5.4.6 Hurricane and Tropical Storm

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 hurricane and tropical storm hazard in Warren County.

2016 HMP Update Changes

- The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, probability of future occurrence, and potential change in climate and its impacts on the hurricane and tropical storm hazard.
- The Hurricane and Tropical Storm hazards are now discussed in their own hazard profile – they were previously incorporated into the High Wind – Straight Line Winds hazard.
- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 2008 and 2015.
- A vulnerability assessment was conducted for the hurricane and tropical storm hazard using a more accurate and updated building inventory; it now directly follows the hazard profile.

5.4.6.1 Profile

Hazard Description

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 rotate counterclockwise around the center in the northern hemisphere and are accompanied by heavy rain and strong winds (NWS 2013a). Almost all tropical storms and hurricanes in the Atlantic basin (which includes the Gulf of Mexico and Caribbean Sea) form between June 1 and November 30 (hurricane season). August and September are peak months for hurricane development (NOAA 2013a).

Over a two-year period, the U.S. coastline is struck by an average of three hurricanes, one of which is classified as a major hurricane. Hurricanes, tropical storms, and tropical depressions pose a threat to life and property. These storms bring heavy rain, storm surge, and flooding (NOAA 2013b). The cooler waters off the coast of New Jersey can diminish the energy of storms that have traveled up the eastern seaboard. However, historical data show that a number of hurricanes/tropical storms have impacted New Jersey, often as the remnants of a larger storm hitting the Gulf or Atlantic Coast hundreds of miles south of New Jersey. These storms maintain sufficient wind and precipitation to cause substantial damage to the state.

Tropical cyclones most frequently affect New Jersey during the month of September, though the state has experienced tropical cyclones throughout the hurricane season, excluding November. Because of peak warm water temperatures in September, storms usually affect New Jersey during this time (Buchholz and Savadore 1993).

For the purpose of this HMP update, this hazard profile will include hurricanes and tropical storms. Detailed information regarding these hazards in Warren County are discussed further in this section.

Hurricanes and Tropical Storm

A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds and heavy rain (winds are at a lower speed than hurricane-force winds, therefore categorized as a tropical storm instead of a hurricane). Tropical storms strengthen when water evaporated from the ocean is

released as the saturated air rises, resulting in condensation of water vapor contained in the moist air. They are fueled by a different heat mechanism than other cyclonic windstorms such as Nor'Easters and polar lows. The characteristic that separates tropical cyclones from other cyclonic systems is that at any height in the atmosphere, the center of a tropical cyclone will be warmer than its surroundings; a phenomenon called "warm core" storm systems (NOAA 2013).

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

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

- *Hurricane/Typhoon Warning* is issued when sustained winds of 74 mph or higher are expected somewhere within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the warning is issued 36 hours in advance of the anticipated onset of tropical storm-force winds. The warning can remain in effect when dangerously high water or combination of dangerously high water and waves continue, even though winds may be less than hurricane force.
- *Hurricane Watch* is issued when sustained winds of 74 mph or higher are possible within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the hurricane watch is issued 48 hours prior to the anticipated onset of tropical storm-force winds.
- *Tropical Storm Warning* is issued when sustained winds of 39 to 73 mph are expected somewhere within the specified area within 36 hours in association with a tropical, subtropical, or post-tropical storm.
- *Tropical Storm Watch* is issued when sustained winds of 39 to 73 mph are possible within the specified area within 48 hours in association with a tropical, sub-tropical, or post-tropical storm.
  (NWS 2013).

Location

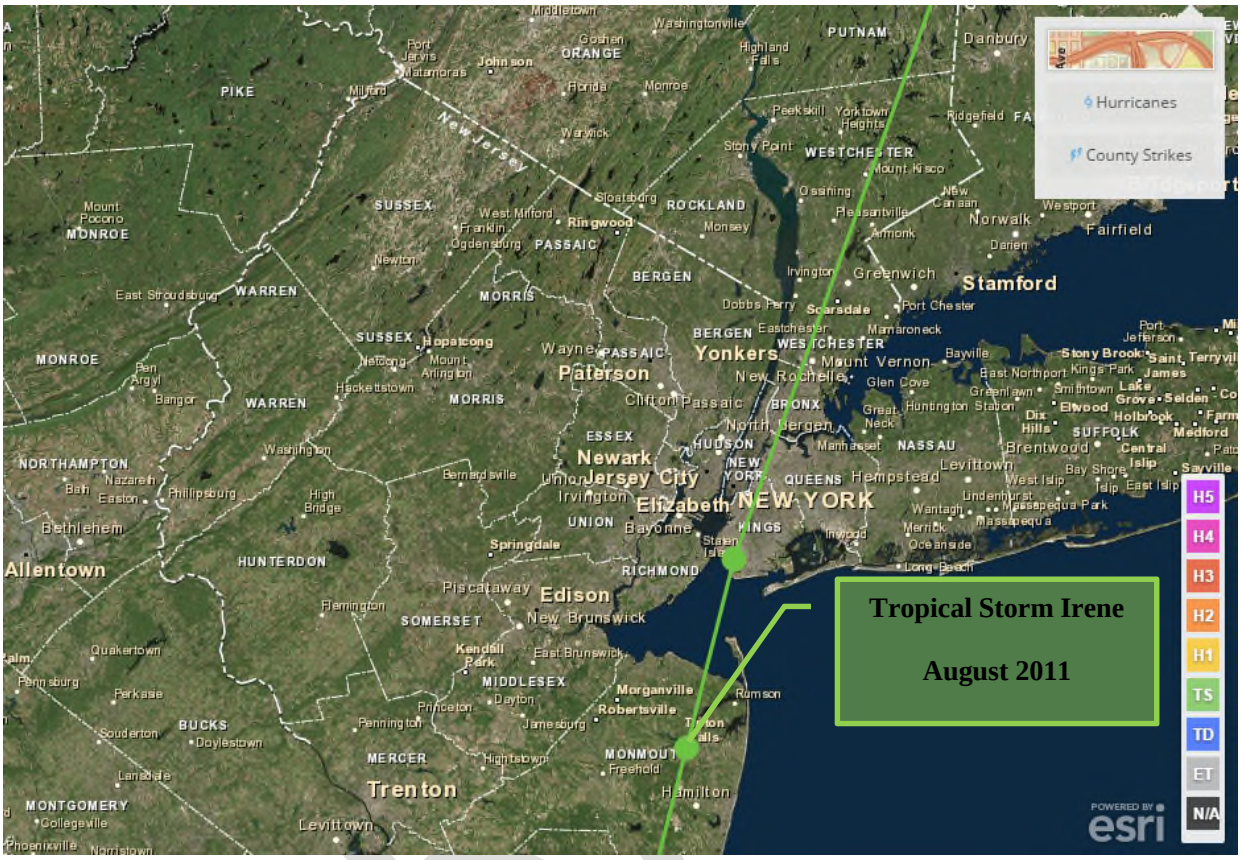
All of Warren County is vulnerable and at risk to flooding due to heavy rains and winds produced by hurricanes and tropical storms.

Tropical Storm and Hurricane Tracks

NOAA's Historical Hurricane Tracks tool is a public interactive mapping application that displays Atlantic Basin and East-Central Pacific Basin tropical cyclone data. This interactive tool catalogs tropical cyclones that have occurred from 1842 to 2014 (latest date available from data source). Between 1842 and 2014, 16 tropical cyclones tracked within 65 nautical miles of Warren County. Figure 5.4.6-1 displays tropical cyclone tracks for Warren County that tracked with 65 nautical miles between 2008 and 2015 (only one event – Hurricane Irene in 2011, identified as a tropical storm when passing by the county). Please note that this figure does not show Tropical Storm Lee or Hurricane Sandy because neither passed Warren County within 65 nautical miles. However, these and other events severely impacted the county with strong winds, power outages, and other

damage. Refer to the "Previous Events and Losses" section for further information regarding hurricane and tropical storm events that impacted Warren County.

Figure 5.4.6-1. Historical Tropical Storm and Hurricane Tracks 2008 to 2015



Source: NOAA 2015b

Extent

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

Table 5.4.6-1. The Saffir-Simpson Hurricane Scale

Category	Wind Speed (mph)	Expected Damage
1	74-95	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	96-110	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.

Category	Wind Speed (mph)	Expected Damage
3 (major)	111-129	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)	130-156	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.

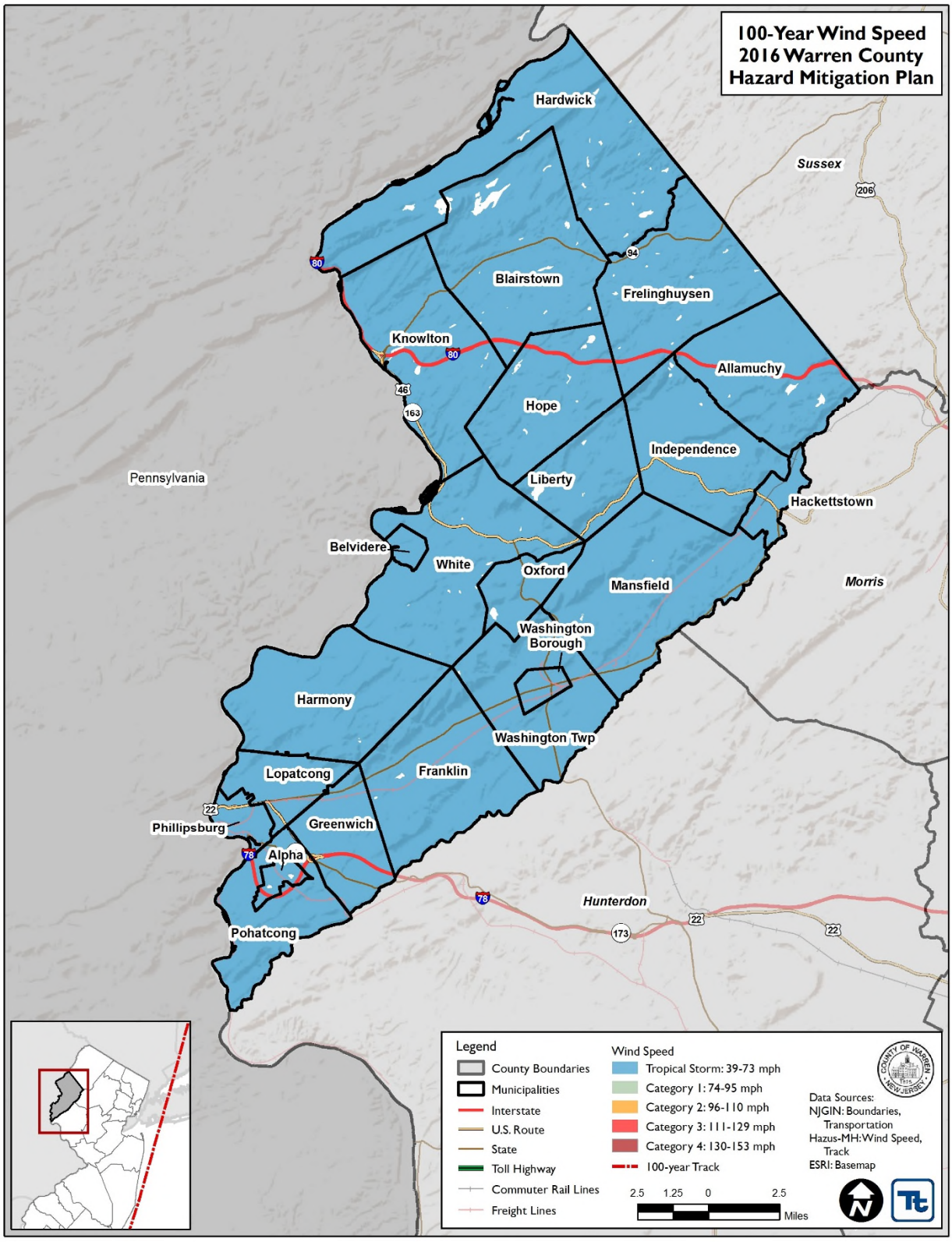
Source: NOAA 2013b
Notes:
mph Miles per hour
> Greater than

Mean Return Period

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

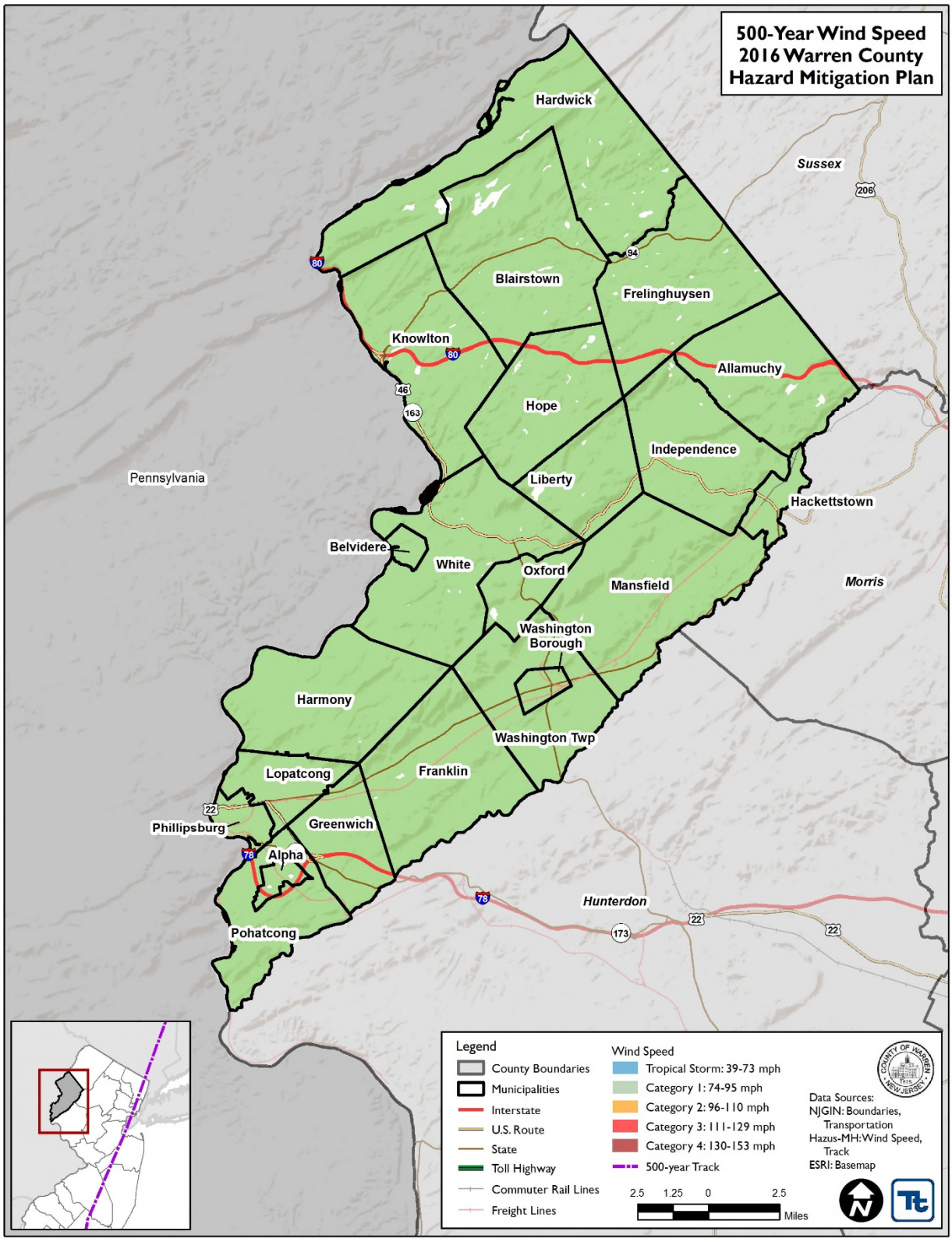
Figure 5.4.6-2 and Figure 5.4.6-3 show the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP events. These peak wind speed projections were generated using FEMA's HAZUS-MH wind model. The estimated hurricane track used for the 100- and 500-year event is also shown. The maximum 3-second gust wind speeds for Warren County range from 64 mph to 69 mph for the 100-year MRP event (tropical storm). The maximum 3-second gust wind speeds for Warren County range from 75 mph to 90 mph for the 500-year MRP event (category 1 hurricane). The associated impacts and losses from these 100-year and 500-year MRP hurricane events are discussed later in the Vulnerability Assessment subsection.

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



Source: HAZUS-MH 2.1

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



Source: HAZUS-MH 2.1

Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with hurricane and tropical storm events throughout Warren County. With so many sources reviewed for the purpose of this HMP update, 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 update.

Between 1954 and 2015, FEMA issued a disaster (DR) or emergency (EM) declaration for the State of New Jersey for eight tropical cyclone-related events, classified as one or a combination of the following disaster types: one or a combination of the following disaster types: hurricane, tropical storm, severe storms, flooding, and tropical depression. Of those events, Warren County has been included in four hurricane and tropical storm-related declarations (EM and DR) (FEMA 2015). Since the original 2011 HMP, Warren County has been included in the following FEMA disaster declarations: Hurricane Irene and Remnants of Tropical Storm Lee in 2011, and Hurricane Sandy in 2012. Table 5.4.6-2 lists FEMA DR and EM declarations from January 1, 2008 to August 31, 2015 for this HMP Update.

Table 5.4.6-3. FEMA DR and EM Declarations since 2008 for Hurricane and Tropical Storm Events in Warren County

FEMA Declaration Number	Date(s) of Event	Event Type	Location
DR-4021	August 26 – September 5, 2011	Hurricane Irene	Twenty-one Counties in New Jersey including Warren County
DR-4039	September 5-14, 2011	Remnants of Tropical Storm Lee	Five Counties in New Jersey including Warren County
DR-4048	October 26 – November 8, 2012	Hurricane Sandy	Twenty-one Counties in New Jersey including Warren County

Source: FEMA 2015

For this 2016 HMP update, hurricane and tropical storm events, including FEMA disaster declarations, which have impacted Warren County between from January 1, 2008 to August 31, 2015 are identified in Appendix E. For detailed information on damages and impacts to each jurisdiction, refer to Section 9 (Jurisdictional Annexes).

Probability of Future Occurrences

Hurricane return periods are the frequency at which a certain intensity of hurricane can be expected within a given distance of a given location. For example, a return period 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. The return period of hurricanes for Warren 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) (NOAA 2013).

In order to determine the recurrence interval and the average annual number of events, data from 1842 to 2014 was looked at using NOAA's Historical Hurricane Tracks tool to calculate these statistics for Warren County. Based on this data, the County has experienced a total of 16 events classified as either a hurricane, tropical storm, or tropical depression. The table below shows these statistics, as well as the annual average number of events and the estimated percent chance of the event occurring in a given year (NOAA-NCDC 2015). It is estimated that Warren County will continue to experience direct and indirect impacts of hurricane and tropical storms annually that may induce secondary hazards such as flooding, extreme wind, infrastructure deterioration or

failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents, and inconveniences.

Table 5.4.6-4. Probability of Future Occurrences of Hurricane and Tropical Storm Events

Hazard Type	Number of Occurrences Between 1950 and 2015	Rate of Occurrence or Annual Number of Events (average)	Recurrence Interval (in years) (# Years/Number of Events)	Probability of Event in any given year	% chance of occurrence in any given year
Hurricane	3	0.017	57.667	0.017	1.734
Tropical Storm	12	0.070	14.417	0.069	6.936
Tropical Depression	3	0.017	57.667	0.017	1.734
All Hurricane/ Tropical Storm	**16**	**0.093**	**10.813**	**0.092**	**9.249**

Source: NOAA 2015
Note: Some storms were catalogued as more than one category of Tropical Depression. Therefore, the total number of all hurricanes/tropical storms is less than the sum of the individual categories.

In Section 5.3, the identified hazards of concern for Warren 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 hurricane and tropical storms in the county is considered "frequent" (likely to occur within 25 years, as presented in Table 5.3-3).

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. According to the National Aeronautics and Space Administration (NASA), warmer temperatures may lead to an increase in frequency of storms, thus leading to more weather events that cause coastal erosion.

Temperatures in the northeastern United States have increased 1.5 degrees °F on average since 1900. Most of this warming has occurred since 1970. The State of New Jersey, for example, has observed an increase in average annual temperatures of 1.2°F between the period of 1971-2000 and 2001-2010 (ONJSC n.d.). Winter temperatures across the Northeast have seen an increase in average temperature of 4°F since 1970 (Northeast Climate Impacts Assessment [NECIA] 2007). By the 2020s, the average annual temperature in New Jersey is projected to increase by 1.5°F to 3°F above the statewide baseline (1971 to 2000), which was 52.7°F. By 2050, the temperature is projected to increase 3°F to 5°F (Sustainable Jersey Climate Change Adaptation Task Force n.d.).

Northern and southern New Jersey have become wetter over the past century. Northern New Jersey's 1971-2000 precipitation average was over 5 inches (12%) greater than the average from 1895-1970. Southern New Jersey became 2 inches (5%) wetter late in the 20th century (ONJSC). Average annual precipitation is projected to increase in the region by 5% by the 2020s, and up to 10% by the 2050s. Most of the additional precipitation is expected to come during the winter months (New York City Panel on Climate Change [NPCC] 2013).

5.4.6.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the hurricane and tropical storm hazard, all of Warren County is exposed and vulnerable. Therefore, all assets in the County (population, structures, critical facilities and lifelines), as described in Section 4 (County Profile), are at risk. The following text evaluates and estimates the potential impact of hurricanes and tropical storms on the County including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2011 Warren County Hazard Mitigation Plan
- Further data collections that will assist understanding this hazard over time

Overview of Vulnerability

To protect life and property from wind events, all counties in New Jersey, including Warren County, are required to comply with the design wind loads developed by the International Building Code (IBC) and the International Residential Code (IRC). The building code administered within the incorporated areas of Warren County require all new construction to be designed and constructed to 90 or 100 mph wind loads (NJDCA 2013).

The high winds and air speeds of a tropical storm or hurricane often result in power outages, disruptions to transportation corridors and equipment, loss of workplace access, significant property damage, injuries and loss of life, and the need to shelter and care for individuals impacted by the events. A large amount of damage can be inflicted by trees, branches, and other objects that fall onto power lines, buildings, roads, vehicles, and, in some cases, people.

The entire inventory of the County is at risk of being damaged or lost due to impacts of severe weather. Certain areas, infrastructure, and types of buildings are at greater risk than others due to proximity to flood waters, falling hazards, and their manner of construction. Potential losses associated with high winds were calculated for Warren County for the 100-year and 500-year MRP wind events.

Data and Methodology

After reviewing historic data, the HAZUS-MH methodology and model were used to analyze the wind hazard for Warren County. Data and tools used to assess this hazard include FEMA's HAZUS-MH 2.1 wind model, professional knowledge, information provided by the Planning Committee. A probabilistic scenario was run for the County for annualized losses and the 100- and 500-year MRPs in HAZUS-MH. Maximum peak gust wind speeds and hurricane storm tracks for these MRPs are displayed on Figures 5.4.7-2 and 5.4.7-3.

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

Impact on Life, Health and Safety

For the purposes of this HMP, the entire population of Warren County (108,692 people) is exposed to hurricane and tropical storm events (U.S. Census, 2010). Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. HAZUS-MH estimates there will be 0 displaced households and 0 people will require temporary shelter as a result of the 100- and 500-year MRP events.

Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate. The population over the age of 65 is also more vulnerable and, physically, they may have more difficulty evacuating. The elderly are considered most vulnerable because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention which may not be available due to isolation during a storm event. Please refer to Section 4 for the statistics of these populations.

Impact on General Building Stock

After considering the population exposed to the hurricane hazard, the value of general building stock exposed to and damaged by 100- and 500-year MRP hurricane wind events was considered. Potential damage is the modeled loss that could occur to the exposed inventory, including damage to structural and content value based on the wind-only impacts associated with a tropical storm or hurricane. The entire study area is considered at risk to the hurricane wind hazard. Please refer to Section 4 (County Profile) which presents the total exposure value for general building stock by occupancy class for Warren County.

Expected building damage was evaluated by HAZUS-MH across the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 5.4.6-5. summarizes the definition of the damage categories.

Table 5.4.6-5. 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 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

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
Severe Damage Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	>50%	> the larger of 20% & 3 and ≤50%	>3 and ≤25%	Typically 10 to 20 impacts	No	No
Destruction Complete roof failure and/or, failure of wall frame. Loss of more than 50% of roof sheathing.	Typically >50%	>50%	>25%	Typically >20 impacts	Yes	Yes

Source: HAZUS-MH Hurricane Technical Manual

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

Table 5.4.6-6. Estimated Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Hurricane-Related Winds

Municipality	Improved Value (Structure Only)	Estimated Total Damages*			Percent of Total Building Improved Value		
		Annualized Loss	100-Year	500-Year	Annualized Loss	100-Year	500-Year
Allamuchy Township	$371,928,938	$20,919	$365,755	$1,733,557	<1%	<1%	<1%
Alpha Borough	$142,442,200	$5,995	$58,618	$664,923	<1%	<1%	<1%
Town of Belvidere	$122,533,598	$4,858	$61,739	$380,887	<1%	<1%	<1%
Blairstown Township	$494,319,677	$17,634	$229,869	$863,531	<1%	<1%	<1%
Franklin Township	$254,753,630	$17,523	$182,198	$1,669,093	<1%	<1%	<1%
Frelinghuysen Township	$161,598,428	$7,383	$116,682	$472,385	<1%	<1%	<1%
Greenwich Township	$471,244,826	$34,775	$338,066	$3,470,141	<1%	<1%	<1%
Town of Hackettstown	$741,234,785	$31,093	$463,835	$2,709,346	<1%	<1%	<1%
Hardwick Township	$96,410,820	$3,510	$53,209	$219,820	<1%	<1%	<1%
Harmony Township	$370,405,710	$11,407	$119,128	$889,689	<1%	<1%	<1%
Hope Township	$129,143,932	$6,119	$93,121	$432,910	<1%	<1%	<1%
Independence Township	$360,549,900	$15,191	$229,275	$1,281,557	<1%	<1%	<1%
Knowlton Township	$166,041,730	$7,480	$105,377	$499,071	<1%	<1%	<1%
Liberty Township	$168,735,159	$5,764	$81,088	$400,459	<1%	<1%	<1%
Lopatcong Township	$570,126,290	$30,270	$284,167	$2,899,568	<1%	<1%	<1%
Mansfield Township	$416,212,280	$23,154	$276,959	$2,069,384	<1%	<1%	<1%
Oxford Township	$148,263,870	$6,207	$81,506	$575,695	<1%	<1%	<1%
Town of Phillipsburg	$724,427,519	$22,934	$230,691	$2,378,486	<1%	<1%	<1%
Pohatcong Township	$216,290,405	$8,788	$87,784	$1,032,591	<1%	<1%	<1%
Washington Borough	$288,556,584	$13,059	$165,105	$1,278,085	<1%	<1%	<1%
Washington Township	$496,189,088	$31,905	$400,975	$3,064,315	<1%	<1%	<1%
White Township	$335,737,423	$16,671	$193,975	$1,234,035	<1%	<1%	<1%
Warren County (Total)	**$7,247,146,792**	**$342,640**	**$4,219,120**	**$30,219,526**	**<1%**	**<1%**	**<1%**

Source: HAZUS-MH 2.1;

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

Table 5.4.6-7. Estimated Residential and Commercial Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Hurricane-Related Winds

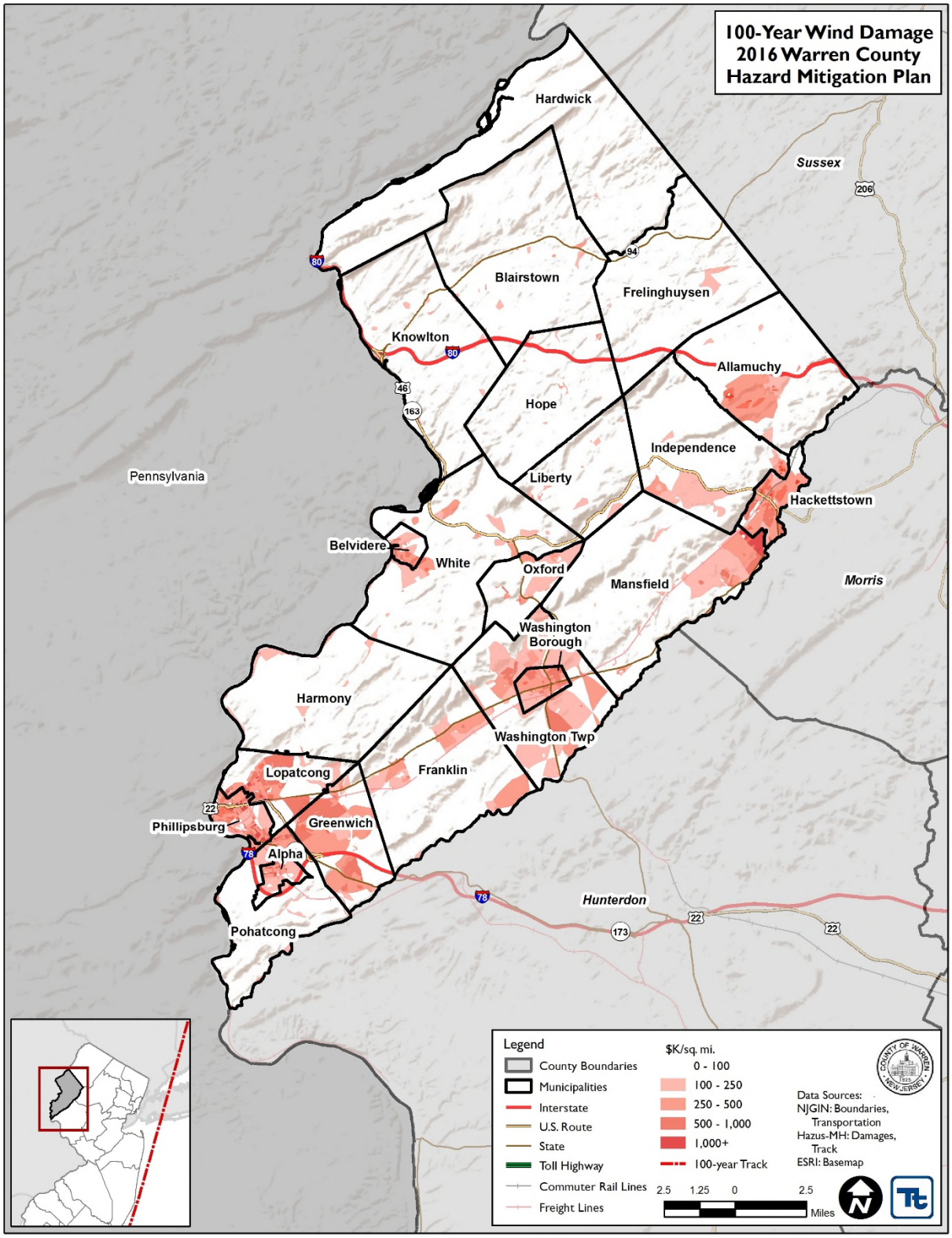
Municipality	Improved Value (Structure Only)	Estimated Residential Damage		Estimated Commercial Damage	
		100-Year	500-Year	100-Year	500-Year
Allamuchy Township	$371,928,938	$362,698	$1,721,805	$986	$3,156
Alpha Borough	$142,442,200	$54,126	$615,360	$2,211	$25,121
Town of Belvidere	$122,533,598	$56,748	$362,342	$1,111	$4,404
Blairstown Township	$494,319,677	$217,873	$843,939	$4,179	$7,004
Franklin Township	$254,753,630	$175,383	$1,512,877	$943	$15,835
Frelinghuysen Township	$161,598,428	$115,567	$467,910	$620	$1,414
Greenwich Township	$471,244,826	$329,353	$3,260,274	$6,937	$164,057
Town of Hackettstown	$741,234,785	$436,724	$2,564,224	$11,762	$67,749
Hardwick Township	$96,410,820	$51,931	$216,821	$482	$580
Harmony Township	$370,405,710	$95,548	$757,376	$569	$5,267
Hope Township	$129,143,932	$91,191	$426,727	$1,067	$2,559
Independence Township	$360,549,900	$225,759	$1,262,117	$1,540	$6,772
Knowlton Township	$166,041,730	$103,446	$492,170	$1,266	$3,216
Liberty Township	$168,735,159	$79,960	$396,237	$389	$833
Lopatcong Township	$570,126,290	$273,632	$2,790,878	$7,502	$73,945
Mansfield Township	$416,212,280	$267,394	$1,973,781	$6,004	$56,779
Oxford Township	$148,263,870	$78,613	$562,824	$395	$2,189
Town of Phillipsburg	$724,427,519	$198,551	$2,157,146	$9,253	$60,737
Pohatcong Township	$216,290,405	$79,484	$918,118	$6,548	$81,537
Washington Borough	$288,556,584	$158,464	$1,219,898	$3,429	$28,948
Washington Township	$496,189,088	$391,268	$2,910,489	$4,908	$77,791
White Township	$335,737,423	$185,936	$1,184,689	$2,348	$16,499
Warren County (Total)	**$7,247,146,792**	**$4,029,647**	**$28,618,002**	**$74,448**	**$706,391**

Source: HAZUS-MH 2.1

The total damage to buildings (structure only) for all occupancy types across the County is estimated to be $4.2 million for the 100-year MRP wind-only event, and approximately $30.2 million for the 500-year MRP wind-only event. The majority of these losses are to the residential building category.

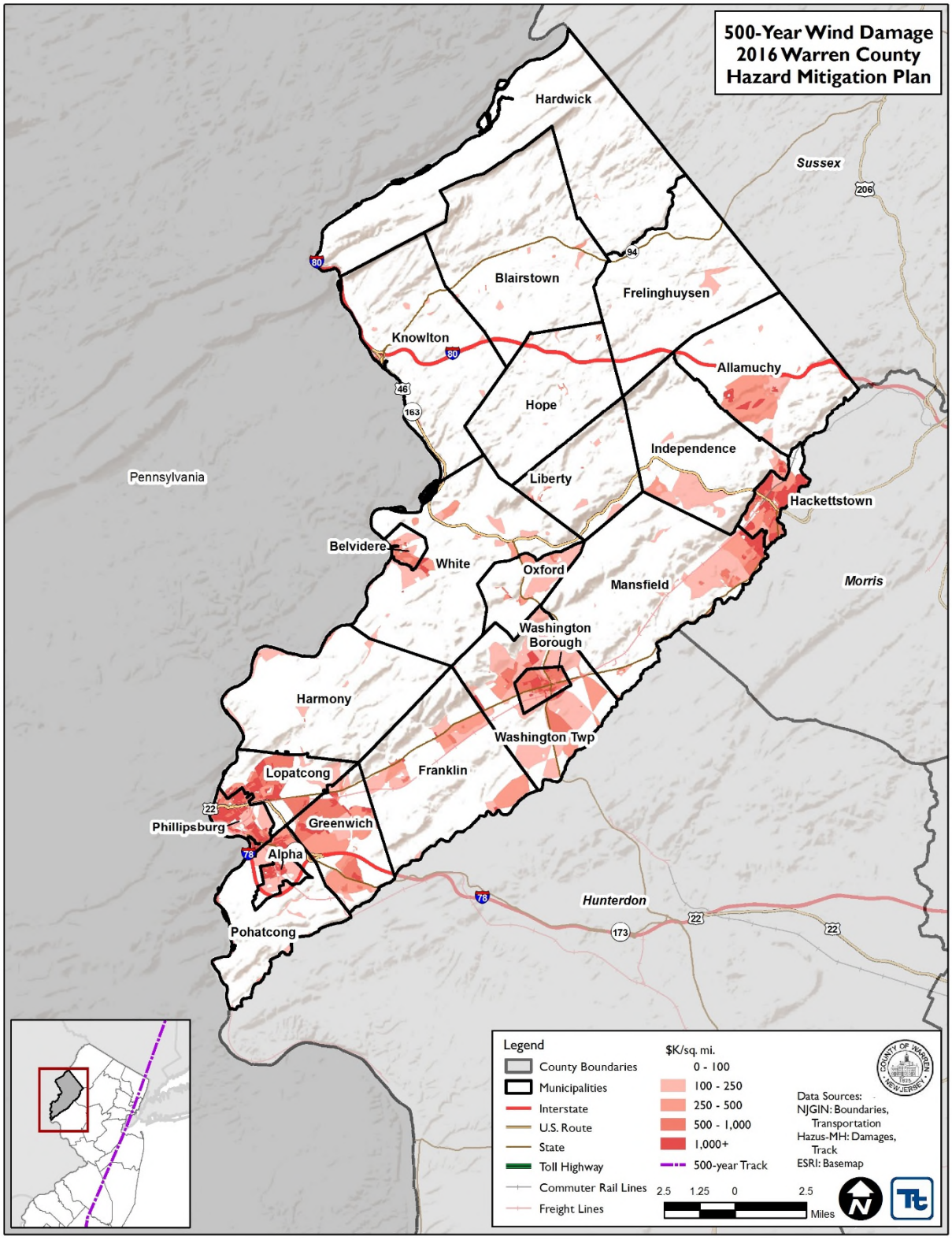
Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. The damage counts include buildings damaged at all severity levels from minor damage to total destruction. Total dollar damage reflects the overall impact to buildings at an aggregate level.

Table 5.4.6-8. Density of Losses for Structures (All Occupancies) for the County 100-Year MRP Hurricane (Wind-Only) Event



Source: HAZUS-MH 2.1

Table 5.4.6-9. Density of Losses for Structures (All Occupancies) for the County 500-Year MRP Hurricane (Wind-Only) Event



Source: HAZUS-MH 2.1

Impact on Critical Facilities

Overall, all critical facilities are exposed to the wind hazard associated with hurricane and tropical storm events. HAZUS-MH estimates the probability that critical facilities (i.e., medical facilities, fire/EMS, police, EOC, schools, and user-defined facilities such as shelters and municipal buildings) may sustain damage as a result of 100-year and 500-year MRP wind events. Additionally, HAZUS-MH estimates the loss of use for each facility in number of days. Due to the sensitive nature of the critical facility dataset, individual facility estimated loss is not provided.

Table 5.4.6-10. Table 5.4.6-10. Estimated Impacts to Critical Facilities for the 100- Year Mean Return Period Hurricane-Related Winds

Facility Type	100-Year Event				
		Percent-Probability of Sustaining Damage			
	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	0-1	0	0	0
Medical	0	1	0	0	0
Police	0	0-1	0	0	0
Fire	0	0	0	0	0
Schools	0	0-1	0	0	0

Source: HAZUS-MH 2.1

Table 5.4.6-11. Estimated Impacts to Critical Facilities for the 500-Year Mean Return Period Hurricane-Related Winds

Facility Type	500-Year Event				
		Percent-Probability of Sustaining Damage			
	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	1-9	0-2	0	0
Medical	0	4-6	5-7	3-5	0
Police	0	1-9	0-2	0	0
Fire	0	0-4	0-1	0	0
Schools	0-20	1-10	0-11	0-2	0

Source: HAZUS-MH 2.1

Impact on Economy

Hurricanes and tropical storms also impact the economy, including: loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. HAZUS-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is reported in the "Impact on General Building Stock" subsection discussed earlier. Business interruption losses are the losses associated with the inability to operate a business because of the wind damage sustained during the storm or the temporary living expenses for those displaced from their home because of the event.

For the 100-year MRP wind event, HAZUS-MH estimates approximately $8,348 in business interruption costs (income loss, relocation costs, rental costs and lost wages) and less than $200 in inventory losses. For the 500-year MRP wind only event, HAZUS-MH estimates approximately $3.6 million in business interruption losses

for the County, which includes loss of income, relocation costs, rental costs and lost wages, in addition to approximately $180,000 in inventory losses.

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

HAZUS-MH 2.1 also estimates the amount of debris that may be produced a result of the 100- and 500-year MRP wind events. Table 5.4.6-10 summarizes the estimated debris by municipality. Because the estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur.

According to the HAZUS-MH Hurricane User Manual: '*The Eligible Tree Debris columns provide estimates of the weight and volume of downed trees that would likely be collected and disposed at public expense. As discussed in Chapter 12 of the HAZUS-MH Hurricane Model Technical Manual, the eligible tree debris estimates produced by the Hurricane Model tend to underestimate reported volumes of debris brought to landfills for a number of events that have occurred over the past several years. This indicates that that there may be other sources of vegetative and non-vegetative debris that are not currently being modeled in HAZUS. For landfill estimation purposes, it is recommended that the HAZUS debris volume estimate be treated as an approximate lower bound. Based on actual reported debris volumes, it is recommended that the HAZUS results be multiplied by three to obtain an approximate upper bound estimate. It is also important to note that the Hurricane Model assumes a bulking factor of 10 cubic yards per ton of tree debris. If the debris is chipped prior to transport or disposal, a bulking factor of 4 is recommended. Thus, for chipped debris, the eligible tree debris volume should be multiplied by 0.4'.*

Table 5.4.6-12. Debris Production for 100- and 500-Year Mean Return Period Hurricane-Related Winds

Municipality	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year
Allamuchy Township	23	150	0	0	1,389	6,098	1,472	6,864
Alpha Borough	5	330	0	0	30	557	149	2,212
Town of Belvidere	3	189	0	0	42	307	370	2,034
Blairstown Township	7	130	0	0	667	2,212	863	2,631
Franklin Township	22	461	0	1	533	8,400	455	6,022
Frelinghuysen Township	0	49	0	0	851	3,517	579	2,355
Greenwich Township	31	699	0	1	126	2,572	303	5,221
Town of Hackettstown	162	887	0	0	165	1,160	1,002	6,295
Hardwick Township	0	23	0	0	941	3,730	407	1,571
Harmony Township	8	199	0	0	529	6,275	472	5,075
Hope Township	0	70	0	0	693	2,885	562	2,348
Independence Township	35	225	0	0	669	6,041	647	6,702
Knowlton Township	2	122	0	0	629	2,970	724	3,054
Liberty Township	0	62	0	0	172	880	292	1,374
Lopatcong Township	27	804	0	0	94	1,840	365	5,663

Table 5.4.6-12. Debris Production for 100- and 500-Year Mean Return Period Hurricane-Related Winds

Municipality	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year
Mansfield Township	46	430	0	0	647	9,897	786	9,351
Oxford Township	1	107	0	0	69	1,830	135	3,618
Town of Phillipsburg	16	1,404	0	0	62	935	633	6,596
Pohatcong Township	3	456	0	0	185	4,281	241	5,410
Washington Borough	111	752	0	0	41	564	367	3,916
Washington Township	84	835	0	3	503	5,656	858	10,143
White Township	12	291	0	0	585	7,070	621	7,111
Warren County (Total)	**598**	**8,675**	**0**	**5**	**9,622**	**79,677**	**12,302**	**105,566**

Source: HAZUS-MH 2.1

Effect of Climate Change on Vulnerability

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

Climate Change in New Jersey: Trends and Projections describes changes in temperature, precipitation, and sea level rise. Each section of the report summarizes observed recent changes in climate in New Jersey. Observations are based on recorded climate data collected by the ONJSC and other institutions, and on other reports summarizing climate change in the northeastern United States. Each section also presents a synthesis of the most current projections for future climate changes based on climate science modeling and techniques. The projections reflect potential average climate over a span of future years (2020, 2050, and 2080). The projections in the report illustrate the potential climate changes that could impact the northeastern United States based on future emissions scenarios (A2, A1B, and B1 – high, medium, and low scenarios). Each emissions scenario would result in a range of potential climate outcomes in the State (Rutgers 2013).

Change of Vulnerability

Warren County and its municipalities continue to be vulnerable to the hurricane and tropical storm hazard. However, there are several differences between the exposure and potential loss estimates between the 2016 HMP update and the results in the original 2011 HMP. These differences are due to changes in the HAZUS model and updated building stock and critical facility inventories. For this plan update, the HAZUS-MH hurricane model was run for the entire County at the block level and results reported at the municipal level. HAZUS-MH version 2.1 was utilized for this plan update; the hurricane model has been enhanced since the 2011 HMP. Model results from a scenario as if Hurricane Floyd had occurred and a probabilistic 100-year event were used in the 2011 HMP. However for this plan update, results from a probabilistic 100-year and 500-year event were used, in addition to annualized losses. The FEMA Wind Hurricane BCA module was not used for this plan update.

Overall, this vulnerability assessment uses a more accurate and updated building inventory which provides more accurate estimated exposure and potential losses for Warren County.

Future Growth and Development

As discussed and illustrated in Sections 4 and 9, areas targeted for future growth and development have been identified across the County. Any areas of growth could be potentially impacted by the Hurricane and Tropical Storm hazard because the entire Planning Area is exposed and vulnerable to the impacts associated with these events. The development of new buildings in these areas must meet or exceed the standards in Section R301.2.1.1 of the International Building Code (IBC) which will assist with mitigating future potential damages and losses. Areas targeted for potential future growth and development in the next five (5) years have been identified across the County at the jurisdiction level. Refer to the jurisdictional annexes in Volume II of this HMP.

Additional Data and Next Steps

Over time, the County will obtain additional data to support the analysis of this hazard. Data that will support the analysis would include additional detail on past hazard events and impacts, building footprints and specific building information such as details on protective features (for example, hurricane straps).