5.4.8 Severe Weather

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

2021 HMP Update Changes

- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 2016 and 2020.
- A vulnerability assessment was conducted for the severe weather hazard using a more accurate and updated building inventory.

5.4.8.1 Profile

Hazard Description

For the purpose of this HMP Update and as deemed appropriated by the Cape May County Hazard Mitigation Planning Committee, the severe weather hazard includes high winds, tornadoes, thunderstorms and lightning, derechos, hail, and extreme temperatures (heat and cold), which are defined below. While hurricanes, tropical storms and Nor'Easters are all types of severe weather, they are included as separate hazards. Refer to Section 5.4.6 (Hurricane and Tropical Storm) and Section 5.4.7 (Nor'Easter).

Thunderstorms

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).

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. 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, large hail one-inch (quarter size) in diameter or larger, or tornadoes (NWS 2020).

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.

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.

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).

In Cape May County, ten tornadoes were reported between 1950 and September 2020. Upper Township was the site of the County's most recent tornado, which was spawned in the wake of Tropical Storm Isaias in August 2020. The tornado caused significant damage in the Marmora section of the Township.

Derechos

A derecho is a long-lived windstorm that is associated with a rapidly moving squall line of thunderstorms. It produces straight-line wind gusts of at least 58 mph and often has isolated gusts exceeding 75 mph. This means that trees generally fall and debris is blown in one direction. To be considered a derecho, these conditions must persist along a path of at least 240 miles. Derechos are more common in the Great Lakes and Midwest regions of the United States, though on occasion can persist into the Mid-Atlantic and Northeast (ONJSC 2013a).

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.

Extreme Cold

Extreme cold events occur when temperatures drop significantly below normal in an area for an extended period of time. In New Jersey, no specific definition or thresholds exist for Extreme Cold. Extreme cold events may be due to winter storms, which can cause hazardous travel conditions or power outages. Prolonged exposure to cold can lead to serious or life-threatening health conditions (NJ OEM 2019).

Extreme Heat

Extreme heat is defined as temperatures which hover 10 degrees or more above the average high temperature for a region and that last for several weeks (CDC 2016). An extended period of extreme heat of three or more consecutive days is typically called a heat wave and is often accompanied by high humidity (NWS 2013d). Humid or muggy conditions occur when a *dome* of high atmospheric pressure traps hazy, damp air near the ground. There is no universal definition of a heat wave because the term is relative to the usual weather in a

particular area. The term heat wave is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century (Meehl and Tebaldi 2004).

Location

All of Cape May County is exposed to high wind, tornadoes, thunderstorms and lightning, derechos, hailstorms, and extreme temperatures. Additionally, all of the County is subject to high winds from severe weather events. According to the FEMA Winds Zones of the United States map, Cape May County is located in Wind Zone II. In this zone, wind speeds can reach up to 160 mph. Additionally, the County is located within a "Hurricane Susceptible Region", meaning Cape May County is susceptible to hurricanes and other tropical cyclone events.

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, and tornadoes in Cape May. Historical data presented in Table 5.4.8-1 shows the most powerful severe weather records in Cape May County.

Table 5.4.8-1. Severe Storm Extent in Cape May County (1950-2020)

Extent of Severe Storms in Cape May County	
Largest Hailstone on Record	1.75 inches
Strongest Tornado on Record	EF-2
Highest Wind Speed on Record	78 knots

Source: NOAA-NCEI 2020

High Winds

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

Table 5.4.8-2. NWS Wind Descriptions

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

Source: NWS 2015

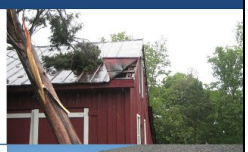
NWS issues advisories and warnings for winds, which are normally site-specific. High wind advisories, watches, and warnings are issued by the NWS when wind speeds may pose a hazard or may be life threatening. The criterion for each of these varies from state to state. Wind warnings and advisories for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

- *High Wind Warnings* are issued when sustained winds of 40 mph or greater are forecast for 1 hour or longer, or wind gusts of 58 mph or greater are forecast for any duration.
- *Wind Advisories* are issued when sustained winds of 30 to 39 mph are forecast for one 1 hour or longer, or wind gusts of 46 to 57 mph are forecast for any duration (NWS 2015).

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 5.4.8-1 illustrates the relationship between EF ratings, wind speed, and expected tornado damage.

Figure 5.4.8-1. 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.		

Thunderstorms and Lightning

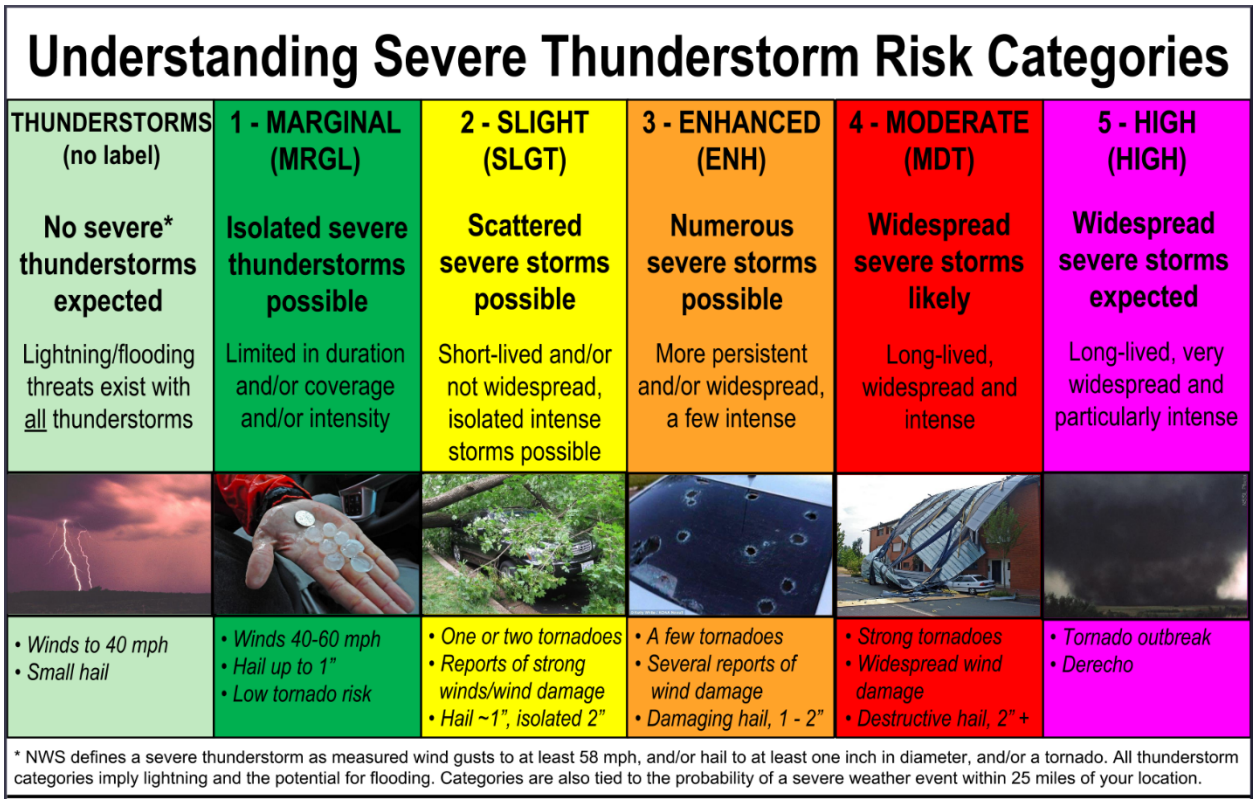
Severe thunderstorm watches and warnings are issued by the local NWS office and SPC. The NWS and SPC will update the watches and warnings and will notify the public when they are no longer in effect. Watches and warnings for tornadoes in New Jersey are as follows:

- Severe Thunderstorm Warnings are issued when there is evidence based on radar or a reliable spotter report that a thunderstorm is producing, or forecast to produce, wind gusts of 58 mph or greater, structural wind damage, and/or hail one-inch in diameter or greater. A warning will include where the storm was located, what municipalities will be impacted, and the primary threat associated with the severe thunderstorm warning. After it has been issued, the NWS office will follow up periodically with Severe Weather Statements which contain updated information on the severe thunderstorm and will let the public know when the warning is no longer in effect (NWS 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 may also occur. Watches are normally issued well in advance of the actual occurrence of severe weather. During the watch, the NWS will keep the public informed on what is happening in the watch area and also let the public know when the watch has expired or been cancelled (NWS 2010c).
- Special Weather State for Near Severe Thunderstorms are issued for strong thunderstorms that are below severe levels, but still may have some adverse impacts. Usually, they are issued for the threat of wind gusts of 40 to 58 mph or small hail less than one-inch in diameter (NWS 2010c).

In addition, the SPC issues severe thunderstorm risk maps based on the likelihood of different severities of thunderstorms. Figure 5.4.8-2 shows the SPC's severe thunderstorm risk categories.

Figure 5.4.8-2. Severe Thunderstorm Risk Categories



Source: NOAA SPC 2017

Lightning is associated with moderate to severe thunderstorms. Lightning severity is determined by the frequency of lightning strikes during a storm.

Derechos

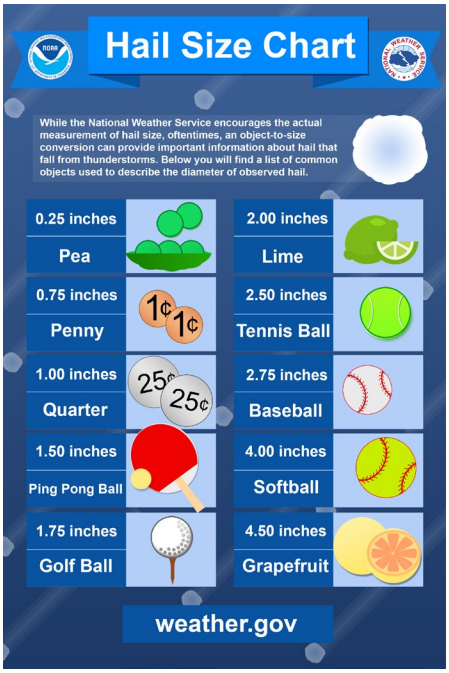
In order for an event to be identified as a derecho, it must have wind gusts of at least 58 mph or greater along most of its length. While derecho winds typically are less than 100 mph, gusts as high as 130 mph have been recorded. Winds associated with derechos are not constant and may vary considerably along the path of the

derecho. Any derecho below 57 mph is considered below severe limits and anything from 75 mph or greater is considered very strong (SPC 2015).

Hailstorms

Duration, hail size, and geographic extent determine hailstorm severity. Hail can exhibit a variety of sizes, though only the very largest hail stones pose serious risk to people, if exposed (NYS DHSES 2019). The size of hail is estimated by comparing it to a known object. Figure 5.4.8-3 shows the different sizes of hail and the comparison to real-world objects.

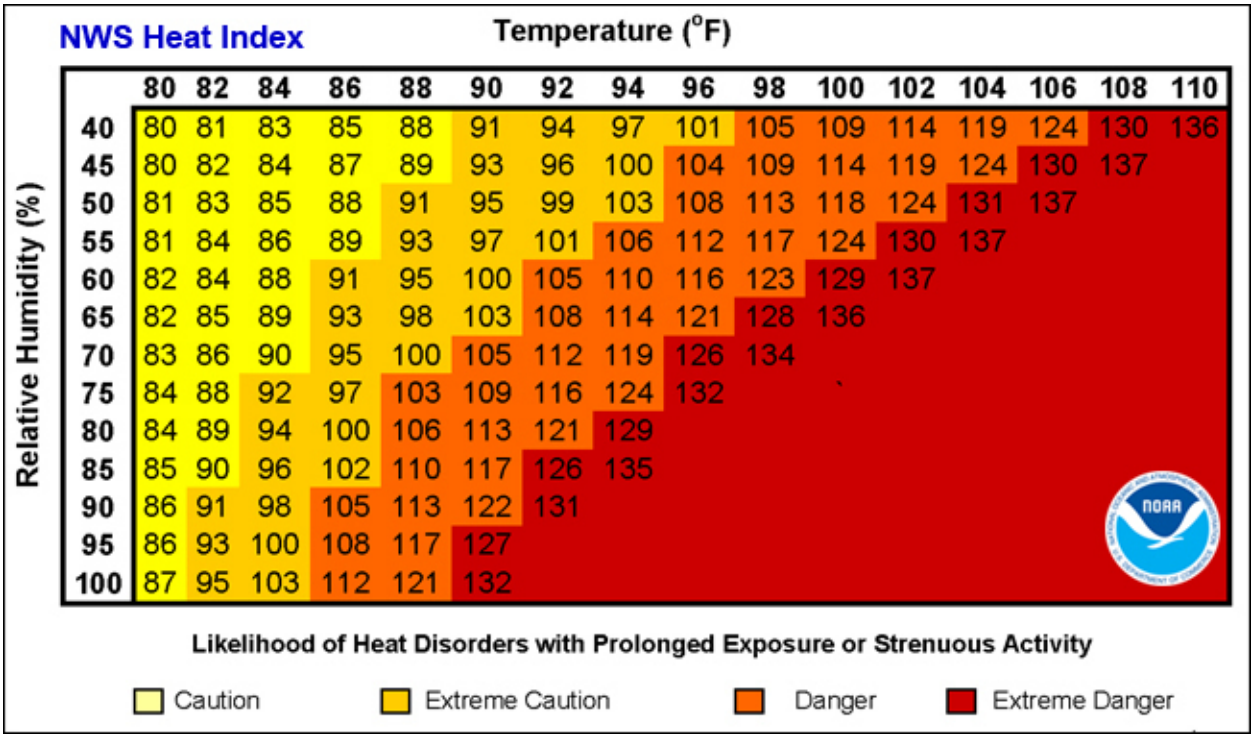
Figure 5.4.8-3. Hail Size Chart



Extreme Heat

NOAA's heat alert procedures are based mainly on Heat Index values. The Heat Index is given in degrees Fahrenheit. The Heat Index is a measure of how hot it really feels when relative humidity is factored in with the actual air temperature. To find the Heat Index temperature, the temperature and relative humidity need to be known. Once both values are known, the Heat Index will be the corresponding number with both values. The Heat Index indicated the temperature the body feels. It is important to know that the Heat Index values are devised for shady, light wind conditions. Exposure to full sunshine can increase heat index values by up to 15°F. Strong winds, particularly with very hot dry air, can also be extremely hazardous (NWS 2013d).

Figure 5.4.8-4. NWS Heat Index Chart



Source: NWS 2020

The NWS station in Mount Holly (which covers Cape May County) provides alerts when Heat Indices approach hazardous levels. Table 5.4.8-3 explains these alerts.

Table 5.4.8-3. National Weather Service Alerts for Extreme Heat Events

Alert	Criteria
Heat Advisory	A period of excessive heat is expected. The combination of hot temperatures and high humidity will create a situation in which heat related illnesses are possible. A Heat Advisory is issued when heat indices are expected to reach at least 100 degrees, except at least 105 degrees over Delmarva and far southern New Jersey (Salem, Cumberland, Cape May, and Atlantic Counties). The aforementioned heat index values must be reached for at least two hours; typically a single day event.
Excessive Heat Watch	A prolonged period of dangerous excessive heat is possible within about 48 hours.
Excessive Heat Warning	A prolonged period of dangerous excessive heat is expected within about 24 hours. The combination of hot temperatures and high humidity will create a dangerous situation in which heat related illnesses are likely. An Excessive Heat Warning is issued when heat indices are expected to reach at least 105 degrees, except at least 110 degrees over Delmarva and far southern New Jersey (Salem, Cumberland, Cape May, and Atlantic Counties). The aforementioned heat index values must be reached for at least two hours per day; typically for a multi-day event.

Source: NWS, 2020

In New Jersey, average days per year where temperatures reach 90°F or higher range from five days to over 30 days, depending on location. Cape May County has an average of 12 to 22 days of temperatures in excess of 90°F; 2 or 4 days of temperatures in excess of 95°F; and 0.1 to 0.2 days of temperatures in excess of 100°F (ONJSC 2013b).

Wind Chill At a Glance

The wind chill is how cold it feels on your skin when the wind is factored in. It may also be referred to as the "feels-like" temperature. Bitterly cold wind chills increase your risk of developing frostbite and hypothermia.

Source: The Weather Channel (2019)

Extreme Cold

The extent (severity or magnitude) of extreme cold temperatures generally are measured through the Wind Chill Temperature (WCT) Index. The WCT Index uses advances in science, technology, and computer modeling to provide an accurate, understandable, and useful formula for calculating the dangers from wind chill. For details regarding the WCT Index, refer to: http://www.nws.noaa.gov/om/winter/windchill.shtml. The WCT Index is presented in Figure 5.4.8-5.

The National Weather Service (NWS) provides alerts when Wind Chill indices approach hazardous levels. Table 5.4.8-4 explains these alerts.

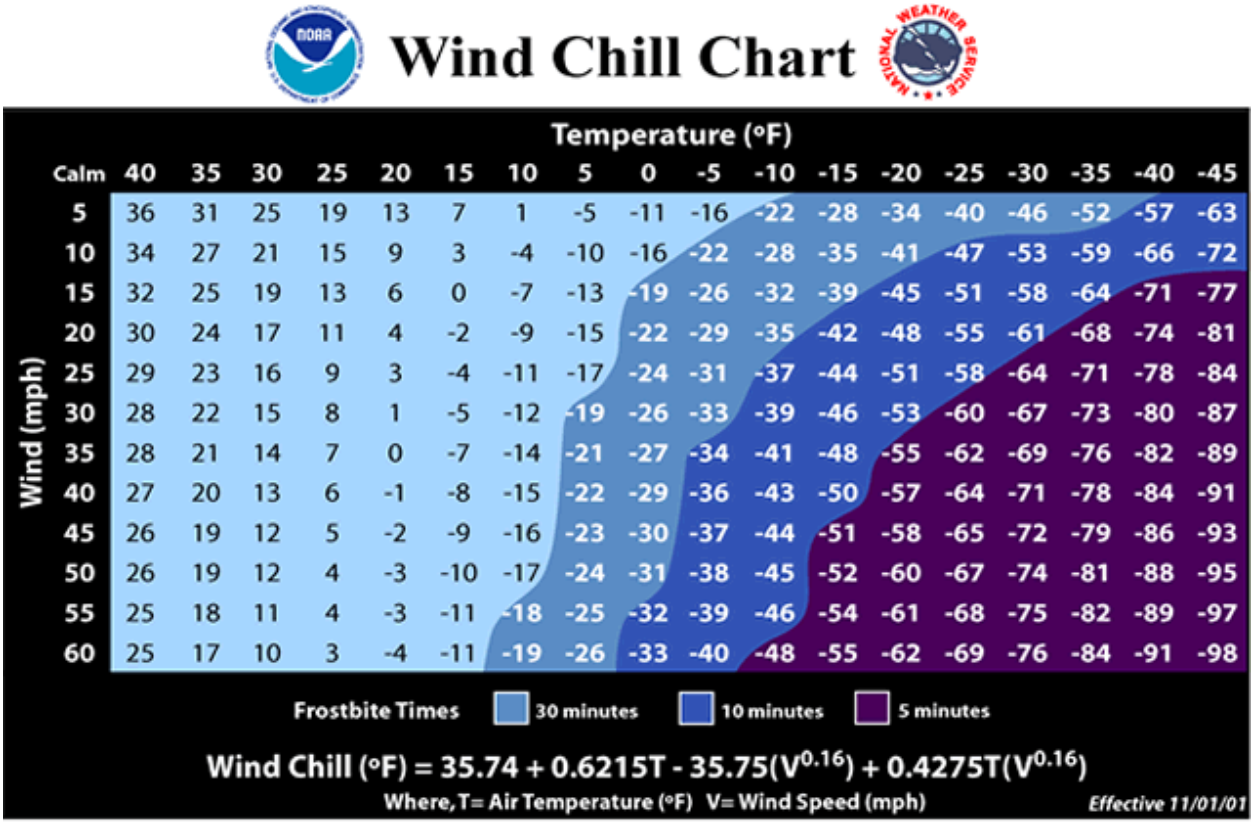
Table 5.4.8-4. National Weather Service Alerts for Extreme Cold

Alert	Criteria
Wind Chill Advisory	NWS issues a wind chill advisory when seasonably cold wind chill values, but not extremely cold values are expected or occurring.
Wind Chill Watch	NWS issues a wind chill watch when dangerously cold wind chill values are possible.
Wind Chill Warning	NWS issues a wind chill warning when dangerously cold wind chill values are expected or occurring.

Source: NWS 2018b

Average days per year when temperatures reached less than 32°F in New Jersey range from six days in the southern part of the State to over 45 days in northern New Jersey. Cape May County has an average of six (northern Cape May County) to 10 (southern Cape May County) days of temperatures below 32°F; 0.1 (southern Cape May County) to 1 (northern Cape May County) days of temperatures below 0°F (ONJSC 2013b).

Figure 5.4.8-5. WCT Index



Source: NWS 2020

Warning Time

Meteorologists can accurately forecast extreme temperature event development and the severity of the associated conditions with several days lead time. These forecasts provide an opportunity for public health and other officials to notify vulnerable populations. For heat events, the NWS issues excessive heat outlooks when the potential exists for an excessive heat event in the next three to seven days. Watches are issued when conditions are favorable for an excessive heat event in the next 24 to 72 hours. Excessive heat warning/advisories are issued when an excessive heat event is expected in the next 36 hours. Winter temperatures may fall to extreme cold readings with no wind occurring. Currently, the only way to headline very cold temperatures is with the use of the NWS-designated Wind Chill Advisory or Warning products. When actual temperatures reach Wind Chill Warning criteria with little to no wind, extreme cold warnings may be issued (NWS n.d.).

Previous Occurrences and Losses

Numerous sources provided historical information regarding previous occurrences and losses associated with severe weather events affecting Cape May County. With so many sources reviewed for the purpose of this HMP, loss and impact information for many events may vary. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP.

FEMA Major Disasters and Emergency Declarations

Between 1954 and 2020, the State of New Jersey was included in 28 FEMA declared severe weather-related disasters (DR) or emergencies (EM) classified as one or a combination of the following hazards: coastal storms, severe storm, straight-line winds, heavy rains, flooding, hail, tornadoes, and high wind. Generally, these disasters

cover a wide region of the State; therefore, they may have impacted many counties. Of those declarations, Cape May County has been included in six declarations (FEMA 2020). Table 5.4.8-5 lists FEMA DR and EM declarations for Cape May County.

Table 5.4.8-5. FEMA DR and EM Declarations since 2010 for Severe Weather Events in Cape May County

FEMA Declaration Number	Date(s) of Event	Date of Declaration	Event Type
DR-3005	December 24, 1974	December 24, 1974	New Jersey Severe Storms, High Winds & High Tides
DR-936	January 4, 1992	March 3, 1992	Severe Coastal Storm
DR-1206	February 4, 1998 - February 8, 1998	March 3, 1998	New Jersey Coastal Storm
DR-1867	November 11, 2009 - November 15, 2009	December 22, 2009	New Jersey Severe Storms And Flooding Associated With Tropical Depression Ida And A Nor'easter
DR-1897	March 12 – April 15, 2010	April 2, 2010	Severe Storms and Flooding
DR-4048	October 29, 2011	November 30, 2011	Severe Weather

Source: FEMA 2020

U.S. Department of Agriculture Disaster Declarations

Between 2016 and 2020, the period for which data was available, Cape May County was included in two USDA Disaster Declarations:

- S4071 – April 1-September 19th, 2016 – combined effects of freeze, excessive heat, and drought
- S4424 – May 1st-June 30th, 2018 – excessive rainfall and cool spring temperatures

Previous Events

For this 2021 Plan Update, known severe weather events, including FEMA disaster declarations, which have impacted Cape May County between 2016 and 2020 are identified in Table 5.4.8-6. With documentation of severe weather for the State of New Jersey and Cape May County being extensive, not all sources have been identified or researched. Therefore, Table 5.4.8-6 may not include all events that occurred in the County. For events prior to 2016, refer to Appendix E (Supplementary Data). For detailed information on damages and impacts to each municipality, refer to Section 9 (Jurisdictional Annexes).

Table 5.4.8-6. Severe Weather Events in Cape May County, 2016 to April 2020

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
January 23, 2016	High Winds	No	N/A	Strong winds up to 56 mph were reported from a nor'easter passing along the coast.
April 2-3, 2016	Thunderstorm Wind	No	N/A	A strong cold front moved into the region overnight, bringing strong winds and causing widespread power outages. Wind gusts up to 63 mph were reported in the County.
June 8, 2016	Thunderstorm Wind	No	N/A	A fast-moving line of thunderstorms produced widespread wind damage and gusts up to 52 mph.
June 21, 2016	Thunderstorm Wind	No	N/A	Widespread power outages and wind speeds up to 61 mph were reported from thunderstorms developing from a stalled frontal boundary.

Table 5.4.8-6. Severe Weather Events in Cape May County, 2016 to April 2020

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
August 21, 2016	Thunderstorm Wind	No	N/A	Thunderstorms producing lightning, heavy rain, and strong winds (up to 52 mph) were reported in the County.
September 19-20, 2016	Heavy Rain	No	N/A	Cape May County was inundated with several rounds of rainfall owing to remnants of Tropical Storm Julia.
September 29, 2016	Heavy Rain	No	N/A	Cape May County saw heavy rainfall due to a stalled frontal boundary.
October 9, 2016	Strong Winds; Heavy Rain	No	N/A	Hurricane Matthew interacted with a cold front, bringing rains and winds to the County.
January 23, 2017	High Winds	No	N/A	An incoming nor'easter brought strong winds (up to 53 mph), power outages, high tides, and mixed precipitation. Ocean City and Wildwood school districts were closed. The Cape May-Lewes Ferry ceased operations for the day.
February 9, 2017	High Winds	No	N/A	A strong cold front caused high winds, with gusts up to 53 mph.
February 13, 2017	High Winds	No	N/A	Wind speeds up to 54 mph were reported in Cape May, leading to downed power lines and wires.
March 1, 2017	Thunderstorm Wind	No	N/A	Unseasonably warm air maintained a line of thunderstorms along a pre-frontal trough. A gust of wind in Ocean City reached 60 mph and more than 2,500 customers lost power in the region.
June 19, 2017	Thunderstorm Wind	No	N/A	Wind damage was reported from a complex of thunderstorms that moved into the region. Wind speeds up to 51 mph were reported.
July 24, 2017	Heavy Rain; Lightning	No	N/A	Multiple rounds of thunderstorms were reported due to a frontal boundary moving through the area.
July 29, 2017	Heavy Rain	No	N/A	Heavy rain, thunderstorms, and winds were reported resulting from a summertime nor'easter.
August 7, 2017	Heavy Rain	No	N/A	Heavy rain and flash flooding were reported following thunderstorms that developed along a cold front.
December 25, 2017	High Wind	No	N/A	Winds up to 50 mph and power outages were reported following a strong wind event.
March 2, 2018	High Wind	No	N/A	Strong winds and flooding causing $100,000 in damage resulted from a stalled cold front from a deep area of low pressure. Recorded wind speeds were up to 71 mph.
February 24-25, 2019	High Wind	No	N/A	High winds with gusts up to 50 mph caused power outages, downed trees, and some structural damage.
April 26, 2019	Thunderstorm Wind	No	N/A	A funnel cloud and 52 mph winds were reported resulting from a severe thunderstorm generated by
June 29, 2019	Thunderstorm Wind	No	N/A	Severe thunderstorms generating 51 mph formed from a stalled frontal boundary that over the mid-Atlantic that left the region during the day and then returned.
July 23, 2019	Thunderstorm Wind	No	N/A	A stalled frontal boundary generated and upper level trough spurred severe weather with wind speeds of 51mph recorded in the County.
August 7, 2019	Thunderstorm Wind	No	N/A	Damaging winds up to 50 mph were reported in the County following a cold front entering the area with a robust shortwave trough. Downed power lines and a transformer fire were reported in Dennis Township (Martucci 2019).
February 7, 2020	Thunderstorm Wind	No	N/A	Wind speeds up to 63mph were recorded following an explosively intensifying area of low pressure moving in to the region from the southeast. Power outages were reported in Middle Township and Dennis Township (Davis 2020).
April 13, 2020	Thunderstorm Wind; High Wind	No	N/A	A warm front moved through the mid-Atlantic, mixing with a low level jet with strong wind gusts, particularly near the coast. Later in the day, a strong cold front entered the region,

Table 5.4.8-6. Severe Weather Events in Cape May County, 2016 to April 2020

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
				bringing extreme wind shear. Heating produced strong to severe thunderstorms and 70 mph winds. In Wildwood, a section of the Boardwalk near the Convention Center was destroyed and historic Congress Hall in Cape May experienced roof damage.
April 21, 2020	Thunderstorm Wind; Hail	No	N/A	An unseasonable strong cold front brought a squall line through the region. Destabilized air masses brought 60 mph winds and a tornado off the coast. In West Cape May, a pole struck by lightning caught fire and downed wires and power lines were reported in Cape May. Dime-sized hail was reported in Tuckahoe of Upper Township, and multiple trees were reported down with power outages in Seaville (Martucci 2020a).
July 1, 2020	Hail	No	N/A	A severe thunderstorm moving through northern Cape May County brought significant wind, flood, and hail. Golf ball-sized hail was reported in Erma and 1.75-inch hail was reported in the Petersburg section of Upper Township. Ocean City and Marmora saw smaller hail.
August 4, 2020	Tropical Storm; Tornado	No	N/A	Remnants of Tropical Storm Isaias came onshore, bringing rains and high winds and causing considerable damage but no casualties. A waterspout spawned near Strathmere and came onshore the mainland at Marmora near Garden State Parkway milemarker 24.3-24.4. The EF-1 tornado caused significant damage to the Pine Hill Mobile Home Park, Coca-Cola facility, and the vicinity along Route 9. The tornado tracked for over five miles. High winds caused widespread power outages in the region, with outages in Marmora being particularly prolonged (Hartman and Brooks 2020; Martucci 2020b).

Source(s): FEMA 2020; NOAA-NCEI 2020; NJ HMP 2019

** 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*

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

Probability of Future Occurrences

Predicting future severe weather events in a constantly changing climate has proven to be a difficult task. Predicting extremes in New Jersey and Cape May County is particularly difficult because of their geographic location. Both are positioned roughly halfway between the equator and the North Pole and are exposed to both cold and dry airstreams from the south. The interaction between these opposing air masses often leads to turbulent weather across the region (Keim 1997).

Table 5.4.8-7 summarizes data regarding the probability of occurrences of severe weather events in Cape May County based on the historic record. The information used to calculate the probability of occurrences is based solely on NOAA-NCEI storm events database results and FEMA disaster declarations.

Table 5.4.8-7. Probability of Future Occurrences of Severe Weather Events

Hazard Type	Number of Occurrences Between 1950 and 2020	% Chance of Occurring in Any Given Year
Cold/Wind Chill	48	67.61%
Excessive Heat	23	32.39%
Extreme Cold/Wind Chill	4	5.63%
Funnel Cloud	3	4.23%
Hail	30	42.25%
Heat	94	100%
Heavy Rain	306	100%
High Wind	109	100%
Lightning	18	25.35%
Strong Wind	275	100%
Thunderstorm Wind	124	100%
Tornado	9	12.68%
Total	**1,043**	**100%**

Source: NOAA-NCEI 2020

Note: Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected storm events since 1968. Due to limitations in data, not all severe weather events occurring between 1954 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.

It is estimated that Cape May County will continue to experience direct and indirect impacts of severe weather events annually that may induce secondary hazards such as flooding, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents and inconveniences. Extreme temperatures are expected to occur more frequently as part of regular seasons. Specifically, extreme heat will continue to impact New Jersey and its counties and, based upon data presented, will increase in the next several decades. As previously stated, several extreme temperature events occur each year in Cape May County. It is estimated that the County will continue to experience these events annually.

In Section 5.3, the identified hazards of concern for Cape May 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 weather events in the County is considered 'frequent' (100% chance of event occurring; occurs multiple times a year).

Climate Change Impacts

Providing projections of future climate change for a specific region is challenging. Shorter term projections are more closely tied to existing trends making longer term projections even more challenging. The further out a prediction reaches the more subject to changing dynamics it becomes.

Climate change includes major changes in temperature, precipitation, or wind patterns, which occur over several decades or longer. Due to the increase in greenhouse gas concentrations since the end of the 1890s, New Jersey has experienced a 3.5° F (1.9° C) increase in the State's average temperature (Office of the New Jersey State Climatologist 2020), which is faster than the rest of the Northeast region (2° F [1.1° C]) (Melillo et al. 2014) and the world (1.5° F [0.8° C]) (IPCC 2014). This warming trend is expected to continue. By 2050, temperatures in New Jersey are expected to increase by 4.1 to 5.7° F (2.3° C to 3.2° C) (Horton et al. 2015). Thus, New Jersey can expect to experience an average annual temperature that is warmer than any to date (low emissions scenario) and future temperatures could be as much as 10° F (5.6° C) warmer (high emissions scenario) (Runkle et al. 2017). New Jersey can also expect that by the middle of the 21st century, 70% of summers will be hotter than the warmest summer experienced to date (Runkle et al. 2017). The increase in temperatures is expected to be

felt more during the winter months (December, January, and February), resulting in less intense cold waves, fewer sub-freezing days, and less snow accumulation.

As temperatures increase, Earth's atmosphere can hold more water vapor which leads to a greater potential for precipitation. Currently, New Jersey receives an average of 46 inches of precipitation each year (Office of the New Jersey State Climatologist 2020). Since the end of the twentieth century, New Jersey has experienced slight increases in the amount of precipitation it receives each year, and over the last 10 years there has been a 7.9% increase. By 2050, annual precipitation in New Jersey could increase by 4% to 11% (Horton et al. 2015). By the end of this century, heavy precipitation events are projected to occur two to five times more often (Walsh et al. 2014) and with more intensity (Huang et al. 2017) than in the last century. New Jersey will experience more intense rain events, less snow, and more rainfalls (Fan et al. 2014, Demaria et al. 2016, Runkle et al. 2017). Also, small decreases in the amount of precipitation may occur in the summer months, resulting in greater potential for more frequent and prolonged droughts (Trenberth 2011). New Jersey could also experience an increase in the number of flood events (Broccoli et al. 2020).

A warmer atmosphere means storms have the potential to be more intense (Guilbert et al. 2015) and occur more often (Coumou and Rahmstorf 2012, Marquardt Collow et al. 2016, Broccoli et al. 2020). In New Jersey, extreme storms typically include coastal nor'easters, snowstorms, spring and summer thunderstorms, tropical storms, and on rare occasions hurricanes. Most of these events occur in the warmer months between April and October, with nor'easters occurring between September and April. Over the last 50 years, in New Jersey, storms that resulted in extreme rain increased by 71% (Walsh et al. 2014) which is a faster rate than anywhere else in the United States (Huang et al. 2017).

5.4.8.2 Vulnerability Assessment

A probabilistic assessment was conducted for the 100- and 500-year MRPs through a Level 2 analysis in HAZUS-MH to analyze the severe weather hazard and provide a range of loss estimates due to wind impacts. A qualitative assessment was conducted to analyze the other severe weather hazards for Cape May County. Quantified residual impacts from severe weather such as flooding can also be reviewed in Section 5.4.5 (Flood). Refer to Section 5.1 (Methodology and Tools) for additional details on the methodology used to assess severe weather risk.

Impact on Life, Health, Safety

The impact of a severe weather 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 Cape May County (93,705) is exposed to this hazard (2014-2018 American Community Survey 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 weather events, residents can be displaced or require temporary to long-term sheltering. The HAZUS-MH results for the 100-year and 500-year MRP hurricane wind events are able to show displaced households and people requiring short-term sheltering. 59 households will be displaced, and 30 people will

require short-term sheltering in the 100-year event. 1,122 households will be displaced, and 615 people will require short-term sheltering in the 500-year event.

Table 5.4.8-8. Displaced Households and Short-Term Sheltering

Jurisdiction	American Community Survey (2014-2018) Population	Hurricane Wind 100-Year Mean Return Period		Hurricane Wind 500-Year Mean Return Period	
		Displaced Households	People Requiring Short-Term Shelter	Displaced Households	People Requiring Short-Term Shelter
Avalon Borough	1,409	1	0	5	2
Cape May City	3,491	2	1	136	85
Cape May Point Borough	188	0	0	22	10
Dennis Township	6,244	0	0	6	3
Lower Township	21,838	1	0	492	257
Middle Township	18,492	1	1	126	73
North Wildwood City	3,849	8	4	57	27
Ocean City	11,202	27	13	15	7
Sea Isle City	1,955	2	1	6	3
Stone Harbor Borough	955	1	0	9	3
Upper Township	11,909	0	0	4	3
West Cape May Borough	1,103	0	0	46	21
West Wildwood Borough	376	2	1	16	11
Wildwood City	5,073	7	5	86	58
Wildwood Crest Borough	3,131	7	4	91	48
Woodbine Borough	2,490	0	0	4	4
Cape May County (Total)	**93,705**	**59**	**30**	**1,122**	**615**

Source: Hazus-MH 4.2

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 several factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

Economically disadvantaged populations are more vulnerable because they often evaluate evacuation needs and make decisions based on the economic impact to their family. The population over the age of 65 (23,572) 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 (2014-2018 American Community Survey 5-Year Population Estimate). Section 4 (County Profile) provides for the statistics for these populations in Cape May County.

Extreme temperature events have potential health impacts including injury and death. According to the Centers for Disease Control and Prevention, populations most at risk to extreme cold and heat events include the following: 1) the elderly, who are less able to withstand extreme temperatures due to their age, health conditions and limited mobility to access shelters; 2) infants and children up to four years of age; 3) individuals with chronic medical conditions (e.g., heart disease or high blood pressure); 4) low-income persons that cannot afford proper heating and cooling; and 5) the general public who may overexert during work or exercise during extreme heat events or experience hypothermia during extreme cold events (CDC 2016).

Risk of structural fire in the winter months is elevated with approximately 30 percent of all deaths caused by fire occurring in the winter months. Cooking and heat sources too close to combustible materials are leading factors in winter home fires. Often times, power outages occur during extreme cold events. Individuals powering their homes with generators are subjected to carbon monoxide poisoning if proper ventilation procedures are not followed. Improperly connected portable generators are capable of 'back feeding' power lines which may cause injury or death to utility works attempting to restore power and may damage house wiring and/or generators (NJOEM 2019).

Meteorologists can accurately forecast extreme heat and cold event development and the severity of the associated conditions with several days of lead time. These forecasts provide an opportunity for public health and other officials to notify vulnerable populations, implement short-term emergency response actions, and focus on surveillance and relief efforts on those at greatest risk. Adhering to extreme temperature warnings can significantly reduce the risk of temperature-related deaths.

Impact on General Building Stock and Critical Facilities

Wind-Only Impacts

Damage to buildings is dependent upon several factors, including wind speed, storm duration, and path of the storm track. Building construction also plays a major role in the extent of damage resulting from a storm. 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.

To better understand these risks, Hazus was used to estimate the expected wind-related building damages. Specific types of wind damages are also summarized in Hazus at the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 5.4.8-9 summarizes the definition of the damage categories. Table 5.4.8-10 summarizes the damage states estimated for structures during the 100-year and 500-year MRP hurricane wind events by occupancy class. Hazus estimates that zero structures will experience complete damage during the 100-year MRP event and approximately 1.5-percent of residential structures will experience complete damage during the 500-year MRP event.

Table 5.4.8-9. Description of Damage Categories

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

Table 5.4.8-9. 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
resulting damage to interior of building from water.						
Severe Damage Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	>50%	> the larger of 20% & 3 and ≤50%	>3 and ≤25%	Typically 10 to 20 impacts	No	No
Destruction Complete roof failure and/or, failure of wall frame. Loss of more than 50% of roof sheathing.	Typically >50%	>50%	>25%	Typically >20 impacts	Yes	Yes

Source: HAZUS-MH Hurricane Technical Manual

Table 5.4.8-10 summarizes the replacement cost value of building and content damages estimated for the 100- and 500-year MRP hurricane wind-only events. Table 5.4.8-11 summarizes the replacement cost value of building and content damages estimated for the 100-year and 500-year MRP hurricane wind-only events for residential and commercial occupancy classes. Less than 1% of the entire building stock may anticipate damages caused by the 100-year hurricane wind event and approximately 3.5-percent of the entire building stock may anticipate damages caused by the 500-year hurricane wind event. The total damage for all occupancy types across the County is estimated to be $415.7 million for the 100-year MRP wind-only event, and approximately $3.2 billion for the 500-year MRP wind-only event. The majority of these losses are to residential structures.

Table 5.4.8-10. Estimated Losses for the 100-Year and 500-Year MRP Hurricane Wind Events

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Total Damages			
		100-Year	Percent of Total	500-Year	Percent of Total
Avalon Borough	$8,232,959,879	$45,556,435	0.6%	$142,708,862	1.7%
Cape May City	$5,153,049,612	$18,709,280	0.4%	$568,267,358	11.0%
Cape May Point Borough	$663,183,164	$2,636,428	0.4%	$79,830,434	12.0%
Dennis Township	$3,813,425,173	$12,131,107	0.3%	$48,012,984	1.3%
Lower Township	$9,950,232,225	$37,563,079	0.4%	$908,850,173	9.1%
Middle Township	$11,557,342,752	$35,443,035	0.3%	$344,730,436	3.0%
North Wildwood City	$4,423,365,953	$17,664,110	0.4%	$121,635,223	2.7%
Ocean City	$17,100,920,036	$101,779,622	0.6%	$73,718,096	0.4%
Sea Isle City	$7,663,928,227	$52,396,504	0.7%	$100,586,788	1.3%
Stone Harbor Borough	$3,291,756,871	$18,644,314	0.6%	$98,106,713	3.0%
Upper Township	$6,506,171,365	$27,896,296	0.4%	$49,218,071	0.8%
West Cape May Borough	$1,178,516,373	$5,450,858	0.5%	$165,050,693	14.0%
West Wildwood Borough	$459,103,094	$3,482,377	0.8%	$30,428,039	6.6%
Wildwood City	$4,379,038,844	$14,497,979	0.3%	$132,807,464	3.0%
Wildwood Crest Borough	$4,552,156,876	$19,719,858	0.4%	$286,440,410	6.3%
Woodbine Borough	$1,335,589,432	$2,166,772	0.2%	$13,861,534	1.0%
Cape May County (Total)	**$90,260,739,877**	**$415,738,054**	**0.5%**	**$3,164,253,276**	**3.5%**

Source: Hazus-MH 4.2

Notes: MRP = Mean return period

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

Table 5.4.8-11. Estimated Losses for the 100-Year and 500-Year MRP Hurricane Wind Events – Residential and Commercial Occupancy Classes Only

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Residential Damages		Estimated Commercial Damages	
		100-Year	500-Year	100-Year	500-Year
Avalon Borough	$8,232,959,879	$45,190,035	$140,894,777	$230,473	$1,309,504
Cape May City	$5,153,049,612	$18,049,569	$507,722,125	$218,154	$30,837,925
Cape May Point Borough	$663,183,164	$2,594,254	$75,810,523	$19,291	$2,146,092
Dennis Township	$3,813,425,173	$11,679,936	$44,268,035	$368,777	$2,436,579
Lower Township	$9,950,232,225	$36,618,753	$844,633,376	$390,377	$34,220,708
Middle Township	$11,557,342,752	$32,817,186	$282,423,878	$1,397,197	$41,348,277
North Wildwood City	$4,423,365,953	$17,092,538	$113,342,260	$304,222	$5,335,252
Ocean City	$17,100,920,036	$100,158,864	$72,898,618	$667,728	$336,658
Sea Isle City	$7,663,928,227	$52,092,081	$99,785,698	$239,376	$640,909
Stone Harbor Borough	$3,291,756,871	$18,527,867	$96,888,250	$89,307	$1,011,580
Upper Township	$6,506,171,365	$26,929,953	$47,165,017	$754,219	$1,455,976
West Cape May Borough	$1,178,516,373	$5,363,662	$156,739,463	$39,885	$4,437,080
West Wildwood Borough	$459,103,094	$3,206,241	$24,275,327	$185,311	$4,981,102
Wildwood City	$4,379,038,844	$13,554,445	$110,141,124	$635,767	$18,031,181
Wildwood Crest Borough	$4,552,156,876	$19,390,664	$277,565,903	$208,662	$6,193,297
Woodbine Borough	$1,335,589,432	$2,003,563	$10,472,374	$31,017	$545,842
Cape May County (Total)	**$90,260,739,877**	**$405,269,612**	**$2,905,026,748**	**$5,779,762**	**$155,267,962**

Source: Hazus-MH 4.2

Notes: MRP = Mean return period

Since 1950, nearly $219 million damages to property has been reported to the NWS in Cape May County due to severe weather events including high wind, thunderstorm wind, strong wind, tornados, lightning, heavy rain, winter storm, hail, and extreme temperature events (NOAA NCEI 2020). High wind events created the greatest value of property damage out of this total ($215.5 million). Table 5.4.8-12 outlines the severe weather events that have reported property damages in Cape May County.

Table 5.4.8-12. Historical Severe Weather Events That Occurred in Cape May County with Recorded Property Damages

Type of Event	Number of Times Event Occurred (1950 – 2020)	Total Value of Losses
Cold/Wind Chill	48	$0
Excessive Heat	23	$0
Extreme Cold/Wind Chill	4	$0
Funnel Cloud	3	$0
Hail	30	$0
Heat	94	$0
Heavy Rain	309	$150,000
High Wind	109	$215,535,000
Lightning	18	$119,020
Strong Wind	275	$1,031,000
Thunderstorm Wind	124	$1,260,000
Tornado	9	$802,750

Type of Event	Number of Times Event Occurred (1950 – 2020)	Total Value of Losses
Total	**1,043**	**$218,897,770**

Source: NOAA NCEI 2020

All buildings are exposed to the extreme temperature hazard. Extreme heat generally does not impact buildings; however, elevated summer temperatures increase the energy demand for cooling. Losses can be associated with the overheating of heating, ventilation, and air conditioning (HVAC) systems. Extreme cold temperature events can damage buildings through freezing/bursting pipes and freeze/thaw cycles, as well as increasing vulnerability to home fires. Additionally, manufactured homes (mobile homes) and antiquated or poorly constructed facilities can have inadequate capabilities to withstand extreme temperatures.

Impact on 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 the safety of its citizens 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.

All critical facilities in the County are exposed to the extreme temperature hazard with similar risks as discussed for the general building stock. It is essential that critical facilities remain operational during natural hazard events. Extreme heat events can sometimes cause short periods of utility failures, commonly referred to as "brown-outs", due to increased usage from air conditioners, appliances, etc. Similarly, heavy snowfall and ice storms, associated with extreme cold temperature events, can cause power interruption as well. Backup power is recommended for critical facilities and infrastructure. Where backup power is needed for critical facilities that provide essential services, municipalities identified mitigation actions in Section 9 (Jurisdictional Annexes).

Hazus estimates that critical facilities in Cape May have a low percent probability of sustaining minor to moderate damages from the 100-year MRP hurricane wind event. Hazus also estimates that there are critical facilities that have a 17.8-percent probability of sustaining severe damage from the 500-year MRP hurricane wind event. These probabilities can be found in Table 5.4.8-13 and **Table 5.4.8-14** by facility type.

Table 5.4.8-13. Estimated Impacts to Critical Facilities for the 100-Year MRP Hurricane Wind Event

Facility Type	100-Year Event				
		Percent-Probability of Sustaining Damage			
	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	1.7%-9.2%	0.0%-2.3%	<0.1%	0.0%
Medical	0	1.5%-7.0%	0.0%-2.7%	<0.1%	0.0%
Police	0	2.0%-9.2%	0.0%-2.3%	<0.1%	0.0%
Fire	0	0.6%-5.0%	0.0%-1.1%	<0.1%	0.0%
Schools	0	1.0%-7.4%	0.0%-4.3%	<0.1%	0.0%

Source: Hazus-MH v4.2

Table 5.4.8-14. Estimated Impacts to Critical Facilities for the 500-Year MRP Hurricane Wind Event

Facility Type	500-Year Event				
		Percent-Probability of Sustaining Damage			
	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	3.6%-22.1%	0.1%-29.1%	0.0%-17.8%	0.0%
Medical	0-3	3.8%-15.3%	0.6%-38.6%	0.0%-10.5%	0.0%-0.6%
Police	0	3.6%-23.8%	0.2%-29.1%	0.0%-17.8%	0.0%
Fire	0	1.6%-15.1%	0.1%-23.9%	0.0%-10.9%	0.0%-0.6%
Schools	0-24	3.5%-12.0%	0.7%-46.0%	0.0%-14.7%	<0.1%

Source: Hazus-MH v4.2

Impact on Economy

Severe weather events can have short- and long-lasting impacts on the economy. When a business is closed during storm recovery, there is lost economic activity in the form of day-to-day business and wages to employees. Overall, economic impacts include the loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. As evidenced by Hurricane Sandy, the State of New Jersey, including Cape May County, lost millions of dollars in wages and economic activity.

Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting and goods transport) transportation needs. Utility infrastructure (power lines, gas lines, electrical systems) could suffer damage and impacts can result in the loss of power, which can impact business operations and can impact heating or cooling provision to the population.

HAZUS-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is reported in the "Impact on General Building Stock" section discussed earlier. Business interruption losses are the losses associated with the inability to operate a business because of the wind damage sustained during the storm or the temporary living expenses for those displaced from their home because of the event.

For the 100-year MRP wind event, Hazus estimates $22.8 million in business interruption costs (income loss, relocation costs, rental costs, and lost wages). For the 500-year MRP wind-only event, Hazus estimates approximately $387.2 million in business interruption losses for the County which includes loss of income, relocation costs, rental costs, and lost wages.

Debris management can be costly and may also impact the local economy. Hazus estimates the amount of building and tree debris that may be produced as result of the 100- and 500-year MRP wind events. Because the estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur. According to the Hazus 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 5.4.8-15 summarizes debris production estimates for the 100- and 500-year MRP wind events.

Table 5.4.8-15. Debris Production for the 100-Year and 500-Year MRP Hurricane Wind Events

Jurisdiction	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100-Year	500-Year	100-Year	500-Year	100-Year	500-Year	100-Year	500-Year
Avalon Borough	3,432	10,725	0	0	157	314	797	1,594
Cape May City	1,272	35,696	0	381	683	3,338	4,211	20,585
Cape May Point Borough	128	5,096	0	43	418	2,460	1,035	6,094
Dennis Township	521	3,228	0	0	14,941	53,452	11,097	34,859
Lower Township	2,007	65,364	0	542	7,400	38,578	22,737	123,870
Middle Township	2,017	25,299	0	121	22,493	81,381	33,112	122,370
North Wildwood City	1,636	10,137	0	39	0	0	0	0
Ocean City	10,947	7,520	3	1	313	313	1,499	1,499
Sea Isle City	5,456	10,301	0	0	140	210	962	1,443
Stone Harbor Borough	1,622	8,160	0	23	134	313	919	2,145
Upper Township	1,415	2,981	0	0	17,192	36,884	24,197	43,507
West Cape May Borough	265	10,536	0	88	864	5,086	2,140	12,600
West Wildwood Borough	457	2,861	0	12	19	88	156	704
Wildwood City	1,849	12,406	0	53	93	365	741	2,903
Wildwood Crest Borough	1,931	23,248	1	261	53	232	99	437
Woodbine Borough	100	926	0	4	1,795	6,417	2,743	9,800
Cape May County (Total)	**35,055**	**234,485**	**4**	**1,567**	**66,696**	**229,431**	**106,445**	**384,410**

Source: Hazus-MH 4.2

Notes: MRP = Mean Return Period

According to the State of New Jersey 2019 HMP, hail alone causes $2 billion worth of crop and property damage on an annual basis in the United States (State of NJ 2019). Even though New Jersey is estimated to experience an average of two hailstorm events per year, the outcome of these events could be detrimental depending on the cost it would take for the community to recover from the damages. Likewise, these costs can add up for other severe weather events such as tornados destroying key infrastructure and level local businesses, or extreme rain events flooding out shopping centers or transportation hubs.

Extreme temperature events also have impacts on the economy, including loss of business function and damages to inventory. Business-owners may be faced with increased financial burdens due to unexpected repairs caused to the building (e.g., pipes bursting), higher than normal utility bills (e.g., less efficient heating or cooling systems overexerting power based on temperature extremes) or business interruption due to power failure (i.e., loss of electricity, telecommunications). In general, the agricultural industry is most at risk in terms of economic impact and damage due to extreme temperature events. Extreme heat events can result in drought and dry conditions and directly impact livestock and crop production. More information about the impacts of drought on the agricultural industry is discussed in Section 5.4.4 (Drought).

Impact on the Environment

The impact of severe weather events on the environment varies, but researchers are finding that the long-term impacts of more severe weather can be destructive to the natural and local environment. National organizations such as USGS and NOAA have been studying and monitoring the impacts of extreme weather phenomena as it impacts long term climate change, streamflow, river levels, reservoir elevations, rainfall, floods, landslides, erosion, etc. (USGS 2017). For example, severe weather that creates longer periods of rainfall can erode natural banks along waterways and degrade soil stability for terrestrial species. Tornadoes can tear apart habitats causing

fragmentation across ecosystems. Researchers also believe that a greater number of diseases will spread across ecosystems because of impacts that severe weather and climate change will have on water supplies (NOAA 2013c). Overall, as the physical environment becomes more altered, species will begin to contract or migrate in response, which may cause additional stressors to the entire ecosystem within Cape May County. Refer to Sections 5.4.3 (Disease Outbreak) for more information about these stressors.

Extreme weather events can have a major impact on the environment. For example, freezing and warming weather patterns create changes in natural processes. An excess amount of snowfall and earlier warming periods may affect natural processes such as flow within water resources (USGS nd). Likewise, rain-on-snow events also exacerbate runoff rates with warming winter weather.

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. Cape May 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

As discussed in Section 4 (County Profile), areas targeted for future growth and development have been identified across Cape May County. Any areas of growth could be potentially impacted by the severe weather hazard because the entire County is exposed and vulnerable. However, due to increased standards and codes, new development may be less vulnerable to the severe weather hazard compared with the aging building stock in the County. The ability of new development to withstand extreme temperature impacts lies in sound land use practices, building design considerations (e.g. Leadership in Energy and Environmental Design [LEED]), and consistent enforcement of codes and regulations for new construction. New development will change the landscape where buildings, roads, and other infrastructure potentially replace open land and vegetation. Surfaces that were once permeable and moist are now impermeable and dry. These changes cause urban areas to become warmer than the surrounding areas forming (heat islands as described above). Specific areas of recent and new development are indicated in tabular form and/or on the hazard maps included in the jurisdictional annexes in Volume II, Section 9 (Jurisdictional Annexes) of this plan.

Projected Changes in Population

Between 2000 and 2010, the County lost nearly five percent of its population. Between 2010 and 2020, the County is expected to have experienced a similar decrease. It is expected that in the next 20 years, population growth will be relatively stagnant (U.S. Census Bureau 2020, SJTPO). Overall, aging infrastructure may result in increased stress on existing infrastructure and related services. Although overall County growth is not expected, individual municipalities that experience increases in population may require utility system upgrades to keep up with utility demands (e.g., water, electric) during extreme temperature events to prevent increased stresses on these systems. Refer to Section 4 (County Profile) for a detailed discussion on population change in Cape May County.

Climate Change

As discussed earlier, studies project that the State of New Jersey will see an increase in average annual temperatures and precipitation. More frequent and severe storms will increase the County's vulnerability to each of the identified severe weather hazards. Section 5.4.5 (Flood) provides a discussion related to the impact of climate change due to increases in rainfall resulting from severe storms. Changes in the climate could alter the frequency of extreme temperature events that occur in the County, resulting in even hotter or colder events. As a result, vulnerable populations could be at risk for experiencing a greater number of illnesses associated with extreme temperature events, such as heatstroke and cardiovascular and kidney disease. Additionally, if temperatures become more extreme, a greater number of buildings, facilities, and infrastructure systems may exceed their ability to cope with these extremes.

Change of Vulnerability Since the 2016 HMP

Overall, the County's vulnerability has not changed, and the entire County will continue to be exposed and vulnerable to severe weather events. As existing development and infrastructure continue to age, they can be at increased risk to failed utility and transportation systems if they are not properly maintained and do not adapt to the changing environment.