cause structural damage to buildings.
- For high wind events, including hurricanes, building construction plays a major role in the extent of damage resulting from a storm event. Due to differences in construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings, in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. High-rise buildings are also very vulnerable structures. Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside.
- The damage that results when a tornado arrives is devastating. An EF 4 tornado can carry wind velocities of 200 mph, resulting in a force of more than 100 pounds per square foot of surface area. This is a wind load that exceeds the design limits of most buildings.

The Hazus wind model was run to estimate potential losses to buildings from hurricanes or other straight-line high wind events. Expected building damage was evaluated across the wind damage categories described in Table 11-10. Building damage as a result of the 100-year and 500-year MRP hurricane wind events was estimated using Hazus, as summarized in Table 11-11. Two residential buildings are expected to be destroyed and five residential and five commercial buildings would be severely damaged by the 100-year MRP hurricane wind event. For the 500-year MRP hurricane wind event, most of the losses would be to residential buildings. An estimated 174 buildings would be destroyed and 83 buildings would experience severe damage. Moderate damage would occur to 1,599 buildings and 11,640 would have minor damage.

Table 11-10. Description of Damage Categories

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
No Damage—Little or no visible damage. No broken windows or failed roof deck. Minimal loss of roof cover. Minimal water penetration.	≤2%	No	No	No	No	No
Minor Damage—Maximum of one broken window or door. Moderate roof cover loss that can be covered to prevent additional water entering the building. Marks or dents on walls requiring painting or patching for repair.	>2% and ≤15%	One window, door, or garage door failure	No	<5 impacts	No	No
Moderate Damage—Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water.	>15% and ≤50%	> 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: FEMA 2022

Table 11-11. Expected Damage from 100- and 500- Year MRP Events

Total Number of Buildings in Occupancy	Severity of Expected Damage	100-Year MRP		500-Year MRP	
		Building Count	% Buildings in Occupancy Class	Building Count	% Buildings in Occupancy Class
Residential Exposure (Single and Multi-Family Dwellings)					
88,431	NONE	86,272	97.6%	74,934	84.7%
	MINOR	2,054	2.3%	11,640	13.2%
	MODERATE	99	0.1%	1,599	1.8%
	SEVERE	5	<0.1%	83	0.1%
	DESTRUCTION	2	<0.1%	174	0.2%
Commercial Buildings					
13,055	NONE	12,559	96.2%	10,772	82.5%
	MINOR	379	2.9%	1,366	10.5%
	MODERATE	112	0.9%	815	6.2%
	SEVERE	5	<0.1%	102	0.8%
	DESTRUCTION	0	0.0%	0	0.0%
Industrial Buildings					
738	NONE	713	96.6%	609	82.5%
	MINOR	20	2.7%	82	11.1%
	MODERATE	5	0.7%	40	5.4%
	SEVERE	0	0.0%	7	0.9%
	DESTRUCTION	0	0.0%	0	0.0%

Total Number of Buildings in Occupancy	Severity of Expected Damage	100-Year MRP		500-Year MRP	
		Building Count	% Buildings in Occupancy Class	Building Count	% Buildings in Occupancy Class
Other Buildings[a]					
1,028	NONE	1,013	98.5%	929	90.4%
	MINOR	14	1.4%	81	7.9%
	MODERATE	1	0.1%	17	1.7%
	SEVERE	0	0.0%	1	0.1%
	DESTRUCTION	0	0.0%	0	0.0%

Source: Hazus v6.1; Microsoft 2019; NJOIT 2024

a. Other = Government, Religion, Agricultural, Education

Table 11-12 summarizes the value of damage estimated for the 100- and 500-year MRP hurricane wind events. The estimates include buildings damaged at all severity levels, from minor damage to destruction. The total estimated damage to buildings for all occupancy types across Passaic County is estimated to be $130 million and $758 million for the 100- and 500-year MRP events, respectively. Most of these losses would be to residential buildings. The City of Clifton is estimated to experience the greatest damage in the 100- and 500-year MRP events—$28 million and $178 million, respectively. Damage to buildings is a affected by wind speed, direction, and duration, which are dependent upon the storm's intensity and track.

11.2.3 Community Lifelines and Other Critical Facilities

Critical facilities are at risk of being impacted by high winds associated with structural damage, or falling tree limbs/flying debris, which can result in the loss of power. Power loss can greatly impact households, business operations, public utilities, and emergency personnel. Emergency personnel such as police, fire, and EMS will not be able to effectively respond in a power loss event to maintain public safety unless backup power and fuel sources are available. 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.

Table 11-13 and Table 11-14 summarize the damage state probabilities for critical facilities during the 100-year and 500-year MRP hurricane wind events:

- As a result of a 100-year MRP event, Hazus estimates that the Hazardous Materials lifeline has the greatest chance of sustaining minor damage (2.6 percent), followed by the Energy and Food, Hydration, and Shelter lifelines (both at 2.4 percent probability). Hazardous Materials lifeline also has the greatest chance of moderate damage, at an approximate 0.7 percent probability. Severe and complete damage to lifelines is negligible.
- As a result of a 500-year MRP event, Hazus estimates that the Food, Hydration, and Shelter lifeline has the greatest chance of sustaining minor damage (11.6 percent). The Hazardous Materials lifeline has the greatest chance of moderate damage (5.4 percent) and severe damage (1.0 percent). Complete damage is negligible.
- For the 100-Year MRP event, there are no days recorded for loss of function of any lifeline.
- For the 500-Year MRP event, the Safety and Security lifeline record less than one day of loss of functionality.

Table 11-12. Estimated Buildings Damaged by General Occupancy by the 100- and 500-Year MRP Events

Jurisdiction	Estimated Building Losses (Residential)		Estimated Building Losses (Commercial)		Estimated Building Losses (Industrial)		Estimated Damage (All Other Occupancies)		Estimated Building Losses (All Occupancies)	
	100-Year MRP Event	500-Year MRP Event	100-Year MRP Event	500-Year MRP Event	100-Year MRP Event	500-Year MRP Event	100-Year MRP Event	500-Year MRP Event	100-Year MRP Event	500-Year MRP Event
Bloomingdale (B)	$1,125,174	$4,041,627	$68,100	$421,915	$635	$5,062	$11,008	$64,637	$1,204,917	$4,533,242
Clifton (C)	$20,884,582	$127,436,679	$5,568,148	$37,344,777	$947,506	$9,350,009	$389,354	$3,825,982	$27,789,590	$177,957,446
Haledon (B)	$1,291,250	$6,906,895	$251,119	$1,595,032	$42,756	$318,222	$51,997	$709,556	$1,637,123	$9,529,705
Hawthorne (B)	$5,866,876	$27,925,697	$718,042	$4,677,063	$195,477	$1,416,864	$53,200	$438,960	$6,833,596	$34,458,584
Little Falls (T)	$3,623,719	$17,311,793	$719,431	$4,456,245	$102,785	$751,394	$89,692	$1,176,330	$4,535,626	$23,695,763
North Haledon (B)	$3,330,593	$15,426,432	$187,822	$1,246,070	$229	$2,279	$40,095	$376,853	$3,558,739	$17,051,633
Passaic (C)	$15,214,582	$98,006,748	$4,605,639	$32,038,073	$352,298	$3,491,229	$594,017	$4,725,344	$20,766,536	$138,261,394
Paterson (C)	$13,819,695	$81,992,753	$8,263,275	$50,956,474	$1,842,869	$16,165,255	$1,017,080	$7,808,701	$24,942,919	$156,923,184
Pompton Lakes (B)	$2,682,733	$10,168,637	$143,506	$1,186,712	$6,194	$54,869	$21,993	$250,694	$2,854,426	$11,660,913
Prospect Park (B)	$791,424	$4,300,514	$68,637	$453,918	$3,860	$27,675	$21,052	$158,244	$884,973	$4,940,351
Ringwood (B)	$2,036,771	$8,132,606	$95,193	$714,658	$11,699	$87,642	$20,364	$151,926	$2,164,027	$9,086,831
Totowa (B)	$3,705,992	$18,611,525	$1,657,058	$11,289,444	$414,822	$3,281,613	$33,990	$441,810	$5,811,862	$33,624,392
Wanaque (B)	$1,643,436	$6,530,474	$116,366	$823,605	$17,974	$161,561	$27,936	$186,900	$1,805,713	$7,702,540
Wayne (T)	$15,175,232	$68,975,722	$2,278,674	$16,701,045	$173,446	$1,710,351	$231,406	$2,523,636	$17,858,758	$89,910,754
West Milford (T)	$3,187,767	$13,290,619	$122,028	$1,069,777	$8,409	$59,575	$40,136	$261,627	$3,358,340	$14,681,598
Woodland Park (B)	$3,194,645	$17,712,891	$728,372	$5,352,149	$56,417	$493,208	$29,709	$396,873	$4,009,143	$23,955,121
Passaic County (Total)	$97,574,471	$526,771,611	$25,591,410	$170,326,957	$4,177,375	$37,376,809	$2,673,030	$23,498,074	$130,016,287	$757,973,450

Source: Hazus v6.1; Microsoft 2019; RS Means 2024; NJOIT 2024

Table 11-13. Estimated Impacts on Critical Facilities for the 100-Year MRP Event

	Loss of Days	Average Percent Probability of Sustaining Damage 100-Year MRP Hurricane			
		Minor	Moderate	Severe	Complete
Communications	0	0.9%	0.1%	<0.1%	0.0%
Energy	0	2.4%	0.5%	<0.1%	0.0%
Food, Hydration, Shelter	0	2.4%	0.3%	<0.1%	0.0%
Hazardous Materials	0	2.6%	0.7%	<0.1%	0.0%
Health and Medical	0	1.9%	0.4%	<0.1%	0.0%
Safety and Security	0	1.8%	0.2%	0.0%	0.0%
Transportation	0	1.7%	0.1%	<0.1%	0.0%
Water Systems	0	1.5%	0.2%	<0.1%	0.0%

Source: Hazus v6.1; Passaic County 2024; (Passaic County HMP 2020); (Passaic County Department of Planning & Economic Development 2024); (HIFLD 2017, 2018, 2022, 2023); (NJGIN 2017, 2021, 2022); (HIFLD 2017, 2018, 2022, 2023); (NJGIN 2017, 2021, 2022)

Table 11-14. Estimated Impacts to Critical Facilities for the 500-Year MRP Event

	Loss of Days	Average Percent Probability of Sustaining Damage 500-Year MRP Hurricane			
		Minor	Moderate	Severe	Complete
Communications	0	5.2%	1.2%	0.2%	0.0%
Energy	0	10.4%	4.5%	0.7%	0.0%
Food, Hydration, Shelter	0	11.6%	4.3%	0.2%	0.0%
Hazardous Materials	0	10.3%	5.4%	1.0%	0.0%
Health and Medical	0	8.4%	4.4%	0.2%	0.0%
Safety and Security	<1	8.1%	4.2%	0.1%	0.0%
Transportation	0	8.6%	2.0%	0.1%	0.0%
Water Systems	0	6.3%	2.0%	0.3%	0.0%

Source: Hazus v6.1; Passaic County 2024; (Passaic County HMP 2020); (Passaic County Department of Planning & Economic Development 2024)

11.2.4 Economy

Economic impacts from severe weather events include the loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss, and rental loss due to the repair or replacement of buildings. Impacts on transportation lifelines affect long-term transportation needs (e.g., day-to-day commuting and goods transport). Recovery and clean-up costs can be costly and impact the economy as well (NJOEM 2024). Weather-related power failures can impact business operations.

Hazus estimates the debris produced as result of the 100- and 500-year MRP hurricane wind events. Table 11-15 summarizes the estimated debris by municipality. The estimates do not include debris generated by flooding, so this is likely a conservative estimate and could be higher if multiple impacts occur. For both MRP events, debris production from trees is the greatest, with the 100-year MRP creating an estimated 92,907 tons of debris and the 500-year MRP event creating 405,438 tons.

Table 11-15. Debris Production for 100- and 500-Year MRP Event Winds

Jurisdiction	Brick and Wood (tons)		Concrete and Steel (tons)		Trees (tons)	
	100-Year	500-Year	100-Year	500-Year	100-Year	500-Year
Bloomingdale (B)	77	397	0	0	296	3,251
Clifton (C)	2,628	14,843	0	60	2,924	9,250
Haledon (B)	195	1,017	0	2	194	637
Hawthorne (B)	556	2,986	0	4	611	1,834
Little Falls (T)	371	1,950	0	7	388	1,269
North Haledon (B)	256	1,420	0	0	389	1,291
Passaic (C)	2,066	11,265	0	47	710	2,124
Paterson (C)	2,997	15,598	0	17	1,551	4,876
Pompton Lakes (B)	149	858	0	0	193	1,205
Prospect Park (B)	124	634	0	1	90	331
Ringwood (B)	127	756	0	0	494	11,423
Totowa (B)	538	2,758	0	3	560	1,999
Wanaque (B)	130	697	0	0	246	3,153
Wayne (T)	1,486	8,056	0	13	1,840	9,070
West Milford (T)	160	1,002	0	0	2,827	30,289
Woodland Park (B)	396	2,129	0	0	402	1,412
Passaic County (Total)	12,256	66,366	0	154	13,715	83,414

Source: Hazus v6.1; Microsoft 2019; NJOIT 2024

11.2.5 Natural, Historic and Cultural Resources

Natural

Severe weather creates longer periods of rainfall, which can erode natural banks along waterways and degrade soil stability for terrestrial species. Tornadoes can tear apart habitats causing fragmentation across ecosystems (United States Environmental Protection Agency 2023). Severe weather events can impact water resources, leading to the spread of diseases across ecosystems (United States Climate Resilience Toolkit 2016). As the physical environment becomes more altered, species may contract or migrate in response, causing additional stressors to the entire ecosystem within Passaic County. The impacts of hurricane-related winds on the environment typically occur over a larger area, resulting in widespread, severe damage to tree and plant species. This includes uprooting or destruction of trees and an increased threat of wildfire in areas where dead trees are not removed.

Historic

Winds associated with severe weather can cause significant damage to historic infrastructure. Historic sites are particularly vulnerable due to their age and construction prior to modern building standards. The materials used in these structures may be aged and prone to maintenance issues, making them more susceptible to damage. Additionally, any damage repair may require compliance with stringent landmark laws, complicating and increasing the cost of repairs.

Historic buildings are at risk of structural damage during flood events caused by thunderstorm or hurricane rains. Many historic resources and structures were built close to waterways, which increases their flood risk. Severe flood events could result in devastating loss of life and property in and around these historical landmarks.

Cultural

Winds associated with severe weather can cause significant damage or destruction to cultural resources. The historic buildings that house such resources may be particularly vulnerable due to their construction prior to modern building standards, which may not withstand high winds. The materials used in these structures may be aged and prone to maintenance issues, further increasing their susceptibility to damage.

Cultural heritage sites exposed to severe weather are subject to weathering and deterioration. Outdoor cultural events are at risk, as severe weather can lead to postponements or cancellations.

The vulnerability of cultural resources is heightened by their irreplaceable nature. Damage to these sites can result in the loss of unique historical and cultural artifacts, which cannot be easily restored or replaced. Additionally, any damage repair may require compliance with stringent landmark laws, complicating and increasing the cost of repairs.

11.3 FUTURE CHANGES THAT MAY AFFECT RISK

11.3.1 Potential or Planned Development

Understanding future changes that impact vulnerability in Passaic County is crucial for planning development and ensuring appropriate mitigation, planning, and preparedness measures. New development and residents will face hurricane and tropical storm hazards, but increased standards and codes may reduce their vulnerability to wind and flood-related impacts compared to older buildings.

New development will replace open land and vegetation with buildings, roads, and other infrastructure that is less able to absorb precipitation. This transformation can make surfaces that were once permeable and moist become impermeable and dry, leading to increased surface runoff and altered water conveyance patterns.

Areas targeted for future growth and development have been identified across the County. These areas are vulnerable to severe storm events, and new development sites should adhere to building codes that provide high wind protection and flood-proofing measures. Specific areas of recent and new development are detailed in tables and hazard maps included in the jurisdictional annexes in Volume II of this plan.

11.3.2 Projected Changes in Population

An increase in population density can create issues for local residents during evacuation from a severe storm event. Densely populated areas of the County may require utility system upgrades to keep up with utility demands (e.g., water, electric) during storms to prevent increased stresses on these systems.

The New Jersey Department of Labor and Workforce Development produced population projections by County for 2029 and 2034. According to these projections, Passaic County is projected to have an increase in population in the upcoming years. These projections include a population of 536,100 by 2029 and 542,500 by 2034 (State of New Jersey 2017).

11.3.3 Climate Change

Climate is defined by the type, frequency, and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the frequency and severity of severe weather. Most studies project that the State of New Jersey will see an increase in average annual precipitation, primarily in the form of heavy rainfalls. Increases in precipitation may alter and expand the floodplain boundaries and runoff patterns, resulting in the exposure of populations, buildings, and critical facilities and infrastructure that were previously outside the floodplain. This increase in exposure would result in an increased risk to life and health, an increase in structural losses, a diversion of additional resources to response and recovery efforts, and an increase in business closures affected by future flooding events due to loss of service or access. Moreover, as the physical environment becomes more altered, species will begin to contract or migrate in response, which may cause additional stressors to ecosystems within Somerset County.