Photo Courtesy of Highlands Borough

4.0 RISK ASSESSMENT

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4.0 RISK ASSESMENT

4.1 RISK ASSESSMENT OVERVIEW

4.1.1 IDENTIFICATION OF HAZARDS

Monmouth County is vulnerable to a wide range of natural and human-caused hazards that threaten life and property. FEMA's current regulations and interim guidance under the Disaster Mitigation Act of 2000 (DMA 2000) require an evaluation of natural hazards. An evaluation of human-caused hazards (i.e., technological hazards, terrorism, etc.) is encouraged, though not required, for plan approval. Since the last Monmouth County HMP, Monmouth County has decided to include the following human-caused hazards: civil unrest, cyber-attack, economic disruption, pandemic, power failure, and terrorism.

Both natural and human-based hazards were identified through an extensive process that utilized input from three key sources: Steering Committee members, the State HMP, and online research. During the 2018 Steering Committee Kick-off Meeting, the Project Team asked the Steering Committee to capture changes in the County since 2015 through a hazard identification worksheet (see Figure 4.1-3 Steering Committee Hazard Identification Worksheet). The Project Team took these responses by Committee members and reorganized the profiled hazards. Table 4.1 - 1 Hazard Identification Crosswalk reflects these changes. The research involved in identifying hazards came from prominent online sources including records of declared disasters and emergencies maintained by FEMA and NJOEM, the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) Storm Event Database, and the Spatial Hazard Events and Losses Database for the United States (SHELDUS) maintained by the Hazards and Vulnerability Research Institute (HVRI) at the University of South Carolina.

Some of the hazards profiled in this plan are considered to be interrelated (i.e. hurricanes can cause flooding, storm surge, and tornadoes) and have been combined into general categories. For example, Hurricane, Tropical Storm, and Nor'easters have been combined to create an umbrella category that also profiles the secondary hazards of Coastal Erosion, Flood, Storm Surge, Tsunami, and Wave Action that result from these coastal storms. Additionally, Severe Weather includes the secondary hazards of Extreme Temperatures, Extreme Wind, Lightning, and Tornado. It should also be noted that impacts from Climate Change and Sea Level Rise will be addressed in each applicable hazard.

Figure 4.1 - 1 Flooding on a King Tide event on October 13, 2016. Courtesy of the Borough of Rumson.

Figure 4.1 - 2 Nor'easter in the Borough of Sea Girt

Figure 4.1 - 3 Steering Committee Hazard Identification Worksheet

Monmouth County
Multi-Jurisdictional Hazard Mitigation Plan Update

Michael Baker INTERNATIONAL

Hazards to Profile in Hazard Mitigation Plan Update

Name______________________________ **Organization** ______________________________

Review this entire handout and check all hazards that apply or should be profiled in the plan update.

Nature-based Hazards included in 2015 Monmouth County HMP:

2015 Monmouth County HMP Hazards	Include in Update (✓)	Comment
Coastal Erosion		
Dam Failure		
Drought		
Earthquake		
Extreme Temperatures		
Extreme Wind		
Flood		
Hurricane & Tropical Storm		
Landslide		
Lightning		
Nor'easter		
Storm Surge		
Tornado		
Wave Action		
Winter Storm		

***Impacts from Climate Change and Se**

Previously considered in the 2015 County Plan, but not included

Nature-based Hazard	Included in Update (✓)	Comment
Avalanche		
Hailstorm		
Expansive Soils		
Land Subsidence		
Tsunami		
Volcano		

Human-based Hazards Profiled in the State HMP, but not the County HMP.

Human-based Hazard	Include in Update (✓)	Comment
Animal Disease		
Civil Unrest		
Crop Failure		
Cyber Attack		
Economic Collapse		
Fishing Failure		
Hazardous Substances		
Nuclear Hazards		
Pandemic		
Power Failure		
Terrorism		

Are there additional hazards that should be profiled in the HMP update that are not listed above?

Comment:____

Table 4.1 - 1 Hazard Identification Crosswalk

2015 Hazards Profiled	2020 Hazards Profiled
Natural Hazards	
Coastal Erosion	*Combined with Hurricane/Tropical Storm/Nor'easter*
Dam Failure	Dam Failure
Drought	Drought
Earthquake	Earthquake
Extreme Temperatures	*Combined with Severe Weather*
Extreme Wind	*Combined with Severe Weather*
Flood	*Combined with Hurricane/Tropical Storm/Nor'easter*
Hurricane & Tropical Storm	*Combined with Hurricane/Tropical Storm/Nor'easter*
Landslide	Landslide
Lightning	*Combined with Severe Weather*
Nor'easter	*Combined with Hurricane/Tropical Storm/Nor'easter*
Storm Surge	*Combined with Hurricane/Tropical Storm/Nor'easter*
Tornado	*Combined with Severe Weather*
Tsunami	*Combined with Hurricane/Tropical Storm/Nor'easter*
Wave Action	*Combined with Hurricane/Tropical Storm/Nor'easter*
Wildfire	Wildfire
Winter Storm	Winter Storm
-	Hurricane/Tropical Storm/Nor'easter
-	Severe Weather
Human-Based Hazards	
-	Civil Unrest
-	Cyber Attack
-	Economic Disruption
-	Pandemic
-	Power Failure
-	Terrorism

Note: Impacts from Climate Change and Sea Level Rise will be addressed in each applicable hazard.

Once the hazards were identified by the Committee or considered from the State HMP or online research, the Project Team used an evaluation process to analyze which hazards were considered significant for the Monmouth County HMP Hazard Risk Assessment. This elevation is documented in Table 4.1 - 2 Documentation of the Hazard Evaluation Process. For each hazard considered, the table indicates whether or not the hazard was identified as a significant hazard to be further assessed, how this determination was made, and why this determination was made. The table works to summarize not only those hazards that *were* identified (and why) but also those that *were not* identified (and why not). Hazard events not identified for inclusion at this time may be addressed during future evaluations and updates to the risk assessment if deemed necessary by the Steering Committee. The table also documents the Planning Team's reassessment of hazard significance during this plan update as part of its ongoing maintenance of the plan to ensure that it reflects current conditions.

As mentioned in Table 4.1 – 1 Hazard Identification Crosswalk, sea level rise and climate change is addressed in each applicable hazard section. This HMP update uses the Science and Technical Advisory Panel (STAP)'s Assessing New Jersey's Exposure to Sea Level Rise and Coastal Storms: Report of the New Jersey Climate Adaptation Alliance Science and Technical Advisory Panel (2016). The STAP likely ranges of sea level rise estimates are consistent with recent guidance proposed by National Oceanic Atmospheric Administration (NOAA), the United States Army Corps of Engineers (USACE), and the United States Geological Survey (USGS). Although STAP's 2019 preliminary report is underway, at the time of plan update, the most recent STAP is from 2016.

Table 4.1 - 2 Documentation of the Hazard Evaluation Process

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
Avalanche	N	N	N	• Review of US Forest Service National Avalanche Center web site. • Review of FEMA's Multi-Hazard Identification and Risk Assessment	There is no risk of avalanche events in New Jersey. The United States avalanche hazard is limited to mountainous western states including Alaska, as well as some areas of low risk in New England. The topography and climate in Monmouth County would not support conditions needed for an avalanche to occur.
Extreme Temperatures	Y	Y	Y	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification and Risk Assessment • Review of NOAA	Extreme temperature events are discussed in the State HMP. NCDC and SHELDUS report 88 extreme temperature events for the County (including 73 extreme heat events and 15 extreme cold events). For these events there are no recorded property damages but there are several attributed fatalities and injuries. Primary impacts of concern for extreme temperatures include the life-threatening effects of heat stress or hypothermia on people, particularly the elderly or

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
				National Climatic Data Center (NCDC) Storm Events Database Review of HVRI SHELDUS database	people in poor physical health. Other significant impacts include strains on livestock and agriculture and excessive demands for electricity during extended heat waves that can lead to power outages and intentional rolling blackouts. Local emergency managers noted significant concerns regarding extreme temperatures including life/safety threats and infrastructure-related losses, damages and expenses.
Hailstorm	N	N	N	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification and Risk Assessment • Review of NOAA NCDC Storm Events Database and National Severe Storms Laboratory (NSSL) web site • Review of HVRI SHELDUS database	Hailstorms are discussed briefly in the State HMP under the section on thunderstorms and tornadoes. NCDC and SHELDUS report 31 severe hailstorm events (3/4-inch size hail or greater) for the County between October 1955 and December 2011. For these events there are no recorded property damages, no deaths and no injuries. Hail probability data available on the NSSL website indicates that the County is at minimal risk to severe weather threats from damaging hail (at least 2 inches in diameter). NCDC reports only one event in which hail of this magnitude fell in Monmouth County (Neptune Township - July 23, 2003). Monmouth County is located in a part of the country with the lowest annual number of days with hailstorms (less than 2). Damaging hailstorm events in Monmouth County aren't very likely, nor are they likely to be very intense. There are minimal hazard mitigation techniques available to reduce hailstorm impacts outside of the emergency preparedness procedures and severe weather warning systems already in place.
Hurricane and Tropical Storm	Y	Y	Y	• Review of NJ State HMP • Analysis of NOAA historical tropical cyclone tracks • FEMA HAZUS-MH storm return periods • Review of NOAA NCDC Storm Events Database and National Hurricane	Hurricane and tropical storm events are discussed in the State HMP. NOAA historical records indicate 36 storm tracks (11 hurricanes, 25 tropical storms) have come within 75 miles of Monmouth County (22 percent annual probability). The 50-year return period peak gust for hurricane and tropical storm events in Monmouth County is between 80 and 92 mph. Recent tropical storm events including Bertha (1996), Floyd (1999), Isabel (2003), Hanna (2008), Irene (2011), and Sandy (2012) have caused significant wind, flood and coastal erosion related damages in Monmouth County.

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
Lightning	Y	Y	Y	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification and Risk Assessment • Review of NOAA NCDC Storm Events Database, NOAA lightning statistics, and National Severe Storms Laboratory (NSSL) web site • Review of HVRI SHELDUS database	Lightning events are discussed briefly in the State HMP as part of the thunderstorm hazard, and the installation of lightning rods is mentioned as a helpful mitigation action. According to NOAA data, Monmouth County is located in an area of the country that experiences an average of 10-30 thunderstorm events and three lightning flashes per square kilometer per year. NCDC and SHELDUS report 51 lightning events for Monmouth County. These events have resulted in a recorded 4 deaths, 11 injuries and more than $1.5 million in property damage. Local emergency managers noted significant concerns regarding lightning including historical casualties, property damages and disruption to electrical power and emergency communications.
Nor'easter	Y	Y	Y	• Review of NJ State HMP • Review of NOAA NCDC Storm Events Database	Nor'easters are discussed in the State HMP as a significant hazard of concern for New Jersey communities, particularly located along the shore. Monmouth County has a lengthy history of devastating impacts wrought by nor'easters. This includes major damages caused by the effects of high wind, rain, snow, heavy surf, coastal flooding and severe beach erosion. Monmouth County's shore is vital to the local economy but remains highly susceptible to the effects of major coastal storms, including nor'easters.
Tornado	Y	Y	Y	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification & Risk Asses. • Review of NOAA NCDC Storm Events Database & NSSL • Review of	Tornado events are discussed in the State HMP. NCDC and SHELDUS report 9 tornado events in the County between August 1952 and December 2011.These events have resulted in no recorded deaths/ injuries but have caused $1.5 million in property damage; most from a F2 that struck Manalapan and Marlboro Townships in May 2001. NSSL tornado probability data indicate that the County is in an area that experiences less than one tornado event per year, but life-threatening and damaging events do remain very possible.

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
				HVRI SHELDUS	
Winter Storm	Y	Y	Y	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification and Risk Assessment • Review of NOAA NCDC Storm Events Database • Review of HVRI SHELDUS database • Office of New Jersey State Climatologist web site	Winter storms including snow storms and ice storms are discussed in the State HMP. The State HMP notes that the County averages between 20 and 25 inches of snowfall per year. NCDC and SHELDUS report that Monmouth County has been affected by 120 snow and ice events. These events resulted in no reported deaths or injuries in Monmouth County, but are associated with more than $2.8 million in property damages. According to the Office of New Jersey State Climatologist, parts of Monmouth County experience an average of 2 days per year with daily snowfall of up to four inches. During the winter of 1995-1996, a recorded 61-80 inches of snowfall fell across Monmouth County (highlighted by the Blizzard of 1996). The 2003 President's Day Storm resulted in more than 20 inches of snow in Monmouth County and caused a high school roof to collapse in Wall Township among other damages. Another winter storm on December 26, 2010 set a new single snowstorm record surpassing the previous record of 20.0 inches during the President's Day snowstorm of February 2003.
Extreme Wind	Y	Y	Y	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification & Risk Assessment • Review of NOAA NCDC Storm Events Database • Review of HVRI SHELDUS database • Review of maximum 3 second wind gust per ASCE Standard 7-98.	Extreme wind events are discussed in the State HMP. NCDC and SHELDUS report 267 significant wind events for the County. These events have resulted in recorded estimates of 7 deaths, 98 injuries and more than $34 million in property damage. Monmouth County is located in a climate region that is highly susceptible to numerous types of extreme wind events including severe thunderstorms, hurricanes, tropical storms, nor'easters and severe winter storms. The maximum 3-second wind gust for Monmouth County per ASCE 7-98 is 120 mph. The remnants of Superstorm Sandy in October 2012 caused extreme wind damage throughout Monmouth County.

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
Coastal Erosion	Y	Y	Y	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification and Risk Assessment • Review of New Jersey Department of Environmental Protection (NJDEP) Coastal Management Program web site	Coastal erosion is discussed in the State HMP as a hazard of concern for Monmouth County. Historic shoreline data for the County indicate erratic long-term shifts between coastal erosion and accretion resulting in dynamic shoreline change. This change is linked to a variety of natural factors as well as human activity. The most severe coastal erosion hazards for Monmouth County are related to rapid, episodic coastal storm events including hurricanes, tropical storms, and nor'easters. Following such an event, areas of the County will be even more vulnerable to the destructive effects of coastal erosion, wave action, and coastal flooding. Shore protection projects are routinely initiated and funded in Monmouth County through NJDEP and the U.S. Army Corps of Engineers. These projects in addition to many other elements of NJDEP's Coastal Management Program serve to reduce damages to public and private property caused by coastal erosion. The remnants of Superstorm Sandy in October 2012 caused catastrophic damage in Monmouth County.
Dam Failure	Y	Y	Y	• Review of NJDEP Bureau of Dam Safety and Flood Control web site. • Review of U.S. Army Corps of Engineers National Inventory of Dams database • Review of Stanford University's National Performance of Dams Program web site	Dam Failure is discussed in the State HMP as a hazard of concern for Monmouth County (classified under "man-made disasters"). New Jersey has seen property damages as a result of small dam failures (including damage or loss of bridges, roads and buildings), but has not experienced a catastrophic dam failure to date. According to the National Inventory of Dams, three major dams classified as high hazard (defined as "where failure or mis-operation will probably cause loss of human life") are located in Monmouth County but are not associated with any recorded dam failure events. Some local emergency managers noted concerns regarding the potential failure of earthen dams and other dam structures that need repair or replacement.

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
Flood	Y	Y	Y	• Review of NJ State HMP • Review of NOAA NCDC Storm Events Database • Review of HVRI SHELDUS database • Review of FEMA's NFIP Community Status Book and CRS • Review of FEMA Preliminary 2013 flood maps for Monmouth County	The flood hazard is thoroughly discussed in the State HMP and indicates that it is the most common natural hazard in New Jersey. More than half of all federal disaster declarations for Monmouth County have involved flooding. According to NCDC, over 125 recorded flood events (coastal flood, flash flood, and flood) have occurred in Monmouth County since 1996. These events have resulted in two reported injuries and an estimated $10 billion in property damages. The remnants of Superstorm Sandy in October 2012 caused catastrophic damage in Monmouth County. Nearly 10% of Monmouth County is located in the identified 100-year floodplain including riverine and coastal flood hazard areas. Nearly all municipalities participate in the NFIP and 16 participate in CRS, as of August 2019.
Storm Surge	Y	Y	Y	• Review of NJ State HMP • Review of U.S. Army Corps of Engineers SLOSH model data	Storm surge is discussed in the State HMP under the flood hazard and tropical storm and hurricane (and nor'easter) hazard, and highlights Monmouth County as being at risk to the forces of storm surge. According to SLOSH model data the majority of Monmouth County's municipalities are at risk to storm surge, and particularly those areas located within three to five miles of the shore. The remnants of Superstorm Sandy in October 2012 caused catastrophic damage in Monmouth County.
Wave Action	Y	Y	Y	• Review of NJ State HMP • Review of NOAA NCDC Storm Events Database • Review of HVRI SHELDUS database • Review of FEMA Q3 flood data for Monmouth County	Wave action is identified as a hazard of concern for Monmouth County in the State HMP. NCDC and SHELDUS report that the County has been affected by 93 coastal flooding and heavy surf events (including rip currents). These incidents resulted in a reported total of 19 deaths and 22 injuries in the County and caused an estimated $1 million in property damages. According to Q3 flood data, 26 municipalities in Monmouth County include coastal flood hazard areas with storm-induced velocity wave action.

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
Drought	Y	Y	Y	• Review of NJ State HMP • Review of NJDEP Drought Information web site • Review of National Drought Mitigation Center web site and Palmer Drought Severity Index	Drought is discussed in the State HMP but indicates that the County is among the least affected areas by drought because of massive groundwater supplies, and low development densities. According to the Palmer Drought Severity Index, New Jersey has experienced severe or extreme drought conditions less than five percent of the time between 1895 and 1995. However less severe, short-term droughts are a more frequent occurrence and can have serious implications for local water supply and the agricultural sector of some areas. Some local emergency managers noted concerns over recent drought conditions that resulted in local water restrictions and drought emergency declarations.
Earthquake	Y	Y	Y	• Review of NJ State HMP • USGS Earthquake Hazards Program web site • Review of New Jersey Geological Survey web site	Earthquake events are discussed in the State HMP. Earthquakes have occurred in and around the State in the past; according to the NJGS seven earthquakes had their epicenter in Monmouth County. According to USGS seismic hazard maps, the peak ground acceleration (PGA) with a 10% probability of exceedance in 50 years for Monmouth County is between 4%g and 5%g. FEMA recommends that earthquakes be further evaluated for mitigation purposes in areas with a PGA of 3%g or more. Historical earthquake events have caused documented damages in Monmouth County. Data provided by NJGS suggest that New Jersey is overdue for a moderate, damaging earthquake.
Expansive Soils	N	N	N	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification and Risk Assessment • Review of USDA Soil Conservation Service's Soil Survey for Monmouth County (1989) • Review of USDA Natural Resources	Expansive soils are not identified in the State HMP. According to FEMA and USDA sources, Monmouth County is located in an area that has a "slight to moderate" clay swelling potential. According to USDOT FHA Report No. FHWA-RD-76-82, Monmouth County lies in an area mapped as generally of low expansive character and/or low frequency of occurrence. The NRCS Freehold Service Center confirms that the potential for expansive soils in Monmouth County is slight to moderate, with more moderate potential in the western, less developed portions of the County where more clay soils exist. New Jersey has adopted the International Building Code of 2000, in which Chapter 18 includes provisions for building on expansive soils (through either design, removal or stabilization) so that new construction will be protected.

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
				Conservation Service (NRCS) Soil Survey Geographic Database	
Land Subsidence	N	N	N	• Review of NJ State HMP • Review of New Jersey Geological Survey digital GIS layers of Bedrock Geology and Abandoned Mines of New Jersey	The State HMP delineates certain areas that are susceptible to land subsidence hazards in New Jersey; however, none of these areas are located in the County. The plan identifies no areas of mapped known sinkholes in the County. Monmouth County's lack of carbonate rock terrain does not favor naturally occurring land subsidence or sinkholes. Further, there are no abandoned mines located in the County that could be prone to collapse.
Landslide	Y	Y	Y	• Review of NJ State HMP • Review of USGS Landslide Incidence and Susceptibility Hazard Map • Review of New Jersey Geological Survey GIS database of historic landslides in New Jersey	Landslide events are discussed in the State HMP, with particular attention focused on the coastal area land-sliding (or slumping) in natural bluff areas of Monmouth County. USGS landslide hazard maps indicate "high landslide incidence" (more than 15% of the area is involved in land-sliding) for areas located in nine municipalities in northeast Monmouth County. Data provided by NJGS indicate nine recorded landslide events in Monmouth County, including five that resulted in documented property damage.
Tsunami	N	N	Y	• Review of NJ State HMP • Review of FEMA's Multi-Hazard Identification and Risk Assessment • Review of FEMA "How-to" mitigation planning	Tsunamis are discussed in the State HMP. The plan states that the return period for a mid-Atlantic tsunami is 1 in every 36 years; however, this includes small scale events with waves of less than 0.5 meters. No record exists of a catastrophic Atlantic basin tsunami impacting the mid-Atlantic coast of the United States. The plan estimates that there is a probability of 0.3% in any given year for a tsunami of great than one meter to occur. Tsunami inundation zone maps are not available for communities located along the U.S. East Coast. FEMA mitigation planning guidance

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
				guidance (Publication 386-2, "Understanding Your Risks - Identifying Hazards and Estimating Losses)	suggests that locations along the U.S. East Coast have a relatively low tsunami risk and need not conduct a tsunami risk assessment at this time.
Volcano	N	N	N	• Review of NJ State HMP • Review of USGS Volcano Hazards Program web site	Volcanoes are not located anywhere near Monmouth County.
Wildfire	Y	Y	Y	• Review of NJ State HMP • Review of NOAA NCDC Storm Events Database • Review of New Jersey Forest Fire Service web site	Wildfires are discussed in the State HMP as a significant hazard of concern, particularly with regard to the Pine Barrens in south and central portions of the state. According to New Jersey Forest Fire Service records, Monmouth County experienced 512 wildfire incidents that burned 353 acres. The statistics indicate an average of 51 wildfire events per year, but also that most are quickly suppressed. NCDC historical records indicate some minor property damage associated with wildfire has occurred within Monmouth County. According to the New Jersey Forest Fire Service Wildfire Hazard Assessment (Draft 2004), portions of Monmouth County have been mapped as high hazard and extreme hazard. There is a high probability of future wildfire occurrences in Monmouth County. Wildfire hazard risks will increase as development and population increase within forested areas.
Radon	N	N	N	• Review of NJDEP's 2015 Radon Tier Assignment Report • Review of Association of New Jersey Environmental Commissions (ANJEC)	According to NJDEP's 2015 Radon Tier Assignment Report, 12 municipalities (Allentown Borough, Colts Neck Township, Freehold Borough, Freehold Township, Holmdel Township, Little Silver Borough, Marlboro Township, Millstone Township, Roosevelt Borough, Shrewsbury Borough, Shrewsbury Township, and Upper Freehold) are Tier I communities with High Radon Potential. These 12 communities make up less than one quarter (23%) of the municipalities in Monmouth County. It is the duty of a

Natural Hazards Considered	Profiled in 2009 Plan	Profiled in First Update (2015)	Profiled in Second Update (2020)	How was this determination made?	Why was this determination made?
				Environmental Manual for Municipal Officials: Second Edition	municipality to inform the public about radon testing. Further, all new public facilities and new residential construction must install passive radon reductions system in high-risk areas for radon (*N.J.S.A. 26:2D-73*); however, property owners are responsible for testing their properties for radon and for radon remediation.

When assessing risk associated with potential hazard occurrences, it is important to determine the probability and frequency of, and severity/vulnerability to, the hazard. By doing so, the Monmouth County HMP can target and concentrate on hazards that are more likely to occur, cause the most harm, require the most attention, and/or are most easily or cost-effectively mitigated. The probability of future events is the chance or likelihood that a hazard will occur in any given year. For instance, a flood event that has at least a 1 in 100 (or 1%) chance of occurring in any given year is known as a 100-year flood event, and the area that could potentially be flooded by such an event is known as the 100-year floodplain. The expected average frequency of such a flood would be once every 100 years. The severity/vulnerability to a specific hazard is the estimate of potential damage or impact that a particular hazard event may have on a designated community. Table 4.1-3 FEMA Major Disaster Declarations in Monmouth County displays emergency and disaster declarations in Monmouth County since 1965. There have 18 D

Table 4.1 - 3 FEMA Major Disaster Declarations in Monmouth County

FEMA Disaster No.	Disaster Date	Type of Disaster
DR205	August 1965	Water shortage
DR310	September 1971	Heavy rains, flooding
DR519	August 1976	Severe storms, high winds, flooding
DR528	February 1977	Ice conditions
EM3083	October 1980	Water shortage
DR701	April 1984	Coastal storms, flooding
DR749	October 1985	Hurricane Gloria
DR936	March 1992	Coastal storm
DR519	August 1976	Severe storms, high winds, flooding
DR528	February 1977	Ice conditions
EM3083	October 1980	Water shortage
DR701	April 1984	Coastal storms, flooding
DR749	October 1985	Hurricane Gloria
DR936	March 1992	Coastal storm
DR973	December 1992	Coastal storm
EM3106	March 1993	Severe blizzard
DR1088	January 1996	Snow, blizzard
EM3148	September 1999	Hurricane Floyd
EM3156	November 2000	Virus threat
EM3169	September 2001	Terrorist attack emergency declaration

FEMA Disaster No.	Disaster Date	Type of Disaster
EM3181	March 2003	Snowstorm
EM3257	September 2005	Hurricane Katrina evacuation
DR1897	April 2, 2010	Severe Storms and Flooding
DR1954	February 4, 2011	Severe Winter Storm and Snowstorm
EM3332	August 2011	Hurricane Irene
DR4086	October – November 2012	Hurricane Sandy
EM3354	October – November 2012	Hurricane Sandy
DR4264	March 14, 2016	Severe Winter Storm and Snowstorm

SOURCE: FEMA, 2020

4.1.2 HAZARD PROFILE

This section includes detailed profiles for each of the hazards identified in the previous section. Each hazard profile includes a general description of the hazard, its location, its extent (magnitude or severity), notable historical occurrences and the probability of future occurrences. Profiles also include specific items noted by members of the Planning Committee as it relates to unique historical or anecdotal hazard information for Monmouth County or a particular municipal jurisdiction.

Table 4.1 – 4 Summary of Identified Hazard Events in Monmouth County lists each significant hazard for Monmouth County and identifies whether or not it has been determined to be a specific hazard of concern for each of the 54 jurisdictions (the County and each of its 53 municipalities) based on best available data and local information provided by the Planning Committee (• = hazard of concern).

Table 4.1 - 4 Summary of Identified Hazard Events in Monmouth County

Jurisdiction	Natural-based Hazards															
	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter											
	Extreme Temps	Extreme Wind	Tornado	Lightning	Hurricane & Tropical Storm	Flood	Nor'easter	Storm Surge	Wave Action	Tsunami	Coastal Erosion	Winter Storm	Dam Failure	Drought	Earthquake	Wildfire
Aberdeen, Township of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Allenhurst, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Allentown, Borough of	•	•	•	•	•	•	•					•	•	•	•	•
Asbury Park, City of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Atlantic Highlands, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Avon-By-The-Sea, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Belmar, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Bradley Beach, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Brielle, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Colts Neck, Township of	•	•	•	•	•	•	•					•	•	•	•	•
Deal, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Eatontown, Borough of	•	•	•	•	•	•	•	•				•		•	•	•
Englishtown, Borough of	•	•	•	•	•	•	•					•	•	•	•	•
Fair Haven, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•

Jurisdiction	Natural-based Hazards															
	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter											
	Extreme Temps	Extreme Wind	Tornado	Lightning	Hurricane & Tropical Storm	Flood	Nor'easter	Storm Surge	Wave Action	Tsunami	Coastal Erosion	Winter Storm	Dam Failure	Drought	Earthquake	Wildfire
Farmingdale, Borough of	•	•	•	•	•	•	•					•		•	•	•
Freehold, Borough of	•	•	•	•	•		•					•		•	•	•
Freehold, Township of	•	•	•	•	•	•	•					•	•	•	•	•
Hazlet, Township of	•	•	•	•	•	•	•	•				•		•	•	•
Highlands, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Holmdel, Township of	•	•	•	•	•	•	•	•				•		•	•	•
Howell, Township of	•	•	•	•	•	•	•	•				•	•	•	•	•
Interlaken, Borough of	•	•	•	•	•	•	•	•				•		•	•	•
Keansburg, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Keyport, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Lake Como, Borough of	•	•	•	•	•	•	•	•				•		•	•	•
Little Silver, Borough of	•	•	•	•	•	•	•	•		•	•	•		•	•	•
Loch Arbour, Village of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Long Branch, City of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Manalapan, Township of	•	•	•	•	•	•	•					•	•	•	•	•
Manasquan, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Marlboro, Township of	•	•	•	•	•	•	•					•		•	•	•
Matawan, Borough of	•	•	•	•	•	•	•	•				•	•	•	•	•
Middletown, Township of	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Millstone, Township of	•	•	•	•	•	•	•					•	•	•	•	•
Monmouth Beach, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Neptune City, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Neptune, Township of	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Ocean, Township of	•	•	•	•	•	•	•	•				•		•	•	•
Oceanport, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Red Bank, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Roosevelt, Borough of	•	•	•	•	•	•	•					•		•	•	•
Rumson, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Sea Bright, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Sea Girt, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Shrewsbury, Borough of	•	•	•	•	•	•	•	•				•		•	•	•
Shrewsbury, Township of	•	•	•	•	•	•	•					•		•	•	•
Spring Lake, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Spring Lake Heights, Borough of	•	•	•	•	•	•	•	•				•		•	•	•
Tinton Falls, Borough of	•	•	•	•	•	•	•	•				•	•	•	•	•
Union Beach, Borough of	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Upper Freehold, Township of	•	•	•	•	•	•	•					•	•	•	•	•
Wall, Township of	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
West Long Branch, Borough of	•	•	•	•	•	•	•	•				•		•	•	•

Human-based Hazards						
Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Aberdeen, Township of	•	•	•	•	•	•
Allenhurst, Borough of	•	•	•	•	•	•
Allentown, Borough of	•	•	•	•	•	•
Asbury Park, City of	•	•	•	•	•	•
Atlantic Highlands, Borough of	•	•	•	•	•	•
Avon-By-The-Sea, Borough of	•	•	•	•	•	•
Belmar, Borough of	•	•	•	•	•	•
Bradley Beach, Borough of	•	•	•	•	•	•
Brielle, Borough of	•	•	•	•	•	•
Colts Neck, Township of	•	•	•	•	•	•
Deal, Borough of	•	•	•	•	•	•
Eatontown, Borough of	•	•	•	•	•	•
Englishtown, Borough of	•	•	•	•	•	•
Fair Haven, Borough of	•	•	•	•	•	•
Farmingdale, Borough of	•	•	•	•	•	•
Freehold, Borough of	•	•	•	•	•	•
Freehold, Township of	•	•	•	•	•	•
Hazlet, Township of	•	•	•	•	•	•
Highlands, Borough of	•	•	•	•	•	•
Holmdel, Township of	•	•	•	•	•	•
Howell, Township of	•	•	•	•	•	•
Interlaken, Borough of	•	•	•	•	•	•
Keansburg, Borough of	•	•	•	•	•	•
Keyport, Borough of	•	•	•	•	•	•
Lake Como, Borough of	•	•	•	•	•	•
Little Silver, Borough of	•	•	•	•	•	•
Loch Arbour, Village of	•	•	•	•	•	•
Long Branch, City of	•	•	•	•	•	•
Manalapan, Township of	•	•	•	•	•	•
Manasquan, Borough of	•	•	•	•	•	•
Marlboro, Township of	•	•	•	•	•	•
Matawan, Borough of	•	•	•	•	•	•
Middletown, Township of	•	•	•	•	•	•
Millstone, Township of	•	•	•	•	•	•
Monmouth Beach, Borough of	•	•	•	•	•	•
Neptune City, Borough of	•	•	•	•	•	•
Neptune, Township of	•	•	•	•	•	•
Ocean, Township of	•	•	•	•	•	•
Oceanport, Borough of	•	•	•	•	•	•
Red Bank, Borough of	•	•	•	•	•	•
Roosevelt, Borough of	•	•	•	•	•	•
Rumson, Borough of	•	•	•	•	•	•
Sea Bright, Borough of	•	•	•	•	•	•
Sea Girt, Borough of	•	•	•	•	•	•
Shrewsbury, Borough of	•	•	•	•	•	•

Human-based Hazards						
Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Shrewsbury, Township of	•	•	•	•	•	•
Spring Lake, Borough of	•	•	•	•	•	•
Spring Lake Hts., Borough of	•	•	•	•	•	•
Tinton Falls, Borough of	•	•	•	•	•	•
Union Beach, Borough of	•	•	•	•	•	•
Upper Freehold, Township of	•	•	•	•	•	•
Wall, Township of	•	•	•	•	•	•
West Long Branch, Borough of	•	•	•	•	•	•

4.1.3 IDENTIFICATION AND CHARACTERIZATION OF ASSETS IN HAZARD AREAS

An inventory of Monmouth County's georeferenced assets (identified assets with specific, identified locations) was created in order to identify and characterize property and persons potentially at risk to the identified hazards. By understanding the type and number of assets that exist and where they are located in relation to known hazard areas, the relative risk and vulnerability for such assets can be assessed. Under this assessment, three categories of assets were created and then further assessed through geographic information systems (GIS) analysis. The three categories of assets include:

- Critical Facilities: Includes emergency operations centers (EOCs), fire stations, police stations and hospitals. Schools that serve as Red Cross shelters are not included in this category but are addressed separately under "other critical facilities." Data for fire stations, police stations and hospitals were provided by Monmouth County; and EOC data was obtained from HAZUS-MH®. HAZUS defines EOCs as municipal government disaster operation and communication centers deemed (for design) to be vital in emergencies; they are dedicated facilities used for emergency operations, separately and distinctly from hospitals, fire stations, police stations, etc. These also include schools (including those used as Red Cross Shelters), childcare facilities and senior care facilities according to data provided by Monmouth County. Additional childcare facilities as well as private schools were obtained from HAZUS-MH and NJGIN. These are non-emergency facilities but still provide critical services and functions for vulnerable sectors of the population.
- Critical Infrastructure and Utilities: Includes airports, ferry ports, potable water treatment facilities, wastewater treatment facilities and municipal public works buildings. Data for ferry ports, airports and municipal public works buildings was provided by Monmouth County, and data for potable water treatment facilities and wastewater treatment facilities was obtained from HAZUS-MH.
- Historic and Cultural Resources: Includes those historic properties and sites that are included in the New Jersey or National Registers of Historic Places, those that have been determined eligible for inclusion through Federal or state processes as administered by the New Jersey Historic Preservation Office, and some locally significant sites.

The remainder of this section provides a more detailed breakdown, by jurisdiction, of georeferenced assets that have been identified for inclusion in the Monmouth County HMP Vulnerability Assessment.

Information on Monmouth County's population can be found in the Section 2.0 Community Profile & Asset Inventory.

Improved Property

There is an estimated $63.5 billion in improved property value throughout Monmouth County. **Table 4.1-5 Improved by Jurisdiction** lists the total number and percentage of improved parcels as well the total assessed value of their improvements by jurisdiction based on data from the 2018 statewide Parcels and MOD-IV Composite available through NJGIN.

Table 4.1 - 5 Improved Property by Jurisdiction

Jurisdiction	Total Number of Parcels	Number of Improved Parcels	Percent of Improved Parcels	Total Assessed Value of Improvements
Aberdeen, Township of	6,810	6,240	92%	$1,074,509,800
Allenhurst, Borough of	343	332	97%	$217,949,000
Allentown, Borough of	691	648	94%	$127,734,200
Asbury Park, City of	4,580	3,894	85%	$1,267,473,400
Atlantic Highlands, Borough of	1,696	1,563	92%	$364,693,600
Avon-By-The-Sea, Borough of	919	902	98%	$266,879,900
Belmar, Borough of	2,635	2,543	97%	$553,347,900
Bradley Beach, Borough of	2,166	2,077	96%	$462,112,100
Brielle, Borough of	1,969	1,893	96%	$669,338,900
Colts Neck, Township of	1,909	1,647	86%	$927,454,500
Deal, Borough of	935	873	93%	$822,100,400
Eatontown, Borough of	3,629	3,375	93%	$1,314,725,700
Englishtown, Borough of	694	661	95%	$158,314,100
Fair Haven, Borough of	2,110	2,059	98%	$785,619,700
Farmingdale, Borough of	421	403	96%	$109,883,900
Freehold, Borough of	3,233	3,116	96%	$771,202,500
Freehold, Township of	12,808	11,823	92%	$4,433,974,800
Hazlet, Township of	6,853	6,579	96%	$1,215,098,000
Highlands, Borough of	2,468	2,250	91%	$342,874,400
Holmdel, Township of	4,631	4,376	94%	$2,104,382,100
Howell, Township of	23,292	17,315	74%	$4,204,216,400
Interlaken, Borough of	428	399	93%	$125,000,500
Keansburg, Borough of	3,353	3,124	93%	$343,826,000
Keyport, Borough of	2,207	2,083	94%	$434,885,600
Lake Como, Borough of	930	893	96%	$140,566,300
Little Silver, Borough of	2,474	2,400	97%	$873,512,700
Loch Arbour, Village of	142	138	97%	$69,262,800
Long Branch, City of	8,299	7,756	93%	$2,478,681,000
Manalapan, Township of	14,384	13,898	97%	$4,619,949,900
Manasquan, Borough of	3,292	3,130	95%	$799,826,975
Marlboro, Township of	14,395	13,602	94%	$4,435,729,800
Matawan, Borough of	2,605	2,422	93%	$517,395,800
Middletown, Township of	23,997	22,709	95%	$5,895,810,731
Millstone, Township of	4,049	3,321	82%	$1,232,191,160
Monmouth Beach, Borough of	1,616	1,467	91%	$501,592,200
Neptune City, Borough of	1,392	1,345	97%	$305,279,900
Neptune, Township of	11,065	10,460	95%	$2,431,214,700
Ocean, Township of	9,625	9,049	94%	$2,684,842,000

Jurisdiction	Total Number of Parcels	Number of Improved Parcels	Percent of Improved Parcels	Total Assessed Value of Improvements
Oceanport, Borough of	1,982	1,852	93%	$562,875,800
Red Bank, Borough of	4,036	3,912	97%	$1,194,733,400
Roosevelt, Borough of	362	329	91%	$50,136,700
Rumson, Borough of	2,429	2,334	96%	$1,600,650,400
Sea Bright, Borough of	1,246	1,053	85%	$235,586,800
Sea Girt, Borough of	1,251	1,200	96%	$732,097,100
Shrewsbury, Borough of	1,496	1,468	98%	$608,635,700
Shrewsbury, Township of	394	393	100%	$30,450,000
Spring Lake, Borough of	1,761	1,679	95%	$1,028,817,800
Spring Lake Heights, Borough of	2,184	2,147	98%	$525,407,200
Tinton Falls, Borough of	6,662	6,278	94%	$1,691,986,800
Union Beach, Borough of	2,440	2,105	86%	$387,844,700
Upper Freehold, Township of	3,050	2,419	79%	$851,779,300
Wall, Township of	9,886	9,344	95%	$3,053,292,400
West Long Branch, Borough of	2,527	2,411	95%	$889,026,200
Monmouth County	230,751	211,689	92%	$63,526,773,666

SOURCE: NJ OFFICE OF INFORMATION TECHNOLOGY, OFFICE OF GIS (NJOGIS)

Emergency Facilities

There are 253 identified emergency facilities in Monmouth County, including 2 Coast Guard stations, 127 fire stations, 60 fire aid headquarters, 15 hospitals, and 47 police stations. **Table 4.1 - 6 Emergency Facilities by Jurisdiction** shows emergency facilities by jurisdiction. Geographic coordinates (latitude and longitude) were used to determine the location of each facility.

Table 4.1 - 6 Emergency Facilities by Jurisdiction

Jurisdiction	Coast Guard	Fire Station	First Aid	Hospital	Police	Jurisdiction Total
Aberdeen Township	0	2	1	0	1	4
Allenhurst Borough	0	1	1	0	1	3
Allentown Borough	0	0	0	0	1	1
Asbury Park City	0	1	1	0	1	3
Atlantic Highlands Borough	0	1	1	0	1	3
Avon-by-the-Sea Borough	1	1	1	0	1	4
Belmar Borough	0	3	1	0	1	5
Bradley Beach Borough	0	3	1	0	1	5
Brielle Borough	0	1	1	0	1	3
Colts Neck Township	0	3	1	0	1	5
Deal Borough	0	1	1	0	1	3
Eatontown Borough	0	1	1	0	1	3
Englishtown Borough	0	1	0	0	1	2
Fair Haven Borough	0	1	1	0	1	3
Farmingdale Borough	0	1	1	0	0	2
Freehold Borough	0	1	1	0	1	3
Freehold Township	0	4	0	1	1	6
Hazlet Township	0	3	1	0	1	5
Highlands Borough	0	1	1	0	1	3
Holmdel Township	0	3	2	1	1	7
Howell Township	0	6	2	0	1	9
Interlaken Borough	0	0	0	0	0	0

Jurisdiction	Coast Guard	Fire Station	First Aid	Hospital	Police	Jurisdiction Total
Keansburg Borough	0	2	1	1	1	5
Keyport Borough	0	5	1	1	1	8
Lake Como Borough	0	0	0	0	0	0
Little Silver Borough	0	1	1	0	1	3
Loch Arbour Village	0	0	0	0	0	0
Long Branch City	0	8	1	5	1	15
Manalapan Township	0	3	1	0	1	5
Manasquan Borough	0	2	1	0	1	4
Marlboro Township	0	4	2	0	1	7
Matawan Borough	0	4	1	0	1	6
Middletown Township	1	14	6	1	1	23
Millstone Township	0	1	1	0	0	2
Monmouth Beach Borough	0	1	1	0	1	3
Neptune City Borough	0	1	1	0	1	3
Neptune Township	0	7	4	1	1	13
Ocean Township	0	3	2	0	1	6
Oceanport Borough	0	2	1	0	1	4
Red Bank Borough	0	5	2	2	1	10
Roosevelt Borough	0	1	1	0	0	2
Rumson Borough	0	2	1	0	1	4
Sea Bright Borough	0	1	1	0	1	3
Sea Girt Borough	0	1	0	0	1	2
Shrewsbury Borough	0	1	1	0	1	3
Shrewsbury Township	0	0	0	0	0	0
Spring Lake Borough	0	2	1	0	1	4
Spring Lake Heights Borough	0	1	0	0	1	2
Tinton Falls Borough	0	4	2	2	1	9
Union Beach Borough	0	4	1	0	1	6
Upper Freehold Township	0	1	1	0	0	2
Wall Township	0	5	3	0	1	9
West Long Branch Borough	0	2	1	0	1	4
Monmouth County	2	127	60	15	47	251

SOURCES: MONMOUTH COUNTY OFFICE OF GIS; NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS

Critical Infrastructure and Utilities

There are 66 identified critical infrastructure and utility elements in Monmouth County. **Table 4.1 -7 Critical Infrastructure and Utilities by Jurisdiction** shows critical infrastructure and utilities by jurisdiction. Geographic coordinates (i.e., latitude and longitude) were used to determine the location of each facility within each jurisdiction.

Table 4.1 - 7 **Critical Infrastructure and Utilities by Jurisdiction**

Jurisdiction	Sea Wall	Rail	Sewer Infrastructure	Wastewater Infrastructure	Water Infrastructure	Pump Station	Utility	Total
Aberdeen Township	1	0	0	0	0	0	0	1
Allenhurst Borough	0	1	0	0	0	0	0	1
Allentown Borough	0	0	0	0	0	0	0	0
Asbury Park City	0	1	0	0	0	0	0	1
Atlantic Highlands Borough	0	0	0	0	5	0	0	5
Avon-by-the-Sea Borough	0	0	0	0	0	0	0	0

Jurisdiction	Sea Wall	Rail	Sewer Infrastructure	Wastewater Infrastructure	Water Infrastructure	Pump Station	Utility	Total
Belmar Borough	0	0	0	0	0	0	0	0
Bradley Beach Borough	0	1	0	0	0	0	0	1
Brielle Borough	0	0	0	0	0	0	0	0
Colts Neck Township	0	0	0	0	0	0	0	0
Deal Borough	0	0	0	0	0	0	0	0
Eatontown Borough	0	0	0	0	0	1	0	1
Englishtown Borough	0	0	0	0	0	0	0	0
Fair Haven Borough	0	0	0	0	0	0	0	0
Farmingdale Borough	0	0	2	0	0	0	2	4
Freehold Borough	0	0	0	0	0	0	0	0
Freehold Township	0	0	0	0	0	0	0	0
Hazlet Township	0	1	0	0	0	0	1	2
Highlands Borough	0	0	0	0	0	0	0	0
Holmdel Township	0	0	0	0	0	0	0	0
Howell Township	0	0	0	0	0	0	0	0
Interlaken Borough	0	0	0	0	0	0	0	0
Keansburg Borough	0	0	0	0	0	0	0	0
Keyport Borough	0	0	2	0	1	0	0	3
Lake Como Borough	0	0	0	0	0	0	0	0
Little Silver Borough	0	1	0	0	0	0	0	1
Loch Arbour Village	0	0	0	0	0	0	0	0
Long Branch City	0	2	0	0	0	0	0	2
Manalapan Township	0	0	0	0	0	0	0	0
Manasquan Borough	0	1	0	0	0	0	0	1
Marlboro Township	0	0	0	0	0	0	0	0
Matawan Borough	0	1	0	0	0	0	0	1
Middletown Township	0	1	0	0	0	0	0	1
Millstone Township	0	0	0	0	0	0	0	0
Monmouth Beach Borough	0	0	0	0	0	0	0	0
Neptune City Borough	0	0	0	0	0	0	0	0
Neptune Township	0	0	0	0	0	1	0	1
Ocean Township	0	0	0	0	0	0	0	0
Oceanport Borough	0	1	0	0	0	0	0	1
Red Bank Borough	0	1	8	0	1	0	0	10
Roosevelt Borough	0	0	0	0	0	0	0	0
Rumson Borough	0	0	0	0	0	0	0	0
Sea Bright Borough	0	0	0	0	0	0	0	0
Sea Girt Borough	1	0	0	0	0	0	0	1
Shrewsbury Borough	0	0	0	0	0	1	0	1
Shrewsbury Township	0	0	0	0	0	0	0	0
Spring Lake Borough	0	1	0	0	0	0	0	1
Spring Lake Heights Borough	0	0	0	0	0	0	0	0
Tinton Falls Borough	0	0	0	0	0	14	0	14
Union Beach Borough	0	0	0	0	0	0	0	0

Jurisdiction	Sea Wall	Rail	Sewer Infrastructure	Wastewater Infrastructure	Water Infrastructure	Pump Station	Utility	Total
Upper Freehold Township	0	0	0	0	0	0	0	0
Wall Township	0	0	0	6	6	0	0	12
West Long Branch Borough	0	0	0	0	0	0	0	0
Monmouth County	2	13	12	6	13	17	3	66

SOURCES: MONMOUTH COUNTY OFFICE OF GIS; NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS

Other Critical Facilities

Excluding critical infrastructure and including emergency facilities, there are 1,113 critical facilities in Monmouth County. These include 262 childcare facilities, 313 educational facilities, and 54 nursing homes, including Assisted Living Facilities. **Table 4.1 - 8 Other Critical Facilities by Jurisdiction** shows select types of facilities by jurisdiction. Geographic coordinates (i.e., latitude and longitude) were used to determine the location of each facility within each jurisdiction.

Table 4.1 - 8 **Other Critical Facilities by Jurisdiction**

Jurisdiction	Child Care	County Building	DPW	Nursing Home	Educational Facility
Aberdeen Township	10	0	1	0	9
Allenhurst Borough	0	0	0	0	0
Allentown Borough	1	0	1	0	3
Asbury Park City	7	1	1	0	12
Atlantic Highlands Borough	1	0	1	0	2
Avon-by-the-Sea Borough	0	0	1	0	1
Belmar Borough	0	0	1	0	3
Bradley Beach Borough	0	0	1	0	2
Brielle Borough	1	0	6	0	1
Colts Neck Township	3	0	1	1	7
Deal Borough	1	0	1	0	1
Eatontown Borough	5	1	1	2	9
Englishtown Borough	1	0	1	1	1
Fair Haven Borough	3	0	1	0	3
Farmingdale Borough	1	0	1	0	1
Freehold Borough	7	30	0	1	6
Freehold Township	15	42	2	5	13
Hazlet Township	11	4	1	1	11
Highlands Borough	1	0	1	0	2
Holmdel Township	6	0	1	4	8
Howell Township	20	16	1	1	23
Interlaken Borough	0	0	1	0	0
Keansburg Borough	4	0	1	2	4
Keyport Borough	3	0	1	0	3
Lake Como Borough	0	0	1	0	1
Little Silver Borough	2	0	1	0	4
Loch Arbour Village	0	0	0	0	0
Long Branch City	8	0	1	1	18
Manalapan Township	17	3	1	2	18
Manasquan Borough	2	0	1	0	4
Marlboro Township	21	4	1	1	18
Matawan Borough	5	0	1	2	1
Middletown Township	35	10	1	4	32

Jurisdiction	Child Care	County Building	DPW	Nursing Home	Educational Facility
Millstone Township	2	0	1	1	5
Monmouth Beach Borough	0	0	1	0	1
Neptune City Borough	1	0	4	1	1
Neptune Township	14	2	1	5	15
Ocean Township	11	2	1	0	12
Oceanport Borough	1	0	1	0	2
Red Bank Borough	8	0	1	3	6
Roosevelt Borough	0	0	1	0	1
Rumson Borough	2	0	1	0	5
Sea Bright Borough	0	0	1	0	0
Sea Girt Borough	1	0	1	0	1
Shrewsbury Borough	3	2	1	2	3
Shrewsbury Township	0	0	1	0	0
Spring Lake Borough	1	0	1	0	2
Spring Lake Heights Borough	3	0	1	0	1
Tinton Falls Borough	7	11	1	5	12
Union Beach Borough	4	0	1	0	1
Upper Freehold Township	2	5	1	0	3
Wall Township	8	11	1	9	15
West Long Branch Borough	3	0	1	0	6
Monmouth County	262	144	60	54	313

SOURCES: MONMOUTH COUNTY OFFICE OF GIS; NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS

Historic and Cultural Resources

Monmouth County, its jurisdictions, and NJDEP have identified 5,505 historic and cultural resources. These properties are listed in **Table 4.1 - 9 Inventory of Historic Properties**. The data does not preclude the existence of other historic properties or sites not within this category or as yet to be identified.

Table 4.1 - 9 **Inventory of Historic Properties**

Jurisdiction	Cultural Resources	Historic Properties	Jurisdiction Total
Aberdeen Township	5	15	20
Allenhurst Borough	7	297	304
Allentown Borough	0	228	228
Asbury Park City	31	14	45
Atlantic Highlands Borough	15	5	20
Avon-by-the-Sea Borough	13	17	30
Belmar Borough	12	3	15
Bradley Beach Borough	11	13	24
Brielle Borough	7	15	22
Colts Neck Township	36	107	143
Deal Borough	6	19	25
Eatontown Borough	6	43	49
Englishtown Borough	6	22	28
Fair Haven Borough	9	20	29
Farmingdale Borough	0	31	31
Freehold Borough	28	107	135
Freehold Township	26	64	90
Hazlet Township	8	4	12
Highlands Borough	12	13	25

Jurisdiction	Cultural Resources	Historic Properties	Jurisdiction Total
Holmdel Township	40	71	111
Howell Township	0	100	100
Interlaken Borough	5	11	16
Keansburg Borough	13	23	36
Keyport Borough	10	222	232
Lake Como Borough	2	0	2
Little Silver Borough	15	26	41
Loch Arbour Village	5	3	8
Long Branch City	21	78	99
Manalapan Township	21	72	93
Manasquan Borough	18	35	53
Marlboro Township	31	146	177
Matawan Borough	13	53	66
Middletown Township	59	0	59
Millstone Township	116	94	210
Monmouth Beach Borough	5	20	25
Neptune City Borough	1	0	1
Neptune Township	25	1811	1836
Ocean Township	15	20	35
Oceanport Borough	6	47	53
Red Bank Borough	31	68	99
Roosevelt Borough	12	246	258
Rumson Borough	18	0	18
Sea Bright Borough	15	10	25
Sea Girt Borough	13	10	23
Shrewsbury Borough	30	61	91
Shrewsbury Township	1	0	1
Spring Lake Borough	22	55	77
Spring Lake Heights Borough	5	11	16
Tinton Falls Borough	21	53	74
Union Beach Borough	9	4	13
Upper Freehold Township	0	144	144
Wall Township	8	91	99
West Long Branch Borough	12	26	38
Monmouth County	856	4,648	5,504

SOURCE: MONMOUTH COUNTY OFFICE OF GIS; NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS

4.1.4 VULNERABILITY OF ASSETS

To analyze vulnerability of specific assets located in Monmouth County, facilities were grouped as follows:

- Airports/Ferry Ports
- Emergency Operations Centers/Fire Stations/Police Stations
- Hospitals
- Public Works Buildings/Wastewater Treatment Facilities
- Schools/Child Care Facilities (including camps)
- Senior Care Facilities

- Historical and Cultural Resources

All assets throughout Monmouth County are exposed to extreme temperatures, extreme winds, hurricanes and tropical storms, lightning, nor'easters, tornadoes, winter storms, drought and earthquakes. For the seven hazards with delineable hazard areas (i.e., flood, wave action, storm surge, coastal erosion, dam failure, and wildfire), tables showing the exposure of Monmouth County's critical facilities by jurisdiction are included in each of the corresponding hazard sub-sections.

Only those jurisdictions which have at least one facility exposed to at least one of the seven delineable hazards are included in the tables. Also, only those facility types which have at least one facility exposed to at least one of the seven hazards are included in the tables. Exposure of these assets was determined through GIS analysis of hazard areas using georeferenced point locations for critical facilities, which were aggregated by facility type.

Three jurisdictions do not have any critical facilities exposed to these hazards, including Borough of Deal, Village of Loch Arbour, and Township of Shrewsbury. The jurisdictions with the highest number of critical facilities determined to be exposed to these hazards include the City of Long Branch (43), Township of Middletown (40), City of Asbury Park (30), Borough of Keansburg (27), and Borough of Highlands (25).

Some hazards have discrete, delineable hazard areas associated with them. In other words, lines can be drawn on a map to show approximate areas that are potentially susceptible to the hazard versus those that are not. Delineable hazards identified in this plan include coastal erosion, dam failure, flooding, storm surge, wave action, and wildfires. Non-delineable hazards could impact any location - their geographic footprint is county-wide. Non-delineable hazards identified in this plan include extreme temperatures, extreme wind, lightning, tornados, drought, earthquakes; and severe storms such as hurricanes, tropical storms, nor'easters, and winter storms.

For the seven hazards with delineable hazard areas, tables showing the exposure of Monmouth County's historical and cultural resources are also included in each of the corresponding hazard sub-sections. Only those historic property locations which intersect with at least one of the seven hazards are included in the tables. Exposure of historic properties was determined through GIS analysis of hazard areas using georeferenced locations for historic properties provided by the New Jersey Historic Preservation Office.

4.1.5 DAMAGE ESTIMATES

Methodology

This multi-jurisdictional vulnerability assessment was conducted with two distinct methodologies, utilizing GIS-based analysis and a statistical risk assessment methodology. Each approach provides estimates for the potential impact of hazards by using a common, systematic framework for evaluation, including historical occurrence information. The results of the multi- jurisdictional vulnerability assessment are provided for each hazard immediately following the Hazard Profiles of each hazard.

A GIS-based analysis was conducted for 10 hazards:

- hurricane and tropical storm;

- nor'easter;
- coastal erosion;
- dam failure;
- flood;
- storm surge;
- wave action;
- earthquake; and
- wildfire.

A statistical risk assessment approach was used to analyze six hazards:

- extreme temperatures;
- extreme wind;
- lightning;
- tornado;
- winter storm; and
- drought.

Below is a brief description of these approaches.

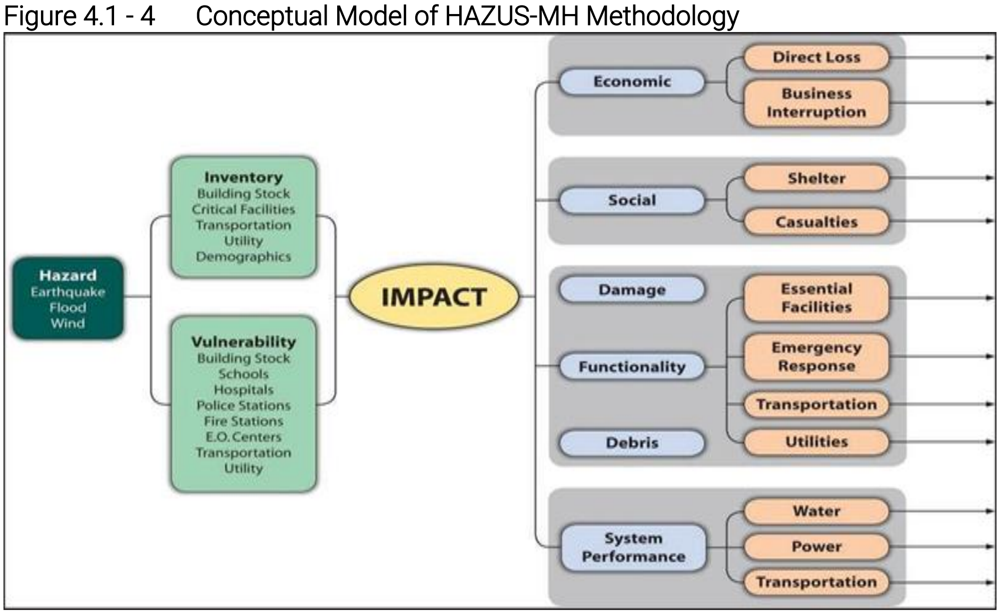
GIS-Based Analysis

For GIS-based assessment, digital data was collected from local, state and national sources. ESRI® ArcGIS™ 10.4 was used to assess risk utilizing digital data including local tax records for individual parcels and georeferenced point locations for buildings and critical facilities. Using these data layers, risk was assessed by estimating the assessed building value for buildings determined to be located in identified hazard areas. For the plan update, population estimates were refined using Census 2010 block level data where the population and value of improved property exposed were estimated to be proportional to the area exposed; and the value of exposed property was refined using updated (2018) improvement values. HAZUS-MH is used to model hurricane winds, riverine flood, storm surge, nor'easter winds and earthquakes, and estimate potential losses for these hazards. HAZUS-MH is FEMA's standardized loss estimation software program built upon an integrated GIS platform (see Figure 4.1 – 4 Conceptual Model of HAZUS-MH Methodology) to conduct analysis at a regional level (i.e., not on a structure-by-structure basis). The objective of the GIS-based analysis was to determine the estimated vulnerability of people, buildings and critical facilities to the identified hazards for Monmouth County using best available geospatial data. In so doing, local databases made available through Monmouth County such as local tax assessor records, parcel boundaries, building footprints and critical facilities data, were used in combination with digital hazard data as included and described in each hazard's Hazard Profile. Where only a portion of a parcel was found to lie within a given hazard area, the ratio of area into area out of the hazard area was applied to the value of improvements on the parcel to estimate the dollars exposed. A similar process was undertaken to estimate population exposed, where the percentage of census block in the hazard area was applied to total census block population to estimate the population exposed to the hazard. The results of the analysis provided an estimated number of people, as well as the numbers and values of buildings and critical facilities determined to be potentially at risk to those hazards with delineable geographic hazard boundaries.

These hazards included the flood, storm surge, wave action, coastal erosion, dam failure and wildfire hazards. A more specific description of the GIS-based analysis for each particular hazard is provided under the vulnerability assessment section of each respective hazard.

The HAZUS-MH risk assessment methodology is parametric, in that distinct hazard and inventory parameters (i.e., wind speed and building types) were modeled using the HAZUS-MH software to determine the impact (i.e., damages and losses) on the built environment. This risk assessment applied HAZUS-MH to produce countywide profiles and estimate losses for five hazards at the jurisdictional level. The 2020 HMP update uses a HAZUS-MH version 4.2, which is run at a Level 2 analysis, with updated census tract data, critical facilities, and depth grids for preliminary and effective FEMA FIRMs for the 1% Annual Chance Flood Event. For the 2015 Plan, the analyses was run using HAZUS-MH 2.1 SP3 (Version 2.1 released in 2012, and Service Pack 3 released in 2014) and the 2009 Plan used the HAZUS Level 1 analyses. A Level 1 analysis yields a rough estimate based on the nationwide database and is a great way to begin the risk assessment process and prioritize high-risk communities." In contrast, the Level 2 analysis type used for this Plan Update produces more accurate loss estimates by including detailed information on local hazard conditions and/or by replacing the national default inventories with more accurate local inventories of buildings, essential facilities and other infrastructure

Figure 4.1 - 4 Conceptual Model of HAZUS-MH Methodology



The results of the HAZUS-MH model analysis include annualized loss estimates for each jurisdiction so that potential loss values may be compared to one another throughout Monmouth County. In generating loss estimates through HAZUS-MH, some data normalization was necessary to account for recognized differences between actual assessed building values as provided by Monmouth County and estimated replacement building value data as provided within HAZUS-MH. In order to account for the difference between modeled and actual values, the ratio of estimated losses produced by HAZUS-MH as compared to total HAZUS-MH building inventory was used to estimate percent damage. The percent damage ratio was then applied to the local assessed values of each jurisdiction to estimate potential losses and loss ratios in Monmouth County for this analysis.

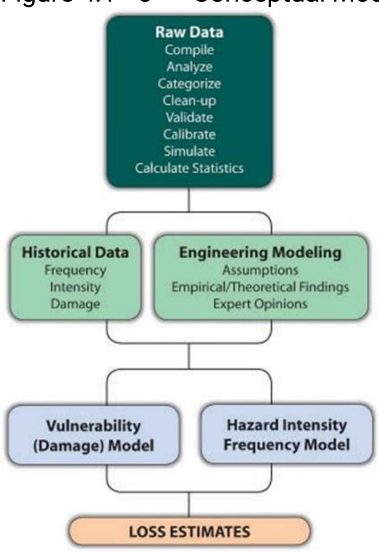
Statistical Risk Assessment Methodology

A statistical risk assessment methodology was applied to analyze hazards of concern that were outside the scope of HAZUS-MH and the GIS-based risk assessment. This methodology uses a statistical approach and mathematical modeling of risk to predict a hazard's frequency of occurrence and estimated impacts based on recorded or historic damage information. This methodology was used to assess risk from extreme temperatures, lightning, tornado, and drought hazards. Historical data for each hazard as described in their Hazard Profiles was used and statistical evaluations were performed using manual calculations. The general steps used in the statistical risk assessment methodology are summarized below:

- Compile data from local, state and national sources, as well as literature;
- Clean up data, including removal of duplicate records and update losses to account for inflation;
- Identify patterns in frequency, intensity, vulnerability andloss
- Statistically and probabilistically extrapolate the patterns[1];and
- Produce meaningful results, including the development of annualized loss estimates.

Figure 4.1-5 Conceptual Model of the Statistical Risk Assessment Methodology illustrates a conceptual model of the statistical risk assessment methodology as applied to Monmouth County.

Figure 4.1 - 5 Conceptual Model of the Statistical Risk Assessment Methodology



Risk is presented in terms of potential annualized losses (monetized economic loss) in dollars whenever possible. In general, presenting results in the annualized form is useful in three ways:

- This approach accounts for the contribution of potential losses from all future disasters;
- Annualized results for different hazards are readily comparable, thus easier to rank; and
- The use of annualized losses is the most objective approach for evaluating mitigation alternatives.

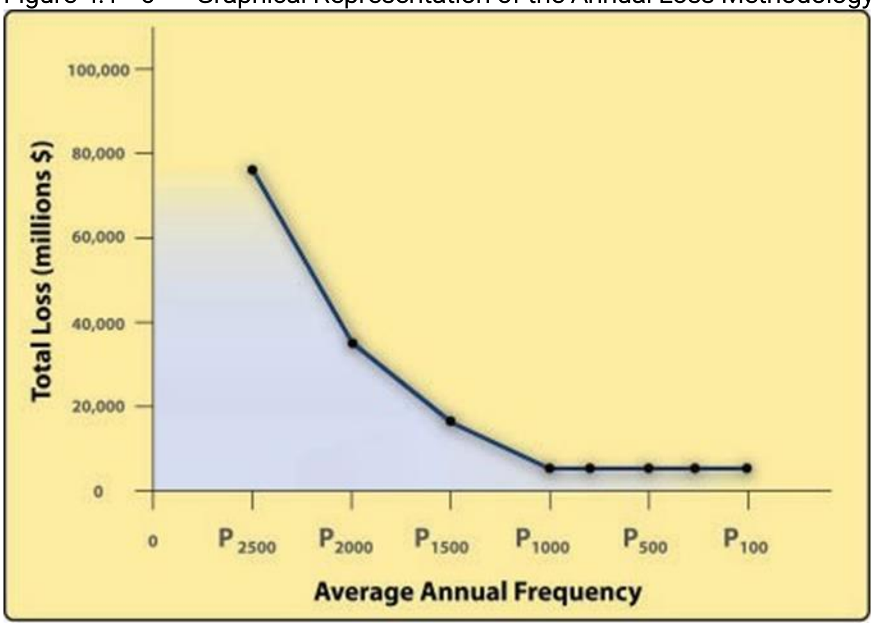
1 In cases where historical events/losses were recorded for the county as a whole, losses were averaged across all jurisdictions in order to estimate losses by jurisdiction and calculate potential annualized losses by jurisdiction.

Annualized losses for the hazards where the parametric approach was utilized were computed in a three- step process:

- Compute/estimate losses for a number of scenario events with different return periods (i.e., 10-year, 100-year, 200-year, 500-year, etc.);
- Approximate the Probability versus Loss Curve through curve fitting; and
- Calculate the area under the fitted curve to obtain annualized losses.

This approach is illustrated graphically in Figure 4.1-6 Graphical Representation of the Annual Loss Methodology. For other hazards where the statistical approach was used, the computations are based primarily on the observed historical losses.

Figure 4.1 - 6 Graphical Representation of the Annual Loss Methodology



The economic loss results are presented here using two interrelated risk indicators: Annualized Loss (AL) and Annualized Loss Ratio (ALR). The Annualized Loss is the estimated long-term weighted average value of losses to property in any single year in a specified geographic area (i.e., municipal jurisdiction). The Annualized Loss Ratio expresses estimated annualized loss normalized by assessed building value. The estimated Annualized Loss addresses the key idea of risk: the probability of the loss occurring in the study area (largely a function of building construction type and quality). By annualizing estimated losses, the AL factors in historic patterns of frequent smaller events with infrequent but larger events to provide a balanced presentation of the risk. The Annualized Loss Ratio represents the AL as a fraction of the assessed value of the local inventory. This ratio is calculated using the following formula:

ALR = Annualized Losses / Total Exposure

The ALR gauges the relationship between average annualized loss and assessed values. This ratio can be used as a measure of vulnerability in the areas and, since it is normalized by assessed value, it can be directly compared across different geographic units such as metropolitan areas, counties, or municipalities.

Loss estimates provided in this vulnerability assessment are based on best available data, and the methodologies applied result in an approximation of risk. These estimates should be used to understand relative risk from hazards and potential losses. Uncertainties are inherent in any loss estimation methodology, arising in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from approximations and simplifications that are necessary for a comprehensive analysis (i.e., incomplete inventories, demographics or economic parameters).

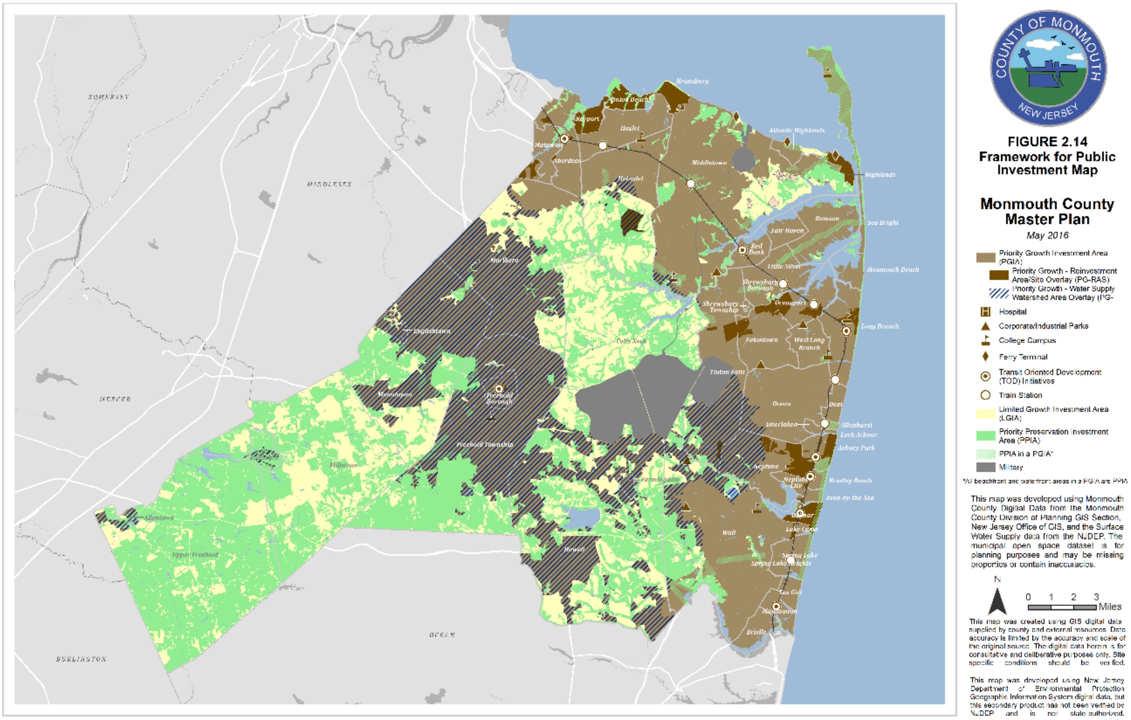
All conclusions are presented in "Conclusions on Hazard Risk" at the end of this chapter. Findings for each hazard are detailed in the hazard-by-hazard vulnerability assessment that follows each Hazard Profile.

4.1.6 HAZARDS POTENTIAL IMPACT ON THE FUTURE

Potential for Future Development in Hazard Areas

While future development patterns are subject to many regulatory and market-driven factors, it is possible to prepare general estimates of the relative potential for future development in those six key delineable hazard areas identified for Monmouth County through GIS analysis using a data layer provided by the New Jersey Office of Information Technology, Office of GIS (NJOGIS). The previous Monmouth HMP Update (2009) used tax parcel records, building footprints, and protected open space provided by the Monmouth County Office of GIS. The previous plan update defined undeveloped parcels as state, county, or municipal-owned open space; preserved farmland; and parcels classified as vacant. The analysis in this Monmouth County HMP update does not include government-owned open space or preserved farmland, as these properties may have legal restrictions against development in perpetuity; this analysis only discussed what would be called “potentially developable parcels” in the last plan update. Further, the last plan update used the New Jersey State Development and Redevelopment Plan to identify areas for Growth, Limited Growth, or Conservation. This methodology has not been carried over into Monmouth County HMP, as the State Plan is now two decades old and previous priorities may no longer apply. However, the County did identify a Framework for Public Investment in the 2016 Monmouth County Master Plan that identified Priority Growth Investment Areas, Priority Growth Reinvestment Area/Site Overlay, Priority Growth-Water Supply Watershed Area Overlays, Limited Growth Areas, and Priority Preservation Investment Area/Sites. Since this is a relatively recent document, these areas should be used as a foundation for potential future development in the county. Also, include a copy of the Framework for Public Investment map as found in the County Master Plan to explain this section.

Figure 4.1 - 7 Monmouth County Master Plan Framework for Public Investment Map



SOURCE: MONMOUTH COUNTY DIVISION OF PLANNING

This Monmouth County HMP analyses uses parcel data and the MOD-IV Composite of New Jersey data layer published by NJOGIS on July 15, 2019, as this is the most recent publicly available data on statewide parcels. There are an estimated 19,062 un-improved parcels in Monmouth County, as determined by the number of parcels with an improvement value of zero in the County; however, this includes almost all property classifications, not only property classified as (Property Class 1). There are 7,136 parcels classified as undeveloped (Property Class 1) in Monmouth County; these parcels all have an improvement value of zero. For this Monmouth County HMP update, “undeveloped land” refers to these 7,136 parcels.

This 2020 plan update analysis also intersect undeveloped parcels with the geographically delineable hazard areas identified for the risk assessment purposes of this plan (coastal erosion, dam failure, flood, storm surge, wave action, and wildfire[2]). Together, Monmouth County's 53 municipalities have approximately 166,612 acres of undeveloped land. After the Vulnerability Assessment for each of the delineable hazards, a Potential for Future Development to Impact Vulnerability section analyzes the likelihood for future development in each of the identified delineable hazard areas. Overall, while new development is expected to result in an increasing number of structures present in Monmouth County, codes and standards in place today will require that they be designed to provide a certain degree of protection from the hazards to which the County and its municipalities are susceptible.

2 Flood hazard areas include the 100-year floodplain; wildfire areas include zones of high or extreme risk; and storm surge areas include Category 1-4 inundation zones.

About 50 percent of undeveloped parcels are located in delineable hazard areas. Undeveloped parcels in delineable hazard areas would be good places to consider designating as open space in perpetuity or rezoned to lower density land or recreational land uses to ensure that people and property do not become exposed in the future. Future losses can be reduced in cases where local communities can work to avoid or minimize development in known hazard areas. In cases where development in hazard areas is unavoidable, future losses can be reduced with the community's stringent enforcement of codes and standards to ensure hazard-resistant construction practices.

Potential for Future Development to Impact Vulnerability for Non-delineable Hazards

In this section, we will address the potential for future development trends to impact vulnerability for non-delineable hazards. Non-delineable hazards identified in this plan include extreme temperatures, extreme wind, lightning, tornados, drought, earthquakes; and severe storms such as hurricanes, tropical storms, nor'easters, and winter storms. Because these hazard areas cover the entirety of Monmouth County and each of its municipalities, future development trends in non-delineable hazard areas would be the same as those observed county-wide.

As more residential and commercial buildings, infrastructure, public facilities and other assets are constructed, potential future hazard vulnerability is likely to increase. In general, more people, buildings, and infrastructure will be exposed to natural hazards over time. If current demographic trends continue, the proportion of the population representing young children, the elderly, and those with other special needs is likely to increase somewhat in the foreseeable future. Monmouth County is cognizant of the risks that it faces due to the impacts of natural hazards. Management of risk in the midst of growth is of paramount importance in each community's overall attainment of sustainability and disaster resiliency. Many municipalities have programs in place today which address certain natural hazards - whether it is a comprehensive or master plan, floodplain management ordinance, or erosion hazard area construction limitations. Together, Monmouth County's municipalities have a total of about 133 square miles of vacant, potentially developable land - about 28 percent of the County's total land area. New development on undeveloped parcels will increase exposure to natural hazards - though many impacts are expected to be reduced or eliminated because they are built to codes and standards which, in many cases, offer a certain degree of protection from future damages. In addition to development of undeveloped parcels, Monmouth County's more densely populated areas (particularly in the Coastal and Bayshore communities that are essentially built-out) are undergoing significant redevelopment. Older buildings (built before current codes and standards were adopted) are being demolished and replaced with new buildings built to current codes and standards. This trend has been observed in Monmouth County in recent years, and it has been exacerbated due to the recovery process from the devastating impacts of Superstorm Sandy. This type of development in hazard areas is actually working to somewhat reduce overall vulnerabilities for those parcels due to the fact that the redeveloped structures are being built to higher codes and standards than the previous structures had been.

In terms of conditions affecting vulnerability, redevelopment would likely offer some reduction in community vulnerability with substantial improvements bringing pre-existing building stock into compliance with current codes and standards, thus offering a certain degree of protection from future events. Greenfield development, on the other hand (that development that occurs on previously undeveloped parcels), is more likely to result in an increase in a community's vulnerability to the hazards because it represents an increase in exposure of people and property. **Table 4.1 - 10 Potential for Future Development to Impact Vulnerability for Non-delineable Hazards** uses relative population trends, potentially developable undeveloped parcels, and local assessments of development trends to assess the potential for a substantial increase in future hazard vulnerability for countywide (non-delineable) hazards.

In the last plan update (2015), each jurisdiction selected certain initiatives for the last plan maintenance phase (2016-2019) to reduce risk for future development. This table can be found in the Plan Maintenance section of this Monmouth County HMP,

Table 4.1 - 10 Potential for Future Development to Impact Vulnerability for Non-delineable Hazards[3]

Jurisdiction	Relative Population Trend[4] (2010-2040)	Number of Undeveloped Parcels	Local Characterization of Development Trends[5]	Potential for a Substantial Increase in Future Hazard Vulnerability Under Existing Conditions
Aberdeen, Township of	Substantial increase	459	Mix of greenfield development, infill and redevelopment	•
Allenhurst, Borough of	Negligible increase	9	Little if any development expected	
Allentown, Borough of	Negligible increase	26	Little if any development expected	
Asbury Park, City of	Substantial increase	370	Mix of greenfield development, infill and redevelopment	•
Atlantic Highlands, Borough of	Moderate increase	196	Mix of greenfield development, infill and redevelopment	•
Avon-by-the-Sea, Borough of	Negligible increase	27	Little if any development expected	
Belmar, Borough of	Low level increase	194	Mix of greenfield development, infill and redevelopment	•
Bradley Beach, Borough of	Moderate increase	94	Mix of greenfield development, infill and redevelopment	•
Brielle, Borough of	Low level increase	105	Mix of greenfield development, infill and redevelopment	•
Colts Neck, Township of	Low level increase	143	Predominantly greenfield development	
Deal, Borough of	Negligible increase	60	Little if any development expected	
Eatontown, Borough of	Substantial increase	230	Mix of greenfield development, infill and redevelopment	•
Englishtown, Borough of	Substantial increase	29	Mix of greenfield development, infill and redevelopment	•
Fair Haven, Borough of	Low level increase	58	Mix of greenfield development, infill and redevelopment	•
Farmingdale, Borough of	Substantial increase	26	Mix of greenfield development, infill and redevelopment	•

3 Non-delineable hazards have hazard areas which cannot be delineated on a map; they can occur anywhere in the County. Non-delineable hazards identified in this plan include extreme temperatures, extreme wind, lightning, tornados, drought, earthquakes; and severe storms such as hurricanes, tropical storms, nor'easters, and winter storms.

4 Relative population trend, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.

5 Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Relative Population Trend[4] (2010-2040)	Number of Undeveloped Parcels	Local Characterization of Development Trends[5]	Potential for a Substantial Increase in Future Hazard Vulnerability Under Existing Conditions
Freehold, Borough of	Substantial increase	74	Mix of greenfield development, infill and redevelopment	
Freehold, Township of	Substantial increase	700	Predominantly greenfield development	•
Hazlet, Township of	Substantial increase	172	Mix of greenfield development, infill and redevelopment	•
Highlands, Borough of	Moderate increase	326	Mix of greenfield development, infill and redevelopment	•
Holmdel, Township of	Substantial increase	236	Predominantly greenfield development	•
Howell, Township of	Moderate increase	2922	Mix of greenfield development, infill and redevelopment	•
Interlaken, Borough of	Negligible increase	17	Little to no development expected	
Keansburg, Borough of	Substantial increase	185	Mix of greenfield development, infill and redevelopment	•
Keyport, Borough of	Substantial increase	139	Mix of greenfield development, infill and	•
Lake Como, Borough of	Negligible increase	37	Little to no development expected	
Little Silver, Borough of	Moderate increase	93	Mix of greenfield development, infill and redevelopment	•
Loch Arbour, Village of	Low level increase	5	Little to no development expected	
Long Branch, City of	Substantial increase	707	Mix of greenfield development, infill and redevelopment	•
Manalapan, Township of	Moderate increase	1619	Predominantly greenfield development	•
Manasquan, Borough of	Moderate increase	147	Mix of greenfield development, infill and redevelopment	•
Marlboro, Township of	Moderate increase	588	Predominantly greenfield development	•
Matawan, Borough of	Substantial increase	179	Mix of greenfield development, infill and redevelopment	•
Middletown, Township of	Moderate increase	1916	Mix of greenfield development, infill and redevelopment	•
Millstone, Township of	Negligible increase	408	Predominantly greenfield development	
Monmouth Beach, Borough of	Negligible increase	120	Mix of greenfield development, infill and redevelopment	
Neptune City, Borough of	Substantial increase	78	Mix of greenfield development, infill and redevelopment	•
Neptune, Township of	Substantial increase	1689	Mix of greenfield development, infill and redevelopment	•
Ocean, Township of	Moderate increase	722	Mix of greenfield development, infill and redevelopment	•
Oceanport, Borough of	Substantial increase	182	Mix of greenfield development, infill and redevelopment	•
Red Bank, Borough of	Substantial increase	259	Mix of greenfield development, infill and redevelopment	•
Roosevelt, Borough of	Negligible increase	10	Little to no development expected	
Rumson, Borough of	Low level increase	87	Mix of greenfield development, infill and redevelopment	•

Jurisdiction	Relative Population Trend[4] (2010-2040)	Number of Undeveloped Parcels	Local Characterization of Development Trends[5]	Potential for a Substantial Increase in Future Hazard Vulnerability Under Existing Conditions
Sea Bright, Borough of	Moderate increase	174	Mix of greenfield development, infill and redevelopment	•
Sea Girt, Borough of	Negligible increase	76	Little to no development expected	
Shrewsbury, Borough of	Substantial increase	41	Mix of greenfield development, infill and redevelopment	•
Shrewsbury, Township of	Substantial increase	1	Little to no development expected	
Spring Lake, Borough of	Negligible increase	66	Mix of development, infill and redevelopment	•
Spring Lake Heights, Borough of	Low level increase	255	Little to no development expected	
Tinton Falls, Borough of	Substantial increase	1843	Predominantly greenfield development	•
Union Beach, Borough of	Low level increase	146	Mix of greenfield development, infill and redevelopment	•
Upper Freehold, Township of	Negligible increase	178	Predominantly greenfield development	•
Wall, Township of	Moderate increase	555	Predominantly greenfield development	•
West Long Branch, Borough of	Substantial increase	145	Mix of greenfield development, infill and redevelopment	•
Monmouth, County of	Moderate increase	19123	Mix of greenfield development, infill and redevelopment	•

Note that new construction must comply with more stringent building codes than those that existed in decades past. Therefore, any substandard housing units replaced by new units through infill or redevelopment would be required to be built to higher codes and standards which in many cases would incorporate various levels of disaster resistance. For an example, replacing a pre-Flood Insurance Rate Map (FIRM) residential structure with a building elevated above the Base Flood Elevation (BFE) could increase community resiliency and decrease vulnerability. However, at the same time, when parcels are redeveloped with higher value and larger structures (i.e. going from a two-bedroom cottage to a four-bedroom house), these factors would contribute to an increase in vulnerability at that same site. For the purposes of this planning level assessment, it has generally been assumed that infill and redevelopment would not typically result in a significant increase in a community's overall vulnerability. This assumption should be re-evaluated by the County Planning Department based on present-day conditions at the time of each future plan update.

4.2 HURRICANE, TROPICAL STORM, FLOOD, AND NOR'EASTER

This section includes the following hazards: hurricane and tropical storm, nor'easter, flood, tsunami, storm surge, wave action, and coastal erosion.

4.2.1 HURRICANE AND TROPICAL STORM: HAZARD DESCRIPTION

Hurricanes and tropical storms are classified as cyclones and defined as any closed circulation developing around a low-pressure center in which the winds rotate counterclockwise in the Northern Hemisphere (or clockwise in the Southern Hemisphere) and with a diameter averaging 10 to 30 miles across. When maximum sustained winds reach or exceed 39 miles per hour, the system is designated a tropical storm, given a name, and is closely monitored by the National Hurricane Center. When sustained winds reach or exceed 74 miles per hour the storm is deemed a hurricane. The primary damaging forces associated with these storms are high-level sustained winds, heavy precipitation and tornadoes. Coastal areas are also vulnerable to the additional forces of storm surge, wind-driven waves and tidal flooding which can be more destructive than cyclone wind. The majority of hurricanes and tropical storms form in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico during the official Atlantic hurricane season, which extends from June through November.

4.2.2 HURRICANE AND TROPICAL STORM: LOCATION

The entire planning area is located within a geographic area that is affected by hurricanes and tropical storms.

4.2.3 HURRICANE AND TROPICAL STORM: EXTENT

As a hurricane develops, barometric pressure (measured in millibars or inches) at its center falls and winds increase. If the atmospheric and oceanic conditions are favorable, it can intensify into a tropical depression. When maximum sustained winds reach or exceed 39 mph, the system is designated a tropical storm, given a name and is closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach 74 mph the storm is deemed a hurricane.

Hurricane intensity is further classified by the Saffir-Simpson Scale (see Table 4.2 - 1 Saffir-Simpson Scale for Hurricanes), which rates hurricane intensity in categories on a scale of 1 to 5 based upon wind, with Category 5 being the most intense. The Saffir-Simpson Scale categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure and storm surge potential, which are combined to estimate potential damage. Categories 3, 4 and 5 are classified as "major" hurricanes, and while hurricanes within this range comprise only 20 percent of total tropical cyclone landfalls, they account for over 70 percent of the damage in the United States.

Table 4.2 - 1 Saffir-Simpson Scale for Hurricanes

Storm Category	Maximum Sustained Wind Speed (mph)	Minimum Surface Pressure (Millibars)	Storm Surge (ft)	Damage Level	Description of Damages
1	74-95	Greater than 980	3-5	MINIMAL	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery and trees. Also, some coastal flooding and minor pier damage.
2	96-110	979-965	6-8	MODERATE	Some roofing material, door and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected moorings might break their moorings.
3	111-129	964-945	9-12	EXTENSIVE	Some structural damage to small residences and utility buildings, with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures, with larger structures damaged by floating debris. Terrain might be flooded well inland.

Storm Category	Maximum Sustained Wind Speed (mph)	Minimum Surface Pressure (Millibars)	Storm Surge (ft)	Damage Level	Description of Damages
4	130-156	944-920	13-18	EXTREME	More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain might be flooded well inland.
5	157 +	Less than 920	19+	CATASTROPHIC	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas might be required.

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

4.2.4 HURRICANE AND TROPICAL STORM: PREVIOUS OCCURRENCES AND LOSSES

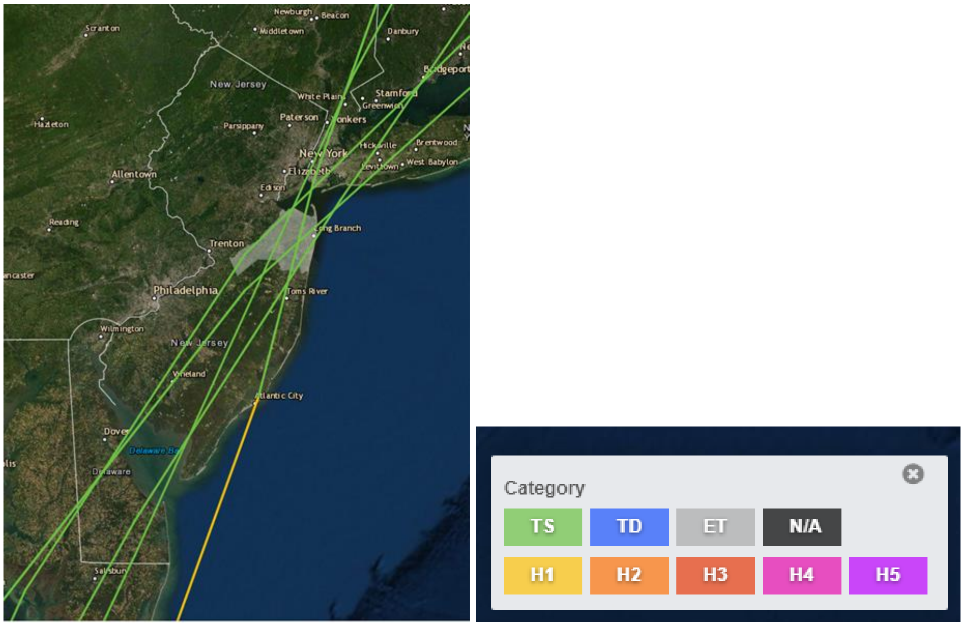
Monmouth County has a history of hurricanes and tropical storms. According to NOAA historical records, five tropical storm tracks traversed directly through Monmouth County since 1850. **Figure 4.2-1 Historical Hurricane and Tropical Storm Tracks, 1851 – 2016** the track of each recorded historical storm track in relation to Monmouth County. As can be seen in the figure, almost all hurricane and tropical storm tracks traverse northward through the area. For each event, **Table 4.2-2 Hurricane and Tropical Storm Tracks Directly over Monmouth County Since 1850** provides the date of occurrence, storm name (if applicable), maximum wind speed and category of the storm based on the Saffir-Simpson Scale.

Notable Storms within 75 miles of Monmouth County are listed in further detail on the next page. Although a hurricane or tropical storm making direct landfall can have a more serious impact, when a hurricane or tropical storm track parallel to the coast impacts can be widespread (Lam, 2016).

Table 4.2 - 2 **Hurricane and Tropical Storm Tracks Directly over Monmouth County Since 1850**

Date	Storm Name	Maximum Wind Speed (mph)	Storm Category
7/30/1960	Brenda	50	Tropical Storm
8/28/1971	Doria	60	Tropical Storm
7/13/1996	Bertha	70	Tropical Storm
9/6/2008	Hanna	45	Tropical Storm
8/28/2011	Irene	65	Tropical Storm

Figure 4.2 - 1 Historical Hurricane and Tropical Storm Tracks, 1851 – 2016



(NOAA, 2019)

September 14-15, 1944 The entire coast of New Jersey was struck by hurricane force winds associated with the Category 2 Hurricane. Wind velocities ranged from 90 miles per hour at Atlantic City to over 100 miles per hour at New York City. The storm produced a maximum tidal elevation of 7.4 feet at a gage in Sandy Hook, located in the Township of Middletown.

September 12, 1960 (Hurricane Donna) Hurricane Donna was a Category 2 storm when it reached Monmouth County with wind speeds up to 110 miles per hour. The concurrence of the hurricane tidal surge and mean high tide resulted in a maximum tidal elevation of 8.6 feet at the gage at Sandy Hook.

August 9, 1976 (Hurricane Belle) Hurricane Belle, a Category 1 storm with wind speeds up to 90 miles per hour. In Asbury Park, 2.56 inches of rain fell in a 24-hour period. At Beach Haven, a tidal surge combined with high tide levels produced a tidal height six feet above normal stage.

zSeptember 27, 1985 (Hurricane Gloria) Hurricane Gloria came ashore in Long Island, New York as a Category 2 storm. The storm knocked out power and forced people to be evacuated from homes along the Jersey Shore, including Monmouth County. Floodwaters on Long Beach Island split the island in half for a period of time. Gloria downed thousands of trees and caused extensive power outages across the state. Storm surge tides averaged two meters above predicted tide levels; however, coastal flooding was minimized as the peak surge arrived during low tide.

July 13, 1996 (Tropical Storm Bertha) A weakening Tropical Storm Bertha passed across eastern parts of the state on July 13th. One storm-related death occurred on the 12th. A 41-year-old man from New Egypt drowned while surfing at Ocean Beach in the Borough of Belmar. Most beaches were already closed due to the rough surf and the potential for rip tides. Otherwise, tidal departures were about two feet or less from normal. Only Monmouth Beach suffered severe beach erosion. Sixty feet of the 120-foot wide beach at the south of the borough was gone. This beach is one of dozens in New Jersey that was being replenished under a U.S. Army Corps of Engineers project. There was little beach erosion elsewhere. While there was urban and poor drainage flooding, no serious property or vehicular damage was reported and there were only a few water rescues of trapped motorists.

July 16, 1999 (Tropical Storm Floyd) Tropical Storm Floyd will go down in history as one of the greatest natural disasters to impact New Jersey before Superstorm Sandy in 2012. Wind gusts rarely exceeded 50 mph, but all the flooding rains made it easier for trees to be knocked over. In Monmouth County, the worst flood-related problems occurred as the torrential rain coincided with the high tide. The worst flooding was reported in Union Beach and bay areas of Middletown, requiring some evacuation. State Routes 35 and 36 were closed due to flooding. Farther inland, Manalapan was hardest hit with overflowing brooks that forced the closure of six roads and sandbagging of homes on Birmingham Road. The strongest winds occurred during the evening and blew down transformers, wires, tree limbs and several trees throughout the county. Coastal areas escaped with minimal damage: just some minor beach erosion and minor back bay flooding at times of high tide. Precipitation storm totals in Monmouth County include 6.4 inches in Hazlet, 5.82 inches in Marlboro, 5.2 inches in Sandy Hook, and 4.57 inches in Keansburg.

September 18-19, 2003 (Tropical Storm Isabel). Isabel produced strong winds and rough surf. In Monmouth County, $100,000 in property damage was recorded by NCDC. Peak wind gusts included 52 mph in Keansburg, and downed trees, tree limbs and power lines. While tide heights along the oceanside only reached minor, wave action caused beach erosion. The heaviest rain with tropical systems often falls west of its storm track, thus the region was spared from the heavier rain with most locations reporting less than 1.5 inches.

September 6, 2008 (Tropical Storm Hanna) Tropical Storm Hanna made landfall on September 6th near the border of North and South Carolina before making a second landfall in New Jersey in eastern Cumberland County. Hanna brought heavy rain and strong winds with storm totals ranging from around 2 to 5 inches and peak wind gusts in Monmouth County of 45 mph in Keansburg and Ocean Grove. The combination of the winds and heavy rain caused some weak trees and tree limbs to be knocked down. About 2,600 homes and businesses lost power in Monmouth and Ocean Counties. All power was restored by the 7th. Minor tidal flooding occurred as the surge averaged around two feet. Many scheduled events were either cancelled or postponed. Strong rip currents on the 7th claimed the life of a 38-year- old man in Spring Lake and led to multiple rescues along Monmouth County beaches including Long Branch, Sea Bright, and Bradley Beach.

August 27-28, 2011 (Tropical Storm Irene) Irene produced torrential downpours that resulted in major flooding and a number of record breaking crests on area rivers, tropical storm force wind gusts with record breaking outages for New Jersey utilities, and a three to five-foot storm surge that caused moderate to severe tidal flooding with extensive beach erosion over the weekend of August 27-28, 2011. Irene was the costliest natural disaster in the history of New Jersey after Tropical Storm Floyd (before Sandy later struck in 2012). In Keansburg, Monmouth Beach and Sea Bright it was mandatory for all residents to evacuate. Evacuations in Asbury Park, Belmar, Bradley Beach, Highlands, Middletown, Manasquan, Spring Lake, Union Beach and Wall Township were limited to flood prone areas. Power outages were widespread. Moderate to severe tidal flooding occurred along the Atlantic Coast and Raritan Bay. Coastal erosion was a major impact. Preliminary damage estimates statewide were near one billion dollars to approximately 200,000 homes and businesses. The combination of wind and flooding forced the closure of about 350 main roadways in the state. Among the major roadways that were closed included U.S. Route 9 and State Routes 33, 35, 36 and 79. In Middletown, a dam broke at the Swimming River Reservoir and flooded the southern part of the township around County Route 50. Elsewhere in the township, a bridge washed out at Hubbard Avenue over the Navesink River. In Allentown, businesses located near Doctors Creek and Conines Millpond were damaged. In Matawan, a thirty-five-foot sinkhole forced the suspension of service along the New Jersey Transit North Jersey Coast Line. The Manasquan River at Squankum had major and record-breaking flooding, cresting at 13.06 feet on the 28th. Event rainfall totals included 8.75 inches in Freewood Acres, 8.57 inches in Howell, 8.07 inches in Red Bank, 6.72 inches in Eatontown and 6.13 inches in Lake Como. FEMA reported that federal disaster assistance statewide topped $275 million through December 12, 2011 with the following approvals:

- 48,904 registrations were approved for assistance;
- Nearly $152 million was approved under the Housing Assistance program for housing repairs;
- Nearly $100 million was approved in U.S. Small Business Administration low-interest loans to 2,585 households and businesses;
- More than $13 million was approved for Other Needs Assistance (i.e., personal property, transportation, medical/dental expenses, etc.);
- More than $10 million in Public Assistance funds for rebuilding public infrastructure; and
- Nearly $100,000 Disaster Unemployment Assistance for those who lost jobs because of the disaster.

October 29, 2012 (Superstorm Sandy). Prior to Sandy's arrival, Governor Christie called for voluntary evacuations of barrier communities on the 26th. A State of Emergency was declared on the 27th and a mandatory evacuation of all barrier island communities was ordered. More than 2,000 National Guard troops were deployed. Tolls along sections of the Garden State Parkway and all of the Westbound Atlantic City Expressway were suspended. On October 28th, President Barack Obama signed a federal emergency declaration for New Jersey. All State Parks and Historic Sites were closed. Late that afternoon, New Jersey Transit began a gradual system-wide shut down.

Sandy made landfall in Atlantic County as a post tropical storm in Brigantine City on the 29th. Approximately 130 miles of the Garden State Parkway was closed from Woodbridge in Middlesex County to its terminus in Cape May County. The New Jersey Turnpike was closed in Central New Jersey. Most schools were closed. The nuclear power plants at Oyster Creek (Ocean County) and Salem (Salem County) suspended operations because of tidal flooding. On the 30th, the day after Sandy's landfall, all 580 school districts in the state were closed. All courts and state offices were closed. Over 200 roadways were closed. Numerous boil water advisories were issued for the northern and coastal parts of the state, some that lasted into November. Governor Christie postponed Halloween in the state until November 5th. On October 31st, Amtrak started limited rail service. State offices were still closed, but some schools reopened. Most major roadways away from the immediate coast including the New Jersey Turnpike were reopened. On November 1st, Governor Christie rescinded evacuation orders for some of the Atlantic County barrier islands. The River Line Transit service between Camden and Trenton resumed. New Jersey Transit bus service resumed as did the Cape May-Lewes Ferry. On November 2nd, the governor lifted the evacuation order for Atlantic City and the casinos opened the next day.

Evacuation orders were also lifted for Cape May County. Limited New Jersey Rail Service resumed. Because of power outages, lines for gas reached 100 cars long in the northern part of the state. The governor declared a limited state of emergency and imposed odd-even rationing for gasoline purchases in twelve northern New Jersey counties because of the shortages. They remained in effect through November 12th. The EPA temporarily suspended some Clean Air Act restrictions. The entire state was also under odd-even water restrictions. On November 3rd about 75 major roadways were still closed. On November 4th, rail service between Philadelphia and Atlantic City resumed. It was estimated that the average New Jersey beach became 30 to 40 feet narrower. It was difficult for people whose homes were uninhabitable to find rental properties.

Sandy was the costliest natural disaster by far in the state of New Jersey. Record breaking high tides and wave action combined with sustained winds as high as 60 to 70 mph with gusts as high as 80 to 90 mph battered the state. Statewide, Sandy caused an estimated $29.4 billion in damage; destroyed or significantly damaged 30,000 homes and businesses; affected 42,000 additional structures and was responsible for 12 deaths. A new temporary inlet formed in Mantoloking (Ocean County) where some homes were swept away. About 2.4 million households in the state lost power. It would take weeks for power to be fully restored.

Hardest hit were the coastal areas of Ocean and Monmouth Counties. Every municipality that bordered Raritan Bay and the Atlantic Ocean suffered widespread damage in Monmouth County and every inland municipality had at least some sporadic damage. Union Beach and Sea Bright were among the hardest hit locations. In Sea Bright, many businesses were totally destroyed, and the fishing pier collapsed. Both Spring Lake and Belmar had miles of their boardwalks destroyed. Some schools were damaged beyond use. Monmouth University was used as an evacuation center. The New Jersey Transit line had to be rebuilt because it was severely damaged. Ferry service between Manhattan and Atlantic Highlands was suspended indefinitely.

Sandy produced record breaking power outages. Statewide, 2.7 million utility customers lost power, by far surpassing the record from Tropical Storm Irene in 2011. Public Service Electric and Gas alone had power lost to 1.4 million of its customers and reported about 48,000 trees had to be removed or trimmed to restore power and over 2,400 poles had to be replaced. Jersey Central Power and Light estimated that nearly 1.0 million of its customers lost power, about ninety percent of its customer base. This included hardest hit areas of Ocean and Monmouth Counties. Monmouth County had the greatest number of sustained outages of any county in the state. The utility had to cut through approximately 45,000 fallen trees. It was unable to restore power to about 30,000 of its shore and barrier island customers because of massive infrastructure damage to those homes and businesses. Elsewhere in the state, power restoration was hampered by a nor'easter that occurred on November 7th. Public Service Electric and Gas restored all power on November 12th and Jersey Central Power and Light by November 14th.

The unique aspect of Sandy and unlike most tropical systems was the multi-tide cycle increase of onshore winds prior to landfall. This caused multiple high tide cycles with tidal flooding and helped produce catastrophic wave action. Record breaking or near record breaking high tides were exacerbated by the high astronomical spring tides associated with the full moon. Sandy's landfall coincided closely with the high tide cycle on the evening of the 29th.

On the ocean side, Raritan Bay, and the lower Delaware Bay experienced minor tidal flooding starting during the high tide cycle on the morning of the 28th with some moderate tidal flooding during the high tide cycle on the evening of the 28th. Widespread major tidal flooding occurred during the morning and evening high tide cycles on the 29th. The highest tide (and surge) along the ocean front and Raritan Bay was with the landfalling high tide cycle on the evening of the 29th.

The ocean front and Raritan Bay surge was 5 to 9 feet. A new all-time record tide was set in Sandy Hook. The tide reached 13.31 feet above mean lower low water before the pier collapsed about 45 minutes before high tide. An after the event survey performed by the USGS and Rutgers University determined that an estimated crest of 14.40 feet above mean lower low water will be used as the new record for Sandy Hook. The entrance to New York Harbor Buoy (a relatively new buoy) had record breaking seas of 32.5 feet. The Delaware Bay Buoy (about 19 miles east of Fenwick Island, Delaware) had seas that reached 24.5 feet.

It was estimated that waves likely reached 12 to 24 feet along the ocean front with the largest waves along Monmouth County. Most of the surveyed damage to barrier island homes that were either destroyed or moved indicated that it was the storm surge and wave action that caused most of the damage. Either minor or no tidal flooding occurred with the subsequent high tide cycles the rest of the month. The highest tide reached a record breaking 13.31 feet above mean lower low water in Sandy Hook before the pier collapsed approximately 45 minutes before the evening high tide on the 29th. The previous record was 10.1 feet above mean lower low water during Hurricane Donna on September 12, 1960 and the December 11, 1992 nor'easter. While there are no established benchmarks for tidal flooding levels at these other stations, the following is a list of the highest tides during Sandy. These may not represent the highest actual tide as there were power outages and some of the graphs plateaued at high crest. The tide gages whose peak crest looks suspect (and may be higher) are marked with an asterisk. At Keansburg* the highest crest was 8.96 feet above mean lower low water, at Sea Bright, the highest crest was 13.79 feet above mean lower low water, at Belmar* the highest crest was 8.70 feet above mean lower low water.

Strong winds associated with Sandy started to spread across the state during the morning of the 29th; most of the peak wind gusts (between 70 mph and 90 mph) occurred during the late afternoon and evening hours as Sandy was making landfall. Most of the strong wind gusts were over by the following morning. The most widespread measured hurricane force wind gusts occurred in northern Ocean County and Monmouth County. Peak wind gusts included 87 mph at Sandy Hook, 79 mph in Sea Girt, Barnegat Light (Ocean County) and High Point (Sussex County), 78 mph in Brick Township (Ocean County), 75 mph in Long Branch, 73 mph in Monmouth Beach, and 61 mph in Wall Township. Maximum sustained winds included 68 mph at Sandy Hook and 61 in Long Branch. Sandy was estimated to have caused $1.75billion in wind-related property damages in Monmouth County alone.

Heavy rain also occurred with Sandy. This made it easier for shallow rooted and leafed trees to be uprooted, as well as complicating tidal flooding. Event rainfall totals averaged 1 to 3 inches in the northern half of the state and 3 to 7 inches in the southern half of the state, except 6 to 12 inches along the southern tier counties of Salem, Cumberland, Cape May, and coastal Atlantic County. The steady rains associated with Sandy occurred from the 28th to the 30th throughout most of the state.

4.2.5 HURRICANE AND TROPICAL STORM: PROBABILITY OF FUTURE OCCURRENCES

The probability of future hurricane and tropical storm events for Monmouth County is high. According to NOAA statistical data, Monmouth County is in an area with an annual probability of a Named Storm between 18 and 24 percent (Figure 4.2 – 2 Empirical Probability of a Named Storm). This empirical probability is consistent with other scientific studies and observed historical data made available through a variety of federal, state and local sources. According to the NOAA data on historical storm tracks, the annual probability of a hurricane or tropical storm coming within 75 miles of Monmouth County is 22 percent. Also, a recent study headed by Colorado State University's Dr. William Gray concluded that the probability of a named storm making landfall in the vicinity of Monmouth County is 13.2 percent.

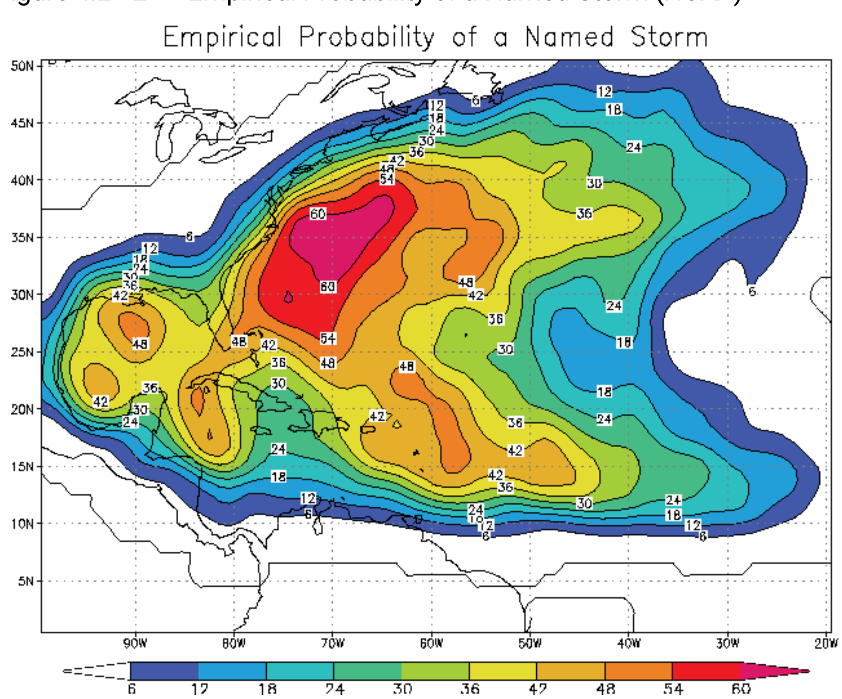
Occurrences are most likely during the official Atlantic hurricane season, which encompasses the months of June through November. The peak of the Atlantic hurricane season is in early to mid-September and the average number of storms that reach hurricane intensity per year in this basin is six. The probability of storm occurrences will vary significantly based on the return interval for different categories of magnitude. The probability of less intense storms (lower return periods) is higher than more intense storms (higher return periods). Table 4.2-3 Peak Gust Wind Speeds Versus Return Period for Monmouth County profiles the potential peak gust wind speeds that can be expected in Monmouth County during a hurricane event for various return periods according to FEMA's HAZUS-MH® loss estimation methodology.

Table 4.2 - 3 Peak Gust Wind Speeds Versus Return Period for Monmouth County, NJ

10-Year	20-Year	50-Year	100-Year	200-Year	500-Year	1,000-Year
44 mph	63 mph	86 mph	102 mph	115 mph	132 mph	143 mph

SOURCE: HAZUS-MH, MR2

Figure 4.2 - 2 Empirical Probability of a Named Storm (NOAA)



4.2.6 HURRICANE AND TROPICAL STORM: POTENTIAL EFFECTS OF CLIMATE CHANGE

The frequency and intensity of coastal storms and severe weather events is expected to increase in the future due to climate change. In the years to come, it is anticipated that Monmouth County will observe drastic changes in storm character, intensity, frequency, and storm tracking. Hurricanes are likely to become more intense with rising sea water temperatures.

The following types of impacts can be anticipated in Monmouth County's future as a result of climate change and sea level rise: inundation of low-lying areas; increased frequency and extent of storm-related flooding; wetland loss; saltwater intrusion into estuaries and freshwater aquifers; land loss through submergence and erosion of lands in coastal areas; migration of coastal landforms and habitats; increased salinity in estuaries and coastal fresh; impacts to human populations (property losses, more frequent flood damage, more frequent flooding of roadways and urban centers, risks to people as the population of coastal areas increases); more buildings and infrastructure exposed; currently exposed buildings and infrastructure could be subject to potentially greater losses as water levels increase, and continued rapid coastal development exacerbates the impacts of sea level rise; impacts on gravity flow stormwater systems; impacts on non-coastal areas.

Impacts of climate change and sea level rise can affect all parts of a community, including: transportation infrastructure (ports, marinas, airports, roads, bridges, railways); public infrastructure (stormwater and wastewater management systems, drinking water supply and distribution systems, power utility systems, communications systems); public facilities (i.e., police, fire, ambulance, hospitals, schools, daycare centers, adult living facilities, historic landmarks, government buildings, libraries, parks, etc.); and economic viability of a community - particularly for communities where tourism tends to drive local economies, as is the case in many of Monmouth County's coastal communities. Climate change and sea level rise could lead to a potential loss of assets that support tourism (i.e., beaches themselves as well as beach access points, lodging, restaurants, marinas, fishing habitats, ecotourism, etc.).

4.2.7 HURRICANE AND TROPICAL STORM: VULNERABILITY ASSESSMENT

Impacts

Coastal areas of Monmouth County are particularly dynamic environments and are quite susceptible to hazards associated with hurricanes and tropical storms. These susceptibilities are expected to increase over time due to the effects of sea level rise. Impacts of hurricanes and tropical storms are associated with damages as a result of flooding (riverine and coastal back bay and oceanfront), as well as storm surge, high winds, damaging waves, and coastal erosion. It is possible for the entire county to be impacted by hurricanes and tropical storms, though in different ways. For example, wind impacts may be widespread but more severe in immediate coastal areas. Structures closest to the Atlantic Coast could suffer catastrophic damages from wind, surge, waves and beach erosion while impacts to inland structures would be less substantial due to lower wind speeds and absence of surge. Riverine flooding would be limited to riverine flood zones and being of slower velocities in most cases would cause less severe types of structure damages. Roads and bridges across the county would be susceptible to overtopping and damage from floodwaters. Beach erosion can often be severe during hurricanes and tropical storms; though beach restoration and maintenance activities are undertaken regularly to offset storm impacts. The Long Branch - Manasquan Project, between Sandy Hook and Manasquan Inlet, is one of the largest beach construction projects completed in the US with over 25 million cubic yards of sand placed on 25 miles of beaches.

Monmouth County is a tourist destination. With summer being the peak vacation time, coincident with hurricane season, the potential population at risk is at its peak during the time of year when Monmouth County is most likely to be impacted by a hurricane or tropical storm. Impacts to the general public include evacuation and sheltering needs, as well as emergency response for those who shelter in place or are injured during the event. All property types are impacted, with residential and commercial impacts being greatest due to their proximity to the coast. Roads, bridges, schools, hospitals and other types of critical facilities are susceptible to wind and water damage. Secondary impacts would be associated with flying debris, as well as drifting sand from storm surges. Sand covered roads and bridges would be common impacts. Beach erosion can be catastrophic depending on the particular area and the nature of the event. Transportation, communications, and governmental services may be severely impacted. Impacts would be exacerbated when coincident with high tides, or during prolonged types of events that extend across several tidal cycles. Sea level rise will increase impacts over time.

Table 4.2 - 4 Hurricane Damage Classifications describes the damage that could be expected for each category of hurricane. Damage during hurricanes might also result from spawned tornadoes, storm surge, and inland flooding associated with heavy rainfall that usually accompanies these storms.

Table 4.2 - 4 Hurricane Damage Classifications

Storm Category	Damage Level	Description of Damages	Photo Example
1	MINIMAL	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery and trees. Also, some coastal flooding and minor pier damage.	
2	MODERATE	Some roofing material, door and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected moorings might break their moorings.	
3	EXTENSIVE	Some structural damage to small residences and utility buildings, with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures, with larger structures damaged by floating debris. Terrain might be flooded well inland.	
4	EXTREME	More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain might be flooded well inland.	

Storm Category	Damage Level	Description of Damages	Photo Example
5	CATASTROPHIC	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas might be required.	

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION; FEDERAL EMERGENCY MANAGEMENT AGENCY

Exposure and Damage Estimates

Hurricanes and tropical storms are complex combinations of discrete component hazards occurring simultaneously. Damages during these events result from the cumulative impacts of a wide range of hazards including flooding, storm surge, coastal erosion, wave action, and high winds. No two hurricanes or tropical storms are identical. Even hurricanes of the same category can bring with them wildly different impacts depending on whether they occur during a time of high tide or low tide. Variations in inland wind affects and precipitation amounts, for example, can vary widely. Thus, it is difficult to estimate total potential losses from these cumulative effects in a manner that would allow for the calculation of a meaningful annual 'hurricane and tropical storm' average annual loss estimate. The current HAZUS-MH hurricane model only analyzes hurricane winds and is not capable of modeling and estimating cumulative losses from all hazards associated with hurricanes; therefore, only hurricane wind losses are reported in this section. This particular Hurricane and Tropical Storm subsection of the plan assesses vulnerability strictly with regard to hurricane winds. Vulnerability to the component hazards of hurricane and tropical storm events such as flooding, storm surge, coastal erosion, wave action, and high winds are addressed separately in this section.

As part of the plan update, a probabilistic scenario was created using HAZUS-MH to assess the vulnerability of Monmouth County to hurricane winds. Default HAZUS-MH wind speed data and damage functions, and methodology were used to determine the potential estimated losses for 50-, 100-, 200-, 500-, and 1000-year frequency events and annual expected loss at the census tract level. According to USGS, the term 50-, 100-, 200-, 500, and 1000-year flood is used to simplify the definition of a flood that statistically has a certain percent chance of occurring in any given year. In any given year, a 50-year flood has a 1 in 50 chance of occurring, a 100-year flood a 1 in 100 chance, a 500-year flood a 1 in 500 chance, and a 1,000-year flood a 1 in 1,000 chance for occurring. Table **4.2-5 Estimated Potential Losses from 50-, 100-, 200-, 500-, and 1000-year Hurricane Wind Events** shows estimated potential losses for 50-, 100-, 200-, 500- and 1000-year hurricane wind event scenarios by jurisdiction. Table 4.2 - 6 Potential Annualized Losses from Hurricane Wind by Jurisdiction shows potential annualized property losses and percent loss ratios resulting from hurricane wind by jurisdiction as estimated using HAZUS. For the plan update, estimates were refined by using a HAZUS Level 2 analysis; population estimates were refined using Census 2010 data; and annualized expected property losses reflect updated (2018) improvement values.

Table 4.2 - 5 Estimated Potential Losses from 50-, 100-, 200-, 500-, and 1000-year Hurricane Wind Events

Jurisdiction	Total Assessed Value of Improvements (2018 values)	Potential Total Losses from Hurricane Wind (2018 Values)				
		50-Year Hurricane Wind Event	100-Year Hurricane Wind Event	200-Year Hurricane Wind Event	500-Year Hurricane Wind Event	1000-Year Hurricane Wind Event
Aberdeen, Township of	$1,074,509,800	$498,399	$1,197,699	$2,075,361	$14,799,514	$46,585,724
Allenhurst, Borough of	$217,949,000	$359,435	$985,305	$3,313,990	$6,276,549	$11,978,111
Allentown, Borough of	$127,734,200	$20,467	$62,237	$20,746	$4,919,619	$4,789,298
Asbury Park, City of	$1,267,473,400	$3,042,549	$10,606,541	$27,017,330	$43,316,809	$67,483,086
Atlantic Highlands, Borough of	$364,693,600	$377,369	$879,374	$1,692,482	$3,892,865	$14,488,107
Avon-By-The-Sea, Borough of	$266,879,900	$926,734	$3,051,724	$9,586,872	$17,845,557	$30,252,555
Belmar, Borough of	$553,347,900	$1,423,360	$4,978,815	$14,592,646	$27,861,807	$44,227,955
Bradley Beach, Borough of	$462,112,100	$1,374,793	$4,701,224	$13,411,556	$22,738,741	$38,195,954
Brielle, Borough of	$669,338,900	$1,607,125	$4,744,240	$12,595,062	$36,538,876	$51,137,835
Colts Neck, Township of	$927,454,500	$1,450,873	$3,302,845	$5,538,792	$39,347,978	$87,008,613
Deal, Borough of	$822,100,400	$1,339,554	$3,585,763	$11,141,516	$21,202,079	$43,321,076
Eatontown, Borough of	$1,314,725,700	$1,376,207	$4,201,969	$8,855,258	$24,923,176	$56,485,673
Englishtown, Borough of	$158,314,100	$24,068	$61,647	$70,783	$2,249,791	$4,554,880
Fair Haven, Borough of	$785,619,700	$1,042,807	$2,459,124	$4,490,847	$11,815,536	$39,712,234
Farmingdale, Borough of	$109,883,900	$103,102	$287,001	$587,174	$3,423,364	$5,341,870
Freehold, Borough of	$771,202,500	$349,996	$793,553	$1,037,086	$20,377,817	$37,568,681
Freehold, Township of	$4,433,974,800	$2,485,118	$5,179,821	$7,835,384	$139,332,200	$259,793,379
Hazlet, Township of	$1,215,098,000	$816,697	$1,896,140	$3,091,083	$16,047,616	$60,687,164
Highlands, Borough of	$342,874,400	$521,476	$1,448,102	$3,062,411	$6,254,536	$21,621,183
Holmdel, Township of	$2,104,382,100	$1,028,747	$2,508,717	$4,802,604	$26,004,822	$86,033,949
Howell, Township of	$4,204,216,400	$4,974,651	$11,909,017	$19,090,277	$165,427,849	$257,311,563
Interlaken, Borough of	$125,000,500	$238,465	$639,792	$1,751,493	$3,381,146	$6,003,101
Keansburg, Borough of	$343,826,000	$321,131	$709,432	$1,471,969	$6,146,236	$23,803,642
Keyport, Borough of	$434,885,600	$239,901	$525,333	$925,858	$6,728,027	$21,955,888
Lake Como, Borough of	$140,566,300	$424,966	$1,332,778	$4,012,413	$8,170,625	$13,006,143
Little Silver, Borough of	$873,512,700	$1,261,354	$3,060,002	$5,437,068	$16,364,105	$48,340,828

Jurisdiction	Total Assessed Value of Improvements (2018 values)	Potential Total Losses from Hurricane Wind (2018 Values)				
		50-Year Hurricane Wind Event	100-Year Hurricane Wind Event	200-Year Hurricane Wind Event	500-Year Hurricane Wind Event	1000-Year Hurricane Wind Event
Loch Arbour, Village of	$69,262,800	$170,605	$492,435	$1,547,419	$2,817,173	$5,196,912
Long Branch, City of	$2,478,681,000	$7,439,333	$24,332,831	$63,307,204	$98,238,891	$223,212,802
Manalapan, Township of	$4,619,949,900	$1,404,921	$3,441,284	$5,147,165	$92,857,548	$201,496,902
Manasquan, Borough of	$799,826,975	$2,239,583	$7,184,399	$20,343,274	$56,791,795	$78,014,173
Marlboro, Township of	$4,435,729,800	$1,977,773	$4,564,717	$7,257,331	$81,276,276	$197,135,172
Matawan, Borough of	$517,395,800	$180,359	$443,720	$816,044	$6,757,783	$18,680,125
Middletown, Township of	$5,895,810,731	$5,629,942	$13,636,598	$24,509,098	$86,927,384	$304,103,799
Millstone, Township of	$1,232,191,160	$236,907	$603,134	$532,232	$34,107,622	$46,521,102
Monmouth Beach, Borough of	$501,592,200	$1,618,079	$5,303,045	$14,965,376	$25,326,120	$69,341,917
Neptune City, Borough of	$305,279,900	$703,910	$2,305,106	$6,203,029	$12,096,050	$20,846,450
Neptune, Township of	$2,431,214,700	$3,629,656	$11,469,383	$30,625,885	$67,840,515	$117,959,365
Ocean, Township of	$2,684,842,000	$4,111,118	$12,108,832	$28,692,007	$72,486,373	$137,188,144
Oceanport, Borough of	$562,875,800	$930,091	$2,553,944	$5,714,048	$14,619,754	$39,352,567
Red Bank, Borough of	$1,194,733,400	$1,416,994	$4,133,138	$7,494,770	$28,129,893	$75,638,891
Roosevelt, Borough of	$50,136,700	$2,193	$7,237	$5,584	$460,689	$620,521
Rumson, Borough of	$1,600,650,400	$3,336,800	$8,120,961	$15,771,157	$33,605,306	$121,805,615
Sea Bright, Borough of	$235,586,800	$1,110,529	$3,054,775	$10,858,360	$21,313,910	$53,246,360
Sea Girt, Borough of	$732,097,100	$1,492,294	$4,561,127	$13,088,986	$36,280,235	$49,963,400
Shrewsbury, Borough of	$608,635,700	$478,613	$1,186,108	$2,256,310	$7,276,514	$21,497,045
Shrewsbury, Township of	$30,450,000	$16,655	$51,779	$104,922	$310,277	$733,215
Spring Lake, Borough of	$1,028,817,800	$3,439,378	$10,593,829	$33,073,319	$74,446,136	$109,226,633
Spring Lake Heights, Borough of	$525,407,200	$1,425,210	$4,505,315	$12,986,902	$27,870,777	$38,232,848
Tinton Falls, Borough of	$1,691,986,800	$2,139,614	$5,888,599	$10,206,677	$39,389,114	$88,553,309
Union Beach, Borough of	$387,844,700	$240,619	$421,618	$718,792	$3,672,714	$18,341,908
Upper Freehold, Township of	$851,779,300	$273,501	$410,370	$362,834	$44,234,144	$52,012,544
Wall, Township of	$3,053,292,400	$5,489,585	$15,780,666	$41,838,522	$128,968,156	$191,543,698

Jurisdiction	Total Assessed Value of Improvements (2018 values)	Potential Total Losses from Hurricane Wind (2018 Values)				
		50-Year Hurricane Wind Event	100-Year Hurricane Wind Event	200-Year Hurricane Wind Event	500-Year Hurricane Wind Event	1000-Year Hurricane Wind Event
West Long Branch, Borough of	$889,026,200	$1,204,868	$3,365,718	$7,415,350	$16,878,323	$42,780,450
Monmouth County	$63,526,773,666	$79,968,475	$225,628,859	$533,350,658	$1,810,366,713	$3,704,934,355

SOURCE: HAZUS-MH

Table 4.2 - 6 Potential Annualized Losses from Hurricane Wind by Jurisdiction

Jurisdiction	Estimated Population At Risk (2017 ACS)	Total Assessed Value of Improvements (2018 Values)	Total Annualized Expected Property Losses - Hurricane Wind (2018 Values)	Annualized Percent Loss Ratio
Sea Bright, Borough of	1,304	$235,586,800	$254,887	0.10%
Monmouth Beach, Borough of	3,247	$501,592,200	$340,758	0.07%
Loch Arbour, Village of	195	$69,262,800	$28,393	0.06%
Bradley Beach, Borough of	4,262	$462,112,100	$210,323	0.05%
Long Branch, City of	30,751	$2,478,681,000	$1,248,692	0.05%
Manasquan, Borough of	5,824	$799,826,975	$369,957	0.05%
Sea Girt, Borough of	1,714	$732,097,100	$246,662	0.05%
Spring Lake, Borough of	2,980	$1,028,817,800	$551,202	0.05%
Asbury Park, City of	15,830	$1,267,473,400	$414,465	0.04%
Avon-By-The-Sea, Borough of	1,814	$266,879,900	$155,267	0.04%
Belmar, Borough of	5,719	$553,347,900	$226,242	0.04%
Brielle, Borough of	4,738	$669,338,900	$237,188	0.04%
Deal, Borough of	579	$822,100,400	$232,869	0.04%
Lake Como, Borough of	1,518	$140,566,300	$66,013	0.04%
Neptune City, Borough of	27,728	$305,279,900	$108,373	0.04%
Neptune, Township of	4,749	$2,431,214,700	$616,407	0.04%
Rumson, Borough of	6,874	$1,600,650,400	$634,056	0.04%
Spring Lake Heights, Borough of	4,645	$525,407,200	$209,379	0.04%
Wall, Township of	26,020	$3,053,292,400	$913,506	0.04%
Atlantic Highlands, Borough of	4,322	$364,693,600	$75,700	0.03%
Fair Haven, Borough of	6,015	$785,619,700	$206,460	0.03%
Highlands, Borough of	4,880	$342,874,400	$110,243	0.03%
Howell, Township of	52,076	$4,204,216,400	$1,072,673	0.03%
Interlaken, Borough of	825	$125,000,500	$35,418	0.03%
Keansburg, Borough of	9,868	$343,826,000	$106,698	0.03%
Little Silver, Borough of	5,917	$873,512,700	$250,551	0.03%
Middletown, Township of	65,952	$5,895,810,731	$1,470,866	0.03%
Ocean, Township of	27,006	$2,684,842,000	$766,949	0.03%
Oceanport, Borough of	5,762	$562,875,800	$197,754	0.03%
Red Bank, Borough of	12,220	$1,194,733,400	$378,281	0.03%
Union Beach, Borough of	5,634	$387,844,700	$74,904	0.03%
West Long Branch, Borough of	7,944	$889,026,200	$223,225	0.03%
Allentown, Borough of	1,890	$127,734,200	$25,866	0.02%
Colts Neck, Township of	10,018	$927,454,500	$408,519	0.02%
Eatontown, Borough of	12,258	$1,314,725,700	$296,481	0.02%
Farmingdale, Borough of	1,470	$109,883,900	$24,781	0.02%
Freehold, Borough of	11,938	$771,202,500	$153,710	0.02%
Freehold, Township of	35,429	$4,433,974,800	$1,000,423	0.02%

Jurisdiction	Estimated Population At Risk (2017 ACS)	Total Assessed Value of Improvements (2018 Values)	Total Annualized Expected Property Losses - Hurricane Wind (2018 Values)	Annualized Percent Loss Ratio
Hazlet, Township of	20,082	$1,215,098,000	$279,141	0.02%
Holmdel, Township of	16,648	$2,104,382,100	$400,754	0.02%
Keyport, Borough of	7,138	$434,885,600	$99,832	0.02%
Manalapan, Township of	40,096	$4,619,949,900	$793,322	0.02%
Marlboro, Township of	40,466	$4,435,729,800	$861,702	0.02%
Matawan, Borough of	8,898	$517,395,800	$92,557	0.02%
Millstone, Township of	10,522	$1,232,191,160	$177,288	0.02%
Shrewsbury, Borough of	4,051	$608,635,700	$104,946	0.02%
Tinton Falls, Borough of	17,902	$1,691,986,800	$445,486	0.02%
Upper Freehold, Township of	6,899	$851,779,300	$185,144	0.02%
Aberdeen, Township of	2,997	$1,074,509,800	$22,992	0.01%
Englishtown, Borough of	2,131	$158,314,100	$17,781	0.01%
Roosevelt, Borough of	808	$50,136,700	$2,641	0.01%
Shrewsbury, Township of	1,117	$30,450,000	$3,791	0.01%
Allentown, Borough of	149	$127,734,200	N/A	N/A
Monmouth County	1,236,224	$125,761,088,532	$35,097,594	-

SOURCE: HAZUS-MH

Table 4.2 – 7 Total Number of Critical Facilities, Critical Infrastructure, and Historic & Cultural Resources with Risk of Storm Surge by Storm Category and Jurisdiction shows the number and percentage of critical facilities, critical infrastructure, and historic and cultural resources with risk of storm surge from Category 1, Category 2, Category 3, and Category 4 Hurricanes. Georeferenced critical facility data points were recorded as at risk of storm surge if they intersected with NOAA storm surge inundation zones from the NOAA National Weather Service (NWS) National Hurricane Center Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model. Historic properties and religious institutions were excluded from this analysis.

Table 4.2 - 7 **Total Number of Critical Facilities, Critical Infrastructure, and Historic & Cultural Resources with Risk of Storm Surge by Storm Category and Jurisdiction**

Jurisdiction	Number of Critical Facilities with Risk of Storm Surge				Percentage of Critical Facilities with Risk of Storm Surge			
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 1	Cat 2	Cat 3	Cat 4
Aberdeen Township	1	1	7	7	3%	3%	21%	21%
Allenhurst Borough	3	3	5	11	27%	27%	45%	100%
Allentown, Borough of	0	0	0	0	0%	0%	0%	0%
Asbury Park City	17	17	23	45	30%	30%	41%	80%
Atlantic Highlands Borough	1	4	4	13	4%	15%	15%	48%
Avon-by-the-Sea Borough	11	11	19	19	58%	58%	100%	100%
Belmar Borough	19	24	24	24	79%	100%	100%	100%
Bradley Beach Borough	0	0	20	20	0%	0%	100%	100%
Brielle Borough	9	9	9	9	47%	47%	47%	47%
Colts Neck Township	4	4	4	4	7%	7%	7%	7%
Deal Borough	1	1	2	2	9%	9%	18%	18%
Eatontown Borough	0	0	0	9	0%	0%	0%	32%
Fair Haven Borough	2	2	2	2	11%	11%	11%	11%
Hazlet Township	9	15	18	25	20%	33%	40%	56%
Highlands Borough	4	4	4	4	22%	22%	22%	22%

Jurisdiction	Number of Critical Facilities with Risk of Storm Surge				Percentage of Critical Facilities with Risk of Storm Surge			
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 1	Cat 2	Cat 3	Cat 4
Holmdel Township	0	0	0	2	0%	0%	0%	3%
Interlaken Borough	0	0	5	6	0%	0%	71%	86%
Keansburg Borough	28	29	29	29	97%	100%	100%	100%
Keyport Borough	9	19	19	27	30%	63%	63%	90%
Lake Como Borough	5	6	6	6	71%	86%	86%	86%
Little Silver Borough	2	2	9	22	7%	7%	33%	81%
Loch Arbour Village	3	3	5	5	60%	60%	100%	100%
Long Branch City	0	0	41	51	0%	0%	61%	76%
Manasquan Borough	7	8	23	23	23%	27%	77%	77%
Matawan Borough	0	0	3	6	0%	0%	9%	19%
Middletown Township	39	52	55	58	24%	32%	33%	35%
Monmouth Beach Borough	1	2	10	10	10%	20%	100%	100%
Neptune City Borough	0	0	5	5	0%	0%	45%	45%
Neptune Township	3	3	12	33	4%	4%	16%	43%
Ocean Township	0	0	0	6	0%	0%	0%	12%
Oceanport Borough	6	6	6	13	40%	40%	40%	87%
Point Pleasant Beach Borough	2	2	2	2	100%	100%	100%	100%
Red Bank Borough	62	62	62	62	90%	90%	90%	90%
Rumson Borough	9	9	10	14	28%	28%	31%	44%
Sea Bright Borough	17	17	17	17	100%	100%	100%	100%
Sea Girt Borough	0	9	11	11	0%	45%	55%	55%
Shrewsbury Borough	0	0	0	4	0%	0%	0%	9%
Spring Lake Borough	0	22	23	23	0%	71%	74%	74%
Spring Lake Heights Borough	0	0	5	5	0%	0%	42%	42%
Tinton Falls Borough	3	3	3	3	4%	4%	4%	4%
Union Beach Borough	19	21	21	21	90%	100%	100%	100%
Wall Township	5	5	7	7	7%	7%	9%	9%
West Long Branch Borough	0	0	0	1	0%	0%	0%	4%
Monmouth County	301	375	530	666	15%	18%	26%	33%

Jurisdiction	Number of Critical Infrastructure with Risk of Storm Surge				Percentage of Critical Infrastructure with Risk of Storm Surge			
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 1	Cat 2	Cat 3	Cat 4
Aberdeen Township	1	1	7	7	3%	3%	21%	21%
Allenhurst Borough	3	3	5	11	27%	27%	45%	100%
Allentown, Borough of	0	0	0	0	0%	0%	0%	0%
Asbury Park City	17	17	23	45	30%	30%	41%	80%
Atlantic Highlands Borough	1	4	4	13	4%	15%	15%	48%
Avon-by-the-Sea Borough	11	11	19	19	58%	58%	100%	100%
Belmar Borough	19	24	24	24	79%	100%	100%	100%
Bradley Beach Borough	0	0	20	20	0%	0%	100%	100%
Brielle Borough	9	9	9	9	47%	47%	47%	47%
Colts Neck Township	4	4	4	4	7%	7%	7%	7%
Deal Borough	1	1	2	2	9%	9%	18%	18%
Eatontown Borough	0	0	0	9	0%	0%	0%	32%
Fair Haven Borough	2	2	2	2	11%	11%	11%	11%
Hazlet Township	9	15	18	25	20%	33%	40%	56%
Highlands Borough	4	4	4	4	22%	22%	22%	22%

Jurisdiction	Number of Critical Infrastructure with Risk of Storm Surge				Percentage of Critical Infrastructure with Risk of Storm Surge			
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 1	Cat 2	Cat 3	Cat 4
Holmdel Township	0	0	0	2	0%	0%	0%	3%
Interlaken Borough	0	0	5	6	0%	0%	71%	86%
Keansburg Borough	28	29	29	29	97%	100%	100%	100%
Keyport Borough	9	19	19	27	30%	63%	63%	90%
Lake Como Borough	5	6	6	6	71%	86%	86%	86%
Little Silver Borough	2	2	9	22	7%	7%	33%	81%
Loch Arbour Village	3	3	5	5	60%	60%	100%	100%
Long Branch City	0	0	41	51	0%	0%	61%	76%
Manasquan Borough	7	8	23	23	23%	27%	77%	77%
Matawan Borough	0	0	3	6	0%	0%	9%	19%
Middletown Township	39	52	55	58	24%	32%	33%	35%
Monmouth Beach Borough	1	2	10	10	10%	20%	100%	100%
Neptune City Borough	0	0	5	5	0%	0%	45%	45%
Neptune Township	3	3	12	33	4%	4%	16%	43%
Ocean Township	0	0	0	6	0%	0%	0%	12%
Oceanport Borough	6	6	6	13	40%	40%	40%	87%
Point Pleasant Beach Borough	2	2	2	2	100%	100%	100%	100%
Red Bank Borough	62	62	62	62	90%	90%	90%	90%
Rumson Borough	9	9	10	14	28%	28%	31%	44%
Sea Bright Borough	17	17	17	17	100%	100%	100%	100%
Sea Girt Borough	0	9	11	11	0%	45%	55%	55%
Shrewsbury Borough	0	0	0	4	0%	0%	0%	9%
Spring Lake Borough	0	22	23	23	0%	71%	74%	74%
Spring Lake Heights Borough	0	0	5	5	0%	0%	42%	42%
Tinton Falls Borough	3	3	3	3	4%	4%	4%	4%
Union Beach Borough	19	21	21	21	90%	100%	100%	100%
Wall Township	5	5	7	7	7%	7%	9%	9%
West Long Branch Borough	0	0	0	1	0%	0%	0%	4%
Monmouth County	301	375	530	666	15%	18%	26%	33%

Jurisdiction	Number of Historic and Cultural Resources with Risk of Storm Surge				Percentage of Historic and Cultural Resources with Risk of Storm Surge			
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 1	Cat 2	Cat 3	Cat 4
Aberdeen Township	1	1	7	7	3%	3%	21%	21%
Allenhurst Borough	3	3	5	11	27%	27%	45%	100%
Allentown, Borough of	0	0	0	0	0%	0%	0%	0%
Asbury Park City	17	17	23	45	30%	30%	41%	80%
Atlantic Highlands Borough	1	4	4	13	4%	15%	15%	48%
Avon-by-the-Sea Borough	11	11	19	19	58%	58%	100%	100%
Belmar Borough	19	24	24	24	79%	100%	100%	100%
Bradley Beach Borough	0	0	20	20	0%	0%	100%	100%
Brielle Borough	9	9	9	9	47%	47%	47%	47%
Colts Neck Township	4	4	4	4	7%	7%	7%	7%
Deal Borough	1	1	2	2	9%	9%	18%	18%
Eatontown Borough	0	0	0	9	0%	0%	0%	32%
Fair Haven Borough	2	2	2	2	11%	11%	11%	11%
Hazlet Township	9	15	18	25	20%	33%	40%	56%

Jurisdiction	Number of Historic and Cultural Resources with Risk of Storm Surge				Percentage of Historic and Cultural Resources with Risk of Storm Surge			
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 1	Cat 2	Cat 3	Cat 4
Highlands Borough	4	4	4	4	22%	22%	22%	22%
Holmdel Township	0	0	0	2	0%	0%	0%	3%
Interlaken Borough	0	0	5	6	0%	0%	71%	86%
Keansburg Borough	28	29	29	29	97%	100%	100%	100%
Keyport Borough	9	19	19	27	30%	63%	63%	90%
Lake Como Borough	5	6	6	6	71%	86%	86%	86%
Little Silver Borough	2	2	9	22	7%	7%	33%	81%
Loch Arbour Village	3	3	5	5	60%	60%	100%	100%
Long Branch City	0	0	41	51	0%	0%	61%	76%
Manasquan Borough	7	8	23	23	23%	27%	77%	77%
Matawan Borough	0	0	3	6	0%	0%	9%	19%
Middletown Township	39	52	55	58	24%	32%	33%	35%
Monmouth Beach Borough	1	2	10	10	10%	20%	100%	100%
Neptune City Borough	0	0	5	5	0%	0%	45%	45%
Neptune Township	3	3	12	33	4%	4%	16%	43%
Ocean Township	0	0	0	6	0%	0%	0%	12%
Oceanport Borough	6	6	6	13	40%	40%	40%	87%
Point Pleasant Beach Borough	2	2	2	2	100%	100%	100%	100%
Red Bank Borough	62	62	62	62	90%	90%	90%	90%
Rumson Borough	9	9	10	14	28%	28%	31%	44%
Sea Bright Borough	17	17	17	17	100%	100%	100%	100%
Sea Girt Borough	0	9	11	11	0%	45%	55%	55%
Shrewsbury Borough	0	0	0	4	0%	0%	0%	9%
Spring Lake Borough	0	22	23	23	0%	71%	74%	74%
Spring Lake Heights Borough	0	0	5	5	0%	0%	42%	42%
Tinton Falls Borough	3	3	3	3	4%	4%	4%	4%
Union Beach Borough	19	21	21	21	90%	100%	100%	100%
Wall Township	5	5	7	7	7%	7%	9%	9%
West Long Branch Borough	0	0	0	1	0%	0%	0%	4%
Monmouth County	301	375	530	666	15%	18%	26%	33%

SOURCE: NOAA NWS SLOSH MODEL, MONMOUTH COUNTY OFFICE OF GIS, NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS

4.2.8 NOR'EASTER: HAZARD DESCRIPTION

Similar to hurricanes, nor'easters are ocean storms capable of causing substantial damage to coastal areas in the Eastern United States due to their associated strong winds and heavy surf. Nor'easters are named for the winds that blow in from the northeast and drive the storm up the East Coast along the Gulf Stream, a band of warm water that lies off the Atlantic coast. They are caused by the interaction of the jet stream with horizontal temperature gradients and generally occur during the fall and winter months when moisture and cold air are plentiful. Nor'easters are known for dumping heavy amounts of rain and snow, producing hurricane-force winds, and creating high surf that causes severe beach erosion and coastal flooding.

4.2.9 NOR'EASTER: LOCATION

The entire planning area is located within a geographic area that is affected by hurricanes and tropical storms.

4.2.10 NOR'EASTER: EXTENT

While there are a variety of indicators for nor'easter intensity, Table 4.2 - 8 Saffir-Simpson Scale for Hurricanes describes the Dolan-Davis Nor'easter Intensity Scale which is based on coastal storm erosion, degradation and property damage.

Table 4.2 - 8 Dolan-Davis Nor'easter Intensity Scale

Storm Class	Beach Erosion	Dune Erosion	Overwash	Property Damage
1-Weak	Minor Changes	None	No	No
2-Moderate	Modest; Mostly to Lower Beach	Minor	No	Modest
3-Significant	Erosion Extends Across Beach	Can be Significant	No	Loss Of Many Structures at Local Level
4-Severe	Severe Beach Erosion and Recession	Severe Dune Erosion or Destruction	On Low Beaches	Loss Of Structures At Community-Scale
5-Extreme	Extreme Beach Erosion	Dunes Destroyed Over Extensive Areas	Massive In Sheets and Channels	Extensive at Regional Scale; Millions Of Dollars

SOURCE: FEDERAL EMERGENCY MANAGEMENT AGENCY

4.2.11 NOR'EASTER: PREVIOUS OCCURANCES AND LOSSES

Monmouth County has a lengthy history of devastating impacts wrought by nor'easters. This includes damages caused by the effects of extreme wind, heavy rain, snow, wave action, storm surge, coastal flooding and beach erosion (also addressed separately within this section).

One of the state's worst nor'easters occurred on March 6-8, 1962 when gale force winds (sustained of 45 miles per hour and gusts to 70 miles per hour) kept storm surges on shore for five successive high tides during a three-day period with a maximum tidal elevation of 7.8 feet at the Sandy Hook gage. During these tides, waves reached heights of 20 to 30 feet doing tremendous damage to dunes and coastal properties. The erosive effect of the storm reportedly changed the face of the shoreline, eroding some beaches entirely away, while also carving new channels and inlets in Monmouth County. Many inland areas were inundated as well, with hundreds of homes damaged or destroyed.

Other notable nor'easter events include the following:

November 25, 1950. This nor'easter brought gale force winds and more than three inches of rainfall to the entire coastline of Monmouth County. A wind velocity of 70 miles per hour was recorded in the City of Long Branch. The gage at Sandy Hook recorded a maximum tidal elevation of 7.2 feet.

March 1984, October 1991, and January 1992. Nor'easters in March 1984, October 1991, and January 1992 all caused severe beach and dune erosion, widespread damage to oceanfront roads, promenades and boardwalks, as well as extensive flooding to coastal and riverine areas. These storm events coincided with astronomically high tides, which worsened the flooding, erosion and associated damages.

December 1992. The nor'easter of December 1992 was the harshest New Jersey storm since 1962, in terms of both damage and weather conditions. The storm caused extreme coastal flooding and extensive beach erosion. Tide heights ranged from a little over 9 feet above mean low water along the ocean front, to an estimated 10 feet above mean low water on some back bays, which is four to five feet above normal. The storm resulted in destruction of public property including debris-ridden roadways, beach erosion, collapsed public facilities, boardwalks and damage to storm drainage facilities. Private properties were also pummeled by the storm; some of these properties were rendered uninhabitable.

March 12-13, 1993. According to the National Weather Service, this "Storm of the Century" was an extremely intense nor'easter which impacted New Jersey with a wide variety of hazardous weather. It was one of the most powerful storms (tropical or extratropical) on record to hit New Jersey, having a record low minimum central pressure of 961 millibars at almost the same time as it passed over New Jersey. Accumulations ranged from three to six inches on the southeastern sections, six to 14 inches in east central and southwestern sections, 10 to 18 inches in west central and northeastern sections, and 15 to 26 inches in northwestern sections. Winds were sustained at 30 to 45 mph, with gusts to 75 mph (hurricane force) measured in Cape May. Moderate coastal flooding occurred the morning of the 13th as a result of the high winds, tides and pounding surf, with waves of six to eight feet above high tide levels. Tide levels reached seven to 7.5 feet above mean low water in the back bays.

February 4, 1998. The strongest nor'easter of the winter season battered coastal New Jersey. Monmouth County was spared by the eastward movement of the nor'easter off of Cape Hatteras, experiencing moderate to severe beach erosion due to the continuous onshore flow. Two to four feet of beach were lost in most areas. At Sandy Hook, tides measured 3.2 feet above normal and about 80 percent of the new sand placed in a replenishment project was lost as several hundred feet of beach disappeared. Both Bradley Beach and Ocean Grove were hard hit by erosion. The waves washed sand onto Ocean Avenue in Bradley Beach. State Route 36 was flooded in Sea Bright. In Middletown, Raritan Bay tidal flooding closed roads.

February 24, 1998. Another strong nor'easter brought very strong winds and coastal flooding to the New Jersey Shore. But, unlike the previous nor'easter, the worst conditions affected Monmouth County. Tidal departures averaged around three feet above normal. A breach in the sea wall occurred in Allenhurst. Flooding forced the closure of New Jersey State Routes 35 and 36 in Keyport, Ocean Avenue in Sea Bright and the entrance road to Sandy Hook, as well as several roads along the bay side of Sea Bright. Wind gusts reached as strong as 61 mph in Ocean Grove.

October 16, 2002. A strong nor'easter caused tidal flooding along the New Jersey coast and in the back bays, gusty winds and beach erosion. Tides, winds and erosion were worse in Ocean and Monmouth counties than farther south. Two downed trees damaged a home in Wall Township. Peak wind gusts included 49 mph winds in Keansburg and 47 mph winds at Sandy Hook. Streets were knee deep in water in Sea Bright. Water spilled over the docks along the Shark River and also in Manasquan. Several roads were flooded in Manasquan, and the Glimmer Glass Bridge was left in the open position. Tides reached seven feet above mean low water at Sandy Hook and six feet above average tide levels in Sea Bright.

December 5-6, 2003. A nor'easter dropped heavy snow across much of New Jersey. Many municipalities declared snow emergencies to help clear the roads for plowing. A man died in Millstone Township after his vehicle left the westbound lanes of Interstate 195 and struck a tree. Specific snow accumulations included 15 inches in Clarksburg, 12.8 inches in Cream Ridge, and 11.5 inches in Oakhurst.

March 15-17, 2007. Strong to high winds along coastal areas with heavy rain and snowfall and minor tidal flooding occurred as a result of the nor'easter. Precipitation started as rain on the evening of the 15th and changed over quickly to snow. Storm totals averaged 1.5 to 3.0 inches across southeast New Jersey, 2 to 6 inches across much of central New Jersey (including Monmouth County) and 6 to 12 inches across northwestern New Jersey. High winds caused a few scattered power outages. Heavy rains that preceded the snow resulted in minor flooding. Minor tidal flooding occurred with the evening high tide on the 16th including 6.89 feet above mean lower low water at Sandy Hook. Motor vehicle accidents were widespread. Two people were injured after their vehicle struck a pole on State Route 36 in Middletown. In Highlands, on the same route, five people were injured in a three-vehicle accident.

April 15-16, 2007. Statewide damage was estimated at $180 million dollars. NOAA NCDC damage records indicate $1 million dollars of damages in Monmouth County associated with this system. At the time, it was the second worst rainstorm (not related to a hurricane) in the state's history. Widespread minor tidal flooding with pockets of moderate tidal flooding occurred along Delaware Bay, Raritan Bay and the Atlantic Ocean. It also caused beach erosion. The worst reported tidal flooding occurred in Monmouth County where tidal flooding occurred for up to three high tide cycles. The combination of the run-off from the heavy rain and the tides caused many roads to flood including State Roads 35 and 36. Areas affected by tidal and roadway flooding included Aberdeen, Belford, Belmar, Hazlet, Manasquan, Middletown, Port Monmouth, Sea Bright and Union Beach. In an effort to reduce tidal flooding, water was pumped from Lake Como in Belmar. On the beaches themselves, vertical cuts to the beaches averaged 2 to 4 feet but reached as high as 6 feet in Sea Bright, Deal and Asbury Park. Cuts to the dune systems themselves occurred in Deal, Long Branch, Monmouth Beach and Sea Bright. The horizontal dune cut in Sea Bright reached 1500 feet. The highest tides included 8.13 feet above mean lower low water at Sandy Hook (Monmouth County) on the morning of the 16th. Minor tidal flooding starts at 6.7 feet above mean lower low water and moderate tidal flooding starts at 7.7 feet above mean lower low water. The heavy rain also closed roadways inland in Monmouth County in Brielle, Howell, Manasquan and Middletown. In Wall Township, the Allenwood-Lakewood Bridge was closed. Precipitation totals included 3.64 inches in Keansburg, 3.00 inches in Oceanport, 2.45 inches in Sea Girt, 2.38 inches in Manasquan, and 2.32 at Belmar Airport. The combination of the heavy rain, some snow and winds knocked down numerous trees and power lines. Peak wind gusts averaged between 40 and 60 mph.

October 15-19, 2009. A pair of nor'easters caused minor to moderate tidal flooding along the ocean from the evening high tide of the 15th into the morning high tide of the 19th. Heavy surf contributed to and exacerbated erosion along the coast. Several major roadways were flooded and closed. In Monmouth County, roadways were closed in Monmouth Beach, Sea Bright and Manasquan. Peak wind gusts reached around 45 mph from Monmouth County southward. A few trees were knocked down in Monmouth County.

November 12-14, 2009. A powerful nor'easter produced wind gusts to nearly 60 mph, widespread moderate tidal flooding, heavy rain and severe beach erosion along the New Jersey coast. By several measures this was one of the worst nor'easters to affect New Jersey since 1990. The Dolan Davis Nor'easter power ranking for Long Island Buoy 44025 ranked it 4th strongest nor'easter to affect New Jersey since 1990, and the strongest since March of 1994. The Miller Storm Erosion Index and the Kraus and Wise Maximum Wave Run-up Index were both ranked second only to December 1992 nor'easter. The highest winds occurred from the afternoon of the 12th into the afternoon of the 13th. Several thousand people lost power. The heaviest rain fell on the 12th. The highest tides in Monmouth County occurred with the morning high tide on the 14th. Those were the highest tides in central and southern New Jersey since either 1998 or 1996. Tidal departures reached up to four feet. Governor Jon Corzine declared a state of emergency in Atlantic, Burlington, Cape May, Cumberland, Ocean and Monmouth Counties on November 15th. More than $500,000 in damages was reported by NOAA in Monmouth County.

March 7, 2013. An intense nor'easter brought strong to high winds across most of central and southern New Jersey on the 6th into the 7th as well as minor to moderate tidal flooding along Raritan Bay, lower Delaware Bay and on the ocean side. The coastal flooding caused new breaches in Mantoloking, flooded roadways and prompted some voluntary evacuations in Monmouth and Ocean Counties. At least minor tidal flooding persisted into the morning high tide cycle on the 10th. This was the greatest and most persistent tidal flooding to affect the New Jersey coast since Superstorm Sandy. In Monmouth County, voluntary evacuations were requested in Brielle and Manasquan. Along Raritan Bay, New Jersey State Route 35 was closed in Aberdeen. In Union Beach, Florence Avenue and Front Street (near the Flat Creek) were closed. Along the ocean side, New Jersey State Route 36 (Ocean Avenue) was closed from Sea Bright through Highlands. In Sea Bright, flood waters reached homes and in the downtown area, vehicles and buildings were surrounded by flood waters. Flooding also occurred along New Jersey State Route 36 in Long Branch. Other road closures occurred in Manasquan, Monmouth Beach and Sea Girt. Northeast winds intensified on the morning of the 6th and reached their peak during the afternoon and early evening. As winds slowly backed to the north during the evening, wind speeds diminished. In Monmouth County, the chafing by high tension wires (caused by the wind) led to a fire at a condiment factory in Sea Bright. Peak wind gusts included 61 mph in Sea Girt, 57 mph in Belmar, 51 mph in Eatontown, and 49 mph in Cream Ridge. Although there were no injuries and no fatalities, the storm caused $85,000 in property damage.

December 9, 2014. A strong nor'easter caused strong winds as well as minor to moderate tidal flooding in Upper Delaware Bay and around Raritan Bay and moderate tidal flooding in Lower Delaware Bay and Atlantic Coastal New Jersey on the 9th. The nor'easter also caused minor to moderate beach erosion. Peak wind gusts averaged 45 to 55 mph along coastal New Jersey and knocked down weak trees, tree limbs and power lines. Tidal flooding affected all of the coastal counties in New Jersey. In Monmouth County, in Sea Bright, two women were rescued from flooded waters in two separate incidents on Ocean Avenue. They both attempted to drive through flood waters. Flooding was also reported along Raritan Bay. Along the tidal Watson Creek at Manasquan, minor flooding occurred on the 8th and moderate flooding occurred on the 9th. Sea Bright and Belmar experienced at least minor tidal flooding. Peak wind gusts included 49 mph in Sea Girt, 47 mph in Monmouth Beach, and 46 mph in Sandy Hook. There were no injuries or fatalities.

January 23, 2016. A strong nor'easter that produced blizzard conditions along the eastern seaboard caused major to record flooding in parts of New Jersey and Delaware during the morning high tide on Saturday, January 23rd. The Atlantic coast and the Raritan Bay shore experienced flooding during this event. Other waterways that experienced flooding during each of the three high tide cycles beginning the morning of January 23rd include the Shrewsbury River at Sea Bright, the Shark River at Belmar, and the Watson Creek at Manasquan. In Sea Bright, large chunks of snow and ice floated down Ocean Avenue during the evening high tide on the 23rd. Highway 36 was shut down in Sea Bright until the flood waters receded. In Manasquan, which issued a voluntary evacuation order Friday, January 22nd, firefighters with the borough's high-water rescue team spent the evening wading through icy waters to perform welfare checks on flooded residents. In Belmar, residents had power knocked out after a sailboat got tangled in power lines. There were no injuries or fatalities.

Other notable reports of historical nor'easter events include the following, as identified by the Planning Committee:

- The Township of Aberdeen has experienced significant beach erosion caused by past nor'easter events.
- The Borough of Atlantic Highlands suffered more than $4 million in damages from the 1992 nor'easter, not including damages to private boats. Repairs to local infrastructure took two years to complete.
- The Borough of Avon-By-The-Sea reportedly experienced the most severe damage in the past 40 years during the 1992 nor'easter event.
- The Borough of Bradley Beach has been victim to several nor'easters over the years, which have caused extensive destruction and beach erosion.
- The Borough of Deal cites that annual storm events cause flooding of Poplar Brook and beach erosion.
- The Borough of Fair Haven indicated that power outages lasted up to six days during the 1992 event.
- The Borough of Little Silver reported that the 1992 event was devastating and resulted in an 11-foot storm surge for the area.
- The Borough of Manasquan's local records indicate that the 1992 nor'easter brought the highest tide of recent memory, with an approximate tide height of 5 feet above average.
- The Township of Marlboro has had issues with power outages, localized flooding, and significant snowstorms causing lengthy disruptions of service to the community as well as limiting the public's ability to travel and commute.

- The Borough of Matawan has experienced minor flooding and other effects from nor'easters, but no major damages to date.
- The Borough of Neptune City has had numerous nor'easters affect the area, with most of the damage attributed to downed power lines and trees as well as flooding from the Shark River.
- The Township of Neptune had beach erosion during the 1992 nor'easter, and the Ocean Grove area lost portions of the boardwalk and had localized flooding. Evacuations were conducted along the North Island/South Concourse area due to flooding. In the Shark River Hills area, there was localized flooding, road closures, and property damage.

4.2.12 NOR'EASTER: PROBABILITY OF FUTURE OCCURRENCE

Nor'easters will continue to have a high probability of occurrence for Monmouth County, and the probability of future occurrences affecting all of Monmouth County's jurisdictions is certain.

4.2.13 NOR'EASTER: VULNERABILITY ASSESSMENT

Nor'easters are known for dumping heavy amounts of rain and snow, producing hurricane-force winds, and creating high surf that causes severe beach erosion and coastal flooding. There are two main components to a nor'easter: (1) a Gulf Stream low-pressure system (counter-clockwise winds) generated off the southeastern U.S. coast, gathering warm air and moisture from the Atlantic, and pulled up the East Coast by strong northeasterly winds at the leading edge of the storm; and (2) an Arctic high-pressure system (clockwise winds) which meets the low-pressure system with cold, arctic air blowing down from Canada. When the two systems collide, the moisture and cold air produce a mix of precipitation and have the potential for creating dangerously high winds and heavy seas. As the low-pressure system deepens, the intensity of the winds and waves will increase and cause serious damage to coastal areas as the storm moves northeast. Nor'easters can be extremely large (up to 1,000 miles in diameter) and their duration can last for days and multiple tidal cycles, often causing major coastal flooding, erosion and damages that could exceed the impacts of shorter-term hurricane events.

Impacts from nor'easters are primarily associated with high winds, severe beach erosion and flood hazards (riverine and coastal flooding, storm surge). Their impacts are often quite similar to winter storms with significant snow accumulations, creating hazardous driving conditions, business/government office closures, potential for damage from snow accumulations on structures, etc. Nor'easters tend to have the greatest impacts in coastal communities, though all of the county has some exposure and past effects have been widespread. Monmouth County's shore is vital to the local economy but remains highly susceptible to the effects of major coastal storms, including nor'easters.

Similar to hurricanes and tropical storms, nor'easters are capable of producing catastrophic impacts, depending upon the nature of the storm, its intensity, and duration. Possible impacts can include high numbers of deaths/injuries, more than 50 percent of property in the affected area could be damaged or destroyed, and critical facilities could be shut down for 30 days or more. Historical records indicate that 18 nor'easters have impacted Monmouth County since 1993. Recent events have caused significant wind, flood and coastal erosion related damages in Monmouth County. They have also resulted in power outages and hazardous driving conditions.

Coastal areas of Monmouth County are particularly dynamic environments and are quite susceptible to hazards associated with nor'easters. These susceptibilities are expected to increase over time due to the effects of sea level rise. Impacts of nor'easters are associated with damages as a result of flooding (riverine and coastal (back bay and oceanfront) as well as storm surge), high winds, damaging waves, and coastal erosion. It is possible for the entire county to be impacted by nor'easters, though in different ways. For example, wind impacts may be widespread but more severe in immediate coastal areas. Structures close to the Atlantic Coast could suffer catastrophic damages from wind, surge, waves and beach erosion while impacts to inland structures would be less substantial due to lower wind speeds and absence of surge impacts. Riverine flooding would be limited to riverine flood zones and being of slower velocities in most cases would cause less severe types of structure damages than in coastal areas but could be more widespread geographically. Roads and bridges across the county would be susceptible to overtopping and damage from floodwaters. Beach erosion can often be severe during nor'easters; though beach restoration and maintenance activities are undertaken regularly to offset storm impacts. As noted earlier, the Long Branch - Manasquan Project, between Sandy Hook and Manasquan Inlet, is one of the largest beach construction projects completed in the US with over 25 million cubic yards of sand placed on 25 miles of beaches.

Monmouth County is a tourist destination. With summer being the peak vacation time - opposite the time of the typical nor'easter occurrences in winter, tourists are not generally impacted. Impacts to the general public include evacuation and sheltering needs, as well as emergency response for those who shelter in place or are injured during the event. All property types are impacted, with residential and commercial impacts being greatest due to their proximity to the coast. Roads, bridges, schools, hospitals and other types of critical facilities are susceptible to wind and water damage. Secondary impacts would be associated with flying debris, as well as drifting sand from storm surges. Sand covered roads and bridges would be common impacts. Beach erosion can be catastrophic depending on the particular area and the nature of the event. Transportation, communications, and governmental services may be severely impacted. Impacts would be exacerbated when coincident with high tides, or during prolonged types of events that extend across several tidal cycles. Sea level rise will increase impacts over time.

Exposure and Damage Estimates

Because nor'easters often impact large areas and cross jurisdictional boundaries, all existing and future buildings, facilities and populations are considered to be exposed to this hazard and could potentially be impacted. Similar to hurricanes and tropical storms, nor'easters are complex combinations of discrete component hazards occurring simultaneously. Damages during these events result from the cumulative impacts of component hazards such as flooding, storm surge, coastal erosion, wave action, and high winds. No two nor'easters are identical. Even storms of the same magnitude and intensity can bring with them wildly different impacts depending on whether they occur during a time of high tide or low tide; and, since it is not uncommon for nor'easters to stall off of the coast, damages are often affected by the number of tidal cycles during which they occur. Variations in inland wind affects and precipitation amounts can also vary widely. Thus, it is difficult to estimate total potential losses from these cumulative effects in a manner that would allow for the calculation of a meaningful average annual loss estimate for nor'easters. However, because nor'easters are low pressure systems, the impacts from winds found in a strong nor'easter can be modeled using methodology similar to that used for hurricanes.

For this assessment, the HAZUS-MH hurricane model was used. The current HAZUS-MH hurricane model only analyzes wind and is not capable of modeling and estimating cumulative losses from all hazards associated with nor'easters; therefore, only nor'easter wind losses are reported here and this subsection of the plan assesses vulnerability strictly with regard to wind. Vulnerability to the component hazards of a nor'easter are addressed elsewhere in this section. HAZUS-MH was used to model two representative nor'easters which directly impacted Monmouth County in December 1992 and April 2007, and for which data was readily available. These two storms were chosen for analysis because wind speed data was available for georeferenced buoy points and varied in strength, with the 1992 storm identified by locals as one of the most memorable in several decades. Although this modeling does not account for increased duration or precipitation levels which may exceed those found in typical hurricanes, it can help quantify a conservative estimate of potential losses if these storms were to impact Monmouth County today. Due to these limitations and other uncertainties inherent in mathematical simulations such as this one, there remains the possibility that the modeled damage estimates may not closely reflect actual recorded damages in every case. To use the HAZUS-MH hurricane model to analyze nor'easter data, historical wind speed data for each storm for georeferenced buoys within range of Monmouth County was obtained (where available) from the National Data Buoy Center5. To model peak intensity, peak wind gusts measured on December 11, 1992 at 4 p.m. EST were used for the December 1992 storm analysis, and peak wind gusts measured on April 16, 2007 at 2 a.m. EST were used for the April 2007 storm analysis. Using known wind gust data normalized to 10-meter height for at least three georeferenced points (buoy locations), wind gust speeds were interpolated to estimate wind gust speed at the centroid of each census tract, which was imported into HAZUS-MH for analysis and potential loss estimates.

Modeling of the April 2007 nor'easter estimates negligible damage resulting from nor'easter winds. Wind gusts in the county ranged from 23 to 56 mph, which is less than tropical-storm force. Modeling of the December 1992 nor'easter estimates over $36 million in damages countywide as a result of wind gusts ranging from 63 to 79 mph, which is comparable to Category 1 hurricane wind speeds in some areas of the county. Table 4.2-9 Potential Losses from Nor'easter Winds by Jurisdiction shows estimated potential wind losses for a nor'easter similar in strength to the December 1992 storm if it were to occur in the current built environment, by jurisdiction.

Table 4.2 - 9 Potential Losses from Nor'easter Winds by Jurisdiction (December 11, 1992 storm model)

Jurisdiction	Total Value of Improvements (2018 Values)	Modeled Nor'easter Wind Losses 12/11/1992 storm
Aberdeen, Township of	$1,074,509,800	$1,497,918
Allenhurst, Borough of	$217,949,000	$160,906
Allentown, Borough of	$127,734,200	$56,743
Asbury Park, City of	$1,267,473,400	$551,584
Atlantic Highlands, Borough of	$364,693,600	$405,776
Avon-By-The-Sea, Borough of	$266,879,900	$192,871
Belmar, Borough of	$553,347,900	$310,187
Bradley Beach, Borough of	$462,112,100	$227,830
Brielle, Borough of	$669,338,900	$167,364
Colts Neck, Township of	$927,454,500	$2,022,658
Deal, Borough of	$822,100,400	$606,451
Eatontown, Borough of	$1,314,725,700	$1,020,712
Englishtown, Borough of	$158,314,100	$80,376
Fair Haven, Borough of	$785,619,700	$954,556
Farmingdale, Borough of	$109,883,900	$56,167
Freehold, Borough of	$771,202,500	$476,898
Freehold, Township of	$4,433,974,800	$3,326,934
Hazlet, Township of	$1,215,098,000	$1,810,871
Highlands, Borough of	$342,874,400	$574,214
Holmdel, Township of	$2,104,382,100	$2,385,061
Howell, Township of	$4,204,216,400	$1,584,410
Interlaken, Borough of	$125,000,500	$74,885
Keansburg, Borough of	$343,826,000	$624,908
Keyport, Borough of	$434,885,600	$645,507
Lake Como, Borough of	$140,566,300	$68,529
Little Silver, Borough of	$873,512,700	$1,136,814
Loch Arbour, Village of	$69,262,800	$38,390
Long Branch, City of	$2,478,681,000	$2,964,932
Manalapan, Township of	$4,619,949,900	$3,164,397
Manasquan, Borough of	$799,826,975	$184,148
Marlboro, Township of	$4,435,729,800	$3,846,927
Matawan, Borough of	$517,395,800	$647,130
Middletown, Township of	$5,895,810,731	$7,665,185
Millstone, Township of	$1,232,191,160	$570,923
Monmouth Beach, Borough of	$501,592,200	$902,666
Neptune City, Borough of	$305,279,900	$145,535
Neptune, Township of	$2,431,214,700	$931,766
Ocean, Township of	$2,684,842,000	$1,602,620
Oceanport, Borough of	$562,875,800	$647,686
Red Bank, Borough of	$1,194,733,400	$1,472,848
Roosevelt, Borough of	$50,136,700	$20,931
Rumson, Borough of	$1,600,650,400	$2,584,529
Sea Bright, Borough of	$235,586,800	$756,345
Sea Girt, Borough of	$732,097,100	$163,438
Shrewsbury, Borough of	$608,635,700	$511,849
Shrewsbury, Township of	$30,450,000	$43,177
Spring Lake, Borough of	$1,028,817,800	$471,888
Spring Lake Heights, Borough of	$525,407,200	$223,560

Jurisdiction	Total Value of Improvements (2018 Values)	Modeled Nor'easter Wind Losses 12/11/1992 storm
Tinton Falls, Borough of	$1,691,986,800	$1,975,497
Union Beach, Borough of	$387,844,700	$411,028
Upper Freehold, Township of	$851,779,300	$273,281
Wall, Township of	$3,053,292,400	$711,376
West Long Branch, Borough of	$889,026,200	$831,669
Monmouth County	$63,526,773,666	$55,025,149

SOURCE: HAZUS-MH

Nor'easters of the strength and magnitude of the December 1992 storm are not common and do not occur on a frequent basis. In the absence of a frequency level determination for this specific event, for the purposes of this analysis it is assumed using professional judgment that the probability of such a strong nor'easter causing this amount of damage could be 0.2 percent in any given year (i.e., a 500-year event frequency). This probability can be multiplied by the modeled losses from the 1992 storm to conservatively estimate potential annualized losses as shown in Table 4.2-10 Potential Annualized Losses from Nor'easter Winds by Jurisdiction. For the plan update, population estimates were refined using Census 2010 block level data, and annualized expected property losses are based on updated (2018) improvement values.

Table 4.2 - 10 Potential Annualized Losses from Nor'easter Winds by Jurisdiction

Jurisdiction	Estimated Population At Risk (2017 ACS)	Total Value of Improvements (2018 Values)	Annualized Expected Property Losses - Nor'easter Winds (2018 Values)	Annualized Percent Loss Ratio
Sea Bright, Borough of	1,304	$235,586,800	$1,704	0.00064%
Highlands, Borough of	4,880	$342,874,400	$1,293	0.00041%
Monmouth Beach, Borough of	3,247	$501,592,200	$2,033	0.00040%
Rumson, Borough of	6,874	$1,600,650,400	$5,821	0.00037%
Keansburg, Borough of	9,868	$343,826,000	$1,408	0.00036%
Atlantic Highlands, Borough of	4,322	$364,693,600	$914	0.00032%
Fair Haven, Borough of	6,015	$785,619,700	$2,150	0.00032%
Shrewsbury, Township of	1,117	$30,450,000	$97	0.00032%
Union Beach, Borough of	5,634	$387,844,700	$926	0.00032%
Keyport, Borough of	7,138	$434,885,600	$1,454	0.00031%
Middletown, Township of	65,952	$5,895,810,731	$17,264	0.00031%
Hazlet, Township of	20,082	$1,215,098,000	$4,079	0.00030%
Little Silver, Borough of	5,917	$873,512,700	$2,561	0.00030%
Aberdeen, Township of	18,372	$1,074,509,800	$3,374	0.00028%
Matawan, Borough of	8,898	$517,395,800	$1,457	0.00026%
Long Branch, City of	30,751	$2,478,681,000	$6,678	0.00025%
Oceanport, Borough of	5,762	$562,875,800	$1,458	0.00025%
Red Bank, Borough of	12,220	$1,194,733,400	$3,318	0.00025%
Colts Neck, Township of	10,018	$927,454,500	$4,555	0.00024%
Deal, Borough of	579	$822,100,400	$1,366	0.00024%
Holmdel, Township of	16,648	$2,104,382,100	$5,372	0.00023%
Shrewsbury, Borough of	4,051	$608,635,700	$1,153	0.00021%

Jurisdiction	Estimated Population At Risk (2017 ACS)	Total Value of Improvements (2018 Values)	Annualized Expected Property Losses - Nor'easter Winds (2018 Values)	Annualized Percent Loss Ratio
West Long Branch, Borough of	7,944	$889,026,200	$1,873	0.00021%
Allenhurst, Borough of	506	$217,949,000	$363	0.00020%
Loch Arbour, Village of	195	$69,262,800	$87	0.00020%
Tinton Falls, Borough of	17,902	$1,691,986,800	$4,449	0.00020%
Marlboro, Township of	40,466	$4,435,729,800	$8,665	0.00019%
Eatontown, Borough of	12,258	$1,314,725,700	$2,298	0.00018%
Freehold, Township of	35,429	$4,433,974,800	$7,493	0.00017%
Manalapan, Township of	40,096	$4,619,949,900	$7,127	0.00017%
Interlaken, Borough of	825	$125,000,500	$169	0.00016%
Freehold, Borough of	11,938	$771,202,500	$1,074	0.00015%
Ocean, Township of	27,006	$2,684,842,000	$3,609	0.00015%
Asbury Park, City of	15,830	$1,267,473,400	$1,242	0.00013%
Englishtown, Borough of	2,131	$158,314,100	$181	0.00013%
Belmar, Borough of	5,719	$553,347,900	$698	0.00012%
Neptune City, Borough of	27,728	$305,279,900	$328	0.00012%
Neptune, Township of	4,749	$2,431,214,700	$2,099	0.00012%
Avon-By-The-Sea, Borough of	1,814	$266,879,900	$435	0.00011%
Bradley Beach, Borough of	4,262	$462,112,100	$514	0.00011%
Millstone, Township of	10,522	$1,232,191,160	$1,286	0.00011%
Farmingdale, Borough of	1,470	$109,883,900	$126	0.00010%
Howell, Township of	52,076	$4,204,216,400	$3,569	0.00010%
Roosevelt, Borough of	808	$50,136,700	$47	0.00010%
Spring Lake Heights, Borough of	4,645	$525,407,200	$503	0.00010%
Allentown, Borough of	1,890	$127,734,200	$127	0.00009%
Lake Como, Borough of	1,518	$140,566,300	$154	0.00009%
Spring Lake, Borough of	2,980	$1,028,817,800	$1,063	0.00009%
Brielle, Borough of	4,738	$669,338,900	$377	0.00007%
Sea Girt, Borough of	1,714	$732,097,100	$368	0.00007%
Upper Freehold, Township of	6,899	$851,779,300	$616	0.00007%
Wall, Township of	26,020	$3,053,292,400	$1,603	0.00006%
Manasquan, Borough of	5,824	$799,826,975	$414	0.00005%
Monmouth County	627,551	$63,526,773,666	$123,934	0.00020%

4.2.14 FLOOD: HAZARD DESCRIPTION

Flooding is caused by the accumulation of water within a water body which results in the overflow of excess water onto adjacent lands, usually floodplains. The floodplain is the land adjoining the channel of a river, stream, ocean, lake or other watercourse or water body that is susceptible to flooding. Most floods fall into the following three categories: riverine flooding, coastal flooding, or shallow flooding (e.g. sheet flow, ponding and urban drainage).

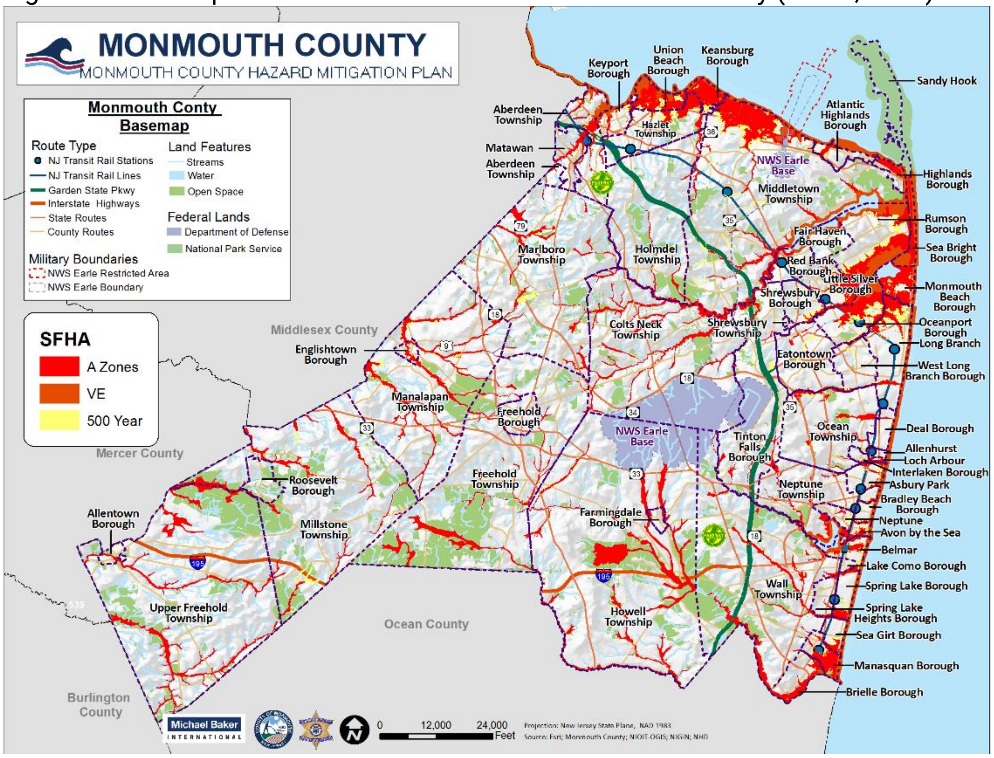
Monmouth County is subject to both riverine and coastal flooding. Riverine flooding occurs along inland channels such as rivers, creeks, and streams. When a channel receives too much water, the excess water flows over its banks and inundates low-lying areas. In addition, when there is debris in the channel, such as fallen trees or trash, the stream cannot fully infiltrate excess stormwater, therefore causing flooding. Coastal flooding, on the other hand, is a result of the storm surge where local sea levels rise to inundate areas along the coasts of oceans, bays, estuaries, coastal rivers, and large lakes. Hurricanes and tropical storms, severe storms, and Nor'easters cause most of the coastal flooding in New Jersey.

There are multiple ways to model future flooding in Monmouth County. For this plan, the Project Team used both National Oceanic Atmospheric Administration's (NOAA) 1-foot and 3-foot of Sea Level Rise (SLR), with a vertical datum of Mean Higher High Water (MHHW), and NJ FRAMES Total Water Level data to project future flooding risk, which are displayed in the Appendix V.I by jurisdiction. The NJ FRAMES data is projected water levels associated with future events, such as the 10-year flood. The projected water levels are calculated by adding the SLR value for specific projections (e.g. Low Emission Central Estimate, High Emission Central Estimate, and High Emission 1-in-20 Chance Estimate) to NOAA's Annual Exceedance Probability (AEP) levels and historic storm tide records using the Sandy Hook, NJ Tide gauge. This analysis resulted in generating water levels between 1 ft. and 14 ft. above current MHHW to assess exposure to the various conditions through 2100. The three levels that NJ FRAMES assessed include 3 feet, 7 feet, and 12 feet above current MHHW. The 3 feet Water Level represents an annual (AEP) flood in 2050 and a permanent inundation (MHHW) under a High Emissions Central Estimate. The 7 feet Water Level represents a 100-year (AEP 1%) flood today, a 10-year (10% AEP) flood under High Emission Scenario in 2100, and an annual (99% AEP) under a low probability, high consequence High Emission Scenario in 2100. The 12 feet Water Level represents a 100-year (1% AEP) flood under low probability high consequence High Emission Scenario in 2100 and Superstorm Sandy under a High Emission Scenario in 2100.

4.2.15 FLOOD: LOCATION

Many areas of Monmouth County are susceptible to riverine and urban (stormwater) flooding, and its coastal jurisdictions are also very susceptible to tidal and coastal flooding due to coastal storm events including storm surge.[7] It is estimated that nearly 10 percent of lands within Monmouth County are located in the 100- year floodplain. Figure 4.2-3 Special Flood Hazard Areas in Monmouth County illustrates the location and extent of currently mapped special flood hazard areas for Monmouth County based on FEMA's Preliminary and Effective Digital Flood Insurance Rate Maps (DFIRMs). This includes Zones A/AE (100-year floodplain), Zone VE (100-year coastal flood zones, associated with wave action) and Zone X500 (500-year floodplain). It is important to note that while FEMA digital flood data is recognized as best available data for planning purposes, it does not always reflect the most accurate and up-to-date flood risk. Flooding and flood-related losses often do occur outside of delineated special flood hazard areas - particularly in areas that were not included in detailed study areas.

Figure 4.2 - 3 Special Flood Hazard Areas in Monmouth County (FEMA, 2019)



SOURCE: FEMA FIRM

Several municipalities in the County, mostly in coastal areas, already benefit from some existing flood protection structures such as floodwalls and beach/dune systems. The FEMA Flood Insurance Study (FIS) notes that small dams are located on Conines Mill Pond and Indian Run in the Borough of Allentown, on Swimming River in the Township of Middletown, on Pine Brook near Tinton Avenue in the Borough of Tinton Falls, and scattered elsewhere throughout the County. Small weirs restrict the passage of tidal surges into inland areas on Whale Pond Brook and Poplar Brook in the Township of Ocean, and small erosion control structures have been placed along the streams in the Township of Holmdel. The Township of Wall has also placed small stone wave protection measures near roads and other critical infrastructure. A bulkhead was constructed along Marine Park in the Borough of Red Bank.

In cases where flood protection structures have been certified by FEMA as providing protection to the "100- year" flood event, their effectiveness in reducing flood risk is implicit in the current flood mapping (Table 4.2-11 Flood Hazard Boundary Statistics by Municipality), since the areas they protect to this level have been removed from the A/AE Zones. However, there is currently no readily available database which identifies these structures, their construction types, dimensions, level of protection, assets protected, and existing maintenance operations. For future updates of this plan, the County should consider as an action item a comprehensive effort to compile such a database, which will aid both the County and individual municipalities in future flood mitigation planning activities.

Table 4.2 - 11 Flood Hazard Boundary Statistics by Municipality

Jurisdiction	Total Municipal Land Area (Acres)	Total Land Area in SFHA (Acres)	Percent Total Land Area in SFHA	Total Land Area in Zone A (Acres)	Percent Total Land Area in Zone A	Total Land Area in Zone VE (Acres)	Percent Total Land Area in Zone VE
Aberdeen, Township of	3,615.25	589.79	16.3%	323.16	8.9%	180.97	5.0%
Allenhurst, Borough of	166.78	14.90	8.9%	4.00	2.4%	6.96	4.2%
Allentown, Borough of	396.12	31.22	7.9%	26.31	6.6%	-	<1.0%
Asbury Park, City of	975.75	197.84	20.3%	86.34	8.8%	53.62	5.5%
Atlantic Highlands, Borough of	791.22	180.61	22.8%	113.53	14.3%	25.71	3.2%
Avon-By-The-Sea, Borough of	318.09	143.59	45.1%	81.56	25.6%	27.11	8.5%
Belmar, Borough of	951.20	315.60	33.2%	157.15	16.5%	67.20	7.1%
Bradley Beach, Borough of	413.35	92.94	22.5%	27.25	6.6%	44.04	10.7%
Brielle, Borough of	1,442.06	174.04	12.1%	149.29	10.4%	4.18	<1.0%
Colts Neck, Township of	20,322.35	980.29	4.8%	912.99	4.5%	-	<1.0%
Deal, Borough of	770.84	54.21	7.0%	16.76	2.2%	33.16	4.3%
Eatontown, Borough of	3,769.62	176.94	4.7%	65.81	1.7%	-	<1.0%
Englishtown, Borough of	378.34	67.29	17.8%	51.94	13.7%	-	<1.0%
Fair Haven, Borough of	1,335.93	36.81	2.8%	14.63	1.1%	15.14	1.1%
Farmingdale, Borough of	336.80	75.34	22.4%	75.34	22.4%	-	<1.0%
Freehold, Borough of	1,235.59	0.07	0.0%	0.07	0.0%	-	<1.0%
Freehold, Township Of	24,881.36	1,258.33	5.1%	1,176.93	4.7%	-	<1.0%
Hazlet, Township of	3,628.55	702.24	19.4%	480.72	13.2%	-	<1.0%
Highlands, Borough of	547.83	191.61	35.0%	173.41	31.7%	13.79	2.5%
Holmdel, Township of	11,561.04	209.87	1.8%	181.93	1.6%	-	<1.0%
Howell, Township of	39,148.96	2,336.43	6.0%	2,197.20	5.6%	-	<1.0%
Interlaken, Borough of	254.60	25.48	10.0%	17.90	7.0%	-	<1.0%
Keansburg, Borough of	776.33	741.82	95.6%	570.03	73.4%	96.59	12.4%

Jurisdiction	Total Municipal Land Area (Acres)	Total Land Area in SFHA (Acres)	Percent Total Land Area in SFHA	Total Land Area in Zone A (Acres)	Percent Total Land Area in Zone A	Total Land Area in Zone VE (Acres)	Percent Total Land Area in Zone VE
Keyport, Borough of	927.85	252.34	27.2%	148.17	16.0%	51.84	5.6%
Lake Como, Borough of	161.35	22.36	13.9%	16.07	10.0%	-	<1.0%
Little Silver, Borough of	2,035.66	452.74	22.2%	345.86	17.0%	-	<1.0%
Loch Arbour, Village of	73.96	34.11	46.1%	22.04	29.8%	6.57	8.9%
Long Branch, City of	3,505.50	899.88	25.7%	427.62	12.2%	178.14	5.1%
Manalapan, Township of	19,759.34	1,014.39	5.1%	671.41	3.4%	-	<1.0%
Manasquan, Borough of	1,002.69	510.81	50.9%	407.02	40.6%	64.25	6.4%
Marlboro, Township of	19,477.44	764.39	3.9%	527.21	2.7%	-	<1.0%
Matawan, Borough of	1,542.15	112.93	7.3%	110.28	7.2%	-	<1.0%
Middletown, Township of	27,864.65	3,151.23	11.3%	2,081.75	7.5%	275.60	1.0%
Millstone, Township of	23,800.31	1,074.95	4.5%	836.97	3.5%	-	<1.0%
Monmouth Beach, Borough of	1,261.94	566.11	44.9%	436.99	34.6%	65.32	5.2%
Neptune City, Borough of	574.00	88.69	15.5%	43.88	7.6%	5.41	<1.0%
Neptune, Township of	5,550.08	398.31	7.2%	288.40	5.2%	47.24	<1.0%
Ocean, Township of	7,030.46	495.90	7.1%	360.25	5.1%	-	<1.0%
Oceanport, Borough of	2,621.24	805.54	30.7%	544.79	20.8%	1.05	<1.0%
Red Bank, Borough of	1,382.60	65.02	4.7%	61.52	4.4%	3.03	<1.0%
Roosevelt, Borough of	1,246.51	48.91	3.9%	48.91	3.9%	-	<1.0%
Rumson, Borough of	4,537.77	1,223.51	27.0%	712.52	15.7%	154.25	3.4%
Sea Bright, Borough of	781.65	492.95	63.1%	245.22	31.4%	244.67	31.3%
Sea Girt, Borough of	714.88	215.34	30.1%	113.83	15.9%	66.70	9.3%
Shrewsbury, Borough of	1,393.02	191.36	13.7%	55.37	4.0%	-	<1.0%
Shrewsbury, Township of	62.75	-	0.0%	-	0.0%	-	<1.0%
Spring Lake Heights, Borough of	945.86	245.53	26.0%	122.40	12.9%	86.15	9.1%

Jurisdiction	Total Municipal Land Area (Acres)	Total Land Area in SFHA (Acres)	Percent Total Land Area in SFHA	Total Land Area in Zone A (Acres)	Percent Total Land Area in Zone A	Total Land Area in Zone VE (Acres)	Percent Total Land Area in Zone VE
Spring Lake, Borough of	837.15	62.74	7.5%	55.61	6.6%	-	<1.0%
Tinton Falls, Borough Of	9,989.22	510.63	5.1%	357.75	3.6%	-	<1.0%
Union Beach, Borough of	1,203.10	1,098.41	91.3%	666.96	55.4%	316.52	26.3%
Upper Freehold, Township of	30,311.34	1,809.99	6.0%	1,808.76	6.0%	-	<1.0%
Wall, Township of	20,288.47	730.92	3.6%	632.20	3.1%	7.74	<1.0%
West Long Branch, Borough of	1,850.28	85.49	4.6%	25.04	1.4%	-	<1.0%

SOURCE: FEMA

4.2.16 FLOOD: EXTENT

In the case of riverine flood hazard, once a river reaches flood stage, the flood extent or severity categories used by the NWS include minor flooding, moderate flooding, and major flooding. Each category has a definition based on property damage and public threat:

- Minor Flooding - minimal or no property damage, but possibly some public threat or inconvenience.
- Moderate Flooding - some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary.
- Major Flooding - extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations (NWS 2011).

The extent of flooding associated with a 1% annual probability of occurrence (the base flood or 100-year flood) is used as the regulatory boundary by many agencies. Also referred to as the SFHA, this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. Corresponding water-surface elevations describe the water elevation resulting from a given discharge level, which is one of the most important factors used in estimating flood damage.

4.2.17 FLOOD: PREVIOUS OCCURENCES AND LOSSES

Flooding is the most common major natural hazard in New Jersey. The FIS notes that flooding in Monmouth County is attributed mainly to tropical storms, extratropical cyclones (nor'easters) and, to a lesser extent, severe thunderstorms. According to NCDC, over 125 recorded flood events (coastal flood, flash flood, and flood) have occurred in Monmouth County since 1996. These events have resulted in two reported injuries and an estimated $10 billion in property damages. Some recent notable events include the following:

February 4, 1998. In Monmouth County, damage was estimated at $500,000 as the county was spared by the eastward movement of the nor'easter off of Cape Hatteras. The continuous onshore flow caused moderate to severe beach erosion (described under coastal erosion hazard). New Jersey State Route 36 was flooded in Sea Bright. In Raritan Bay, tidal flooding caused road closures in Middletown Township.

September 16, 1999. Hurricane Floyd brought torrential rains. In Monmouth County, the worst flooding related problems occurred when the torrential rain coincided with the high tide. The worst flooding was reported in Union Beach and bay areas of Middletown Township. For more information on Hurricane Floyd, please see the description of Hurricane Floyd under the Tropical Storms and Hurricanes subsection

October 13-14, 2005. Heavy rain associated with a low-pressure system southeast of New Jersey moved into Monmouth County on the 13th. Three-day storm totals (from the 11th through the 14th) in the county averaged between four and 11 inches, with the highest amounts near the coast. In Asbury Park and Loch Arbour Village, Deal Lake overflowed and forced the evacuation of about 65 homes in Loch Arbour and 30 homes in Asbury Park. In Eatontown Borough, Eatoncrest Apartments flooded as water was three to four feet deep in areas. In Belmar Borough, flooding occurred along Lake Como and along the Shark River. In Monmouth Beach, flooding along the Shrewsbury River affected several blocks. In Ocean Township, flooding along the Poplar Brook caused the evacuation of the entire 104-unit Poplar Village Senior Citizens Center. After the brook receded, 22 units were deemed uninhabitable. In Rumson Borough, flooding along the Shrewsbury River closed roads near the Sea Bright-Rumson Bridge. In Howell Township, seven units of the Friendship Gardens (Senior Citizen) complex were evacuated. Metedeconk River flooding also affected Freehold Township, the Borough of Spring Lake and Wall Township. The Manasquan River at Squankum reached its 7.5-foot flood stage on the 13th, cresting at 9.62 feet on the 14th. Specific storm totals included 11.58 inches in Manasquan and 10.15 inches in Tinton Falls.

March 2, 2007. Flooding occurred during the morning of the 2nd along State Route 35 in Hazlet and Aberdeen. The flooding may have been enhanced due to the high tide. Flooding also occurred along State Route 33, Howell Road, Church Road and Fairfield near Freehold. Rainfall totals include: 1.81 inches in Jackson; 1.54 inches in Marlboro; and 1.23 inches in Cream Ridge. The NCDC does not report injuries, fatalities, property damages, or crop damages for this event.

June 14, 2008. A slow-moving cold front helped trigger scattered showers and thunderstorms across New Jersey during the evening of the 14th. The thunderstorms moved slowly and caused flash flooding in Monmouth County. Torrential downpours caused roadway flooding and flooding of smaller streams and creeks in the northeastern part of Monmouth County. A Skywarn spotter measured three inches of rain within 45 minutes in Middletown Township. Roadway flooding was reported in Middletown and Highlands.

August 21, 2011. Thunderstorms with torrential downpours caused small stream flash flooding as well as poor drainage flooding in the southern half of Monmouth County. Howell, Ocean and Wall Townships were hardest hit with around a dozen homes damaged. The runoff also caused moderate flooding along the Manasquan River that lasted into the 22nd. In Howell, the Mariner's Cove development near the

Manasquan River was hard hit by flooding. Rescue boats were used to evacuate families as mud and water entered the first floor of homes. The U.S. Route 9 bridge over the Manasquan River was closed due to concern about its integrity. It was re-opened on the 22nd. Another bridge over the Manasquan River on Allentown-Lakewood Road near Robert Brice Memorial Park was also flooded and closed. In Ocean Township, flooding displaced residents of the Middlebrook at Monmouth Apartments on Deal Road. In Freehold, Post Road flooded by a creek and State Route 33 was closed in both directions at Halls Mill Road. In Long Branch, 2nd Avenue was under three feet of water, and barricades were floating away. In Deal, State Route 71 was closed in both directions. Streams were reported out of their banks in Millstone Township. Precipitation totals included 4.61 inches in Howell Township, 3.75 inches in Ocean Township, 3.16 inches in Asbury Park and 2.96 inches in Eatontown.

Hurricane Irene 2011. Irene's torrential downpours caused major flooding and a number of record-breaking crests on area rivers and a three to five-foot storm surge that caused moderate to severe tidal flooding with extensive beach erosion over the weekend of August 27th and 28th. Moderate to severe tidal flooding occurred along the Atlantic Coast 2nd Raritan Bay. Event precipitation totals averaged 5 to 10 inches and caused widespread record-breaking flooding. For more discussion of Hurricane Irene, please see Hurricane Irene under the Tropical Storms and Hurricanes subsection.

Superstorm Sandy 2012. Monmouth County was one of the two hardest-hit counties in the State of New Jersey. For more discussion of Superstorm Sandy, please see Superstorm Sandy under the Tropical Storms and Hurricanes subsection.

Other notable reports of historical flood events include the following, as identified by the Planning Committee:

- Major tidal and storm surge flooding occurred to jurisdictions located along the immediate shoreline and along the Shrewsbury River during the 1992 nor'easter, resulting in an estimated $270 million in insured damage to public and private property.
- The Township of Aberdeen indicated that the low-lying areas of Cliffwood Beach have been subject to repeated flooding during storms. They also noted that several roadways in the Township are flood prone, including but not limited NJDOT's State Highway 35 at Long Neck Creek, Lakeshore Drive and Greenwood Avenue, and Amboy Avenue.
- The Borough of Allentown reported that during periods of heavy rainfall, Doctors Creek and Indian Creek have overflowed their banks and backed up the municipality's drainage system, which causes flooding of streets and adjacent properties.
- Major tidal and storm surge flooding occurred to jurisdictions located along the immediate shoreline and along the Shrewsbury River during the 1992 nor'easter, resulting in an estimated $270 million in insured damage to public and private property.
- The Township of Aberdeen indicated that the low-lying areas of Cliffwood Beach have been subject to repeated flooding during storms. They also noted that several roadways in the Township are flood prone, including but not limited NJDOT's State Highway 35 at Long Neck Creek, Lakeshore Drive and Greenwood Avenue, and Amboy Avenue.

- The Borough of Allentown reported that during periods of heavy rainfall, Doctors Creek and Indian Creek have overflowed their banks and backed up the municipality's drainage system, which causes flooding of streets and adjacent properties.
- The Borough of Avon-By-The-Sea reported that coastal flooding occurs even during moderate storm events.
- The Borough of Brielle indicated that historically the damages caused by flood events have been confined to flooded basements on private property.
- The Borough of Farmingdale stated that Mariners Cove rests in the middle of an oxbow in the Manasquan River and has flooded five residences on at least five different occasions and has inundated the road and threatened the residences on a regular basis.
- The Township of Hazlet indicated that there are multiple roadways that flood during extreme rain events, including state highways.
- The Borough of Keansburg has certain areas that currently flood during extreme high tides and severe rainstorms.
- The Village of Loch Arbour reported that the flood event of October 2005 affected 80 percent of the village.
- The Township of Marlboro explained that its flooding issues have been worsening in the past seven to 10 years. Small streams overflow their banks regularly during prolonged rain events, and severe storms cause widespread flooding in these areas.
- The Borough of Matawan reported that Aberdeen Road, Ravine Drive and occasionally Main Street (near Lake Matawan) have been subject to historical flooding.
- The Borough of Neptune City indicated that it is vulnerable to both street flooding during heavy rains as well as tidal and storm flooding from the Shark River.
- The Township of Neptune noted that the Shark River Hills and North Island section of the community frequently flood on high moon tides, heavy rains, and certain storm events. The Ocean Grove section of the Township experiences flooding during certain tidal and heavy rain events. The coastal lakes (Fletcher and Wesley Lakes) also experience flooding during high tides and heavy rains.
- The Township of Ocean experiences a severe flooding issue every time it rains hard for more than 30 minutes. During any storm, there is an 85 percent chance or better that the Township will have to evacuate residents (mostly senior citizens) from their homes. This has occurred every year since 1985.
- The Borough of Oceanport indicated that even frequent heavy rains will cause minor to moderate flooding (particularly street flooding) due to the low-lying nature of the area. In addition, the storm drainage infrastructure reportedly needs improvements due to development over the years. Past flooding has caused major traffic issues with County and local roadways flooding.
- The Borough of Shrewsbury has reported that only minor localized flooding occurs in the town, mostly surrounding local streams and due to poor storm drainage along the roads.
- The Borough of Spring Lake reported significant riverine flooding occurrences in the Wreck Pond sub watershed. Damages of $9.8 million were reported in this area following the October 2005 flood event.

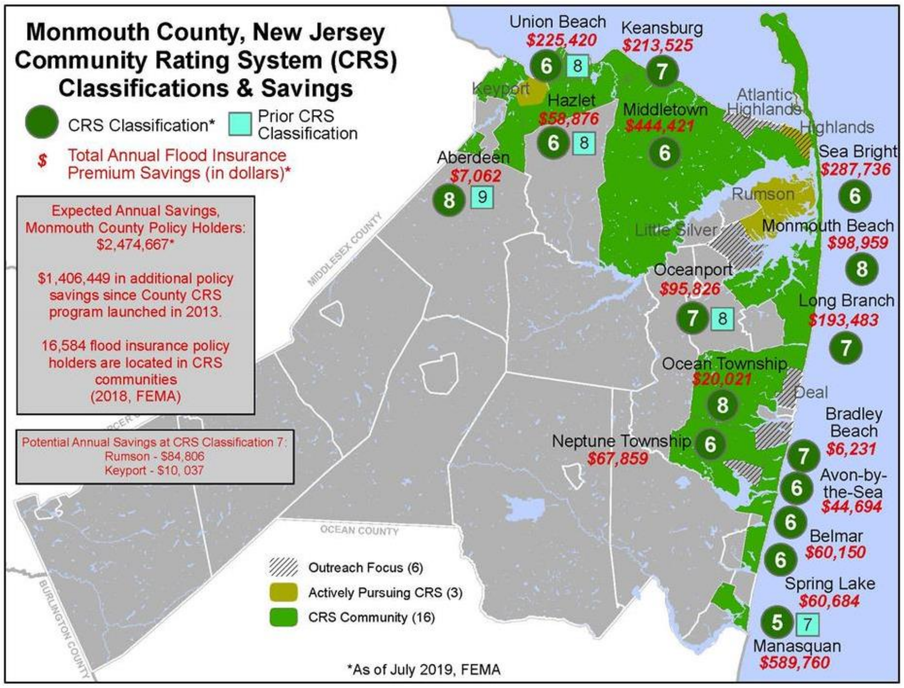
- The Township of Upper Freehold has indicated that all County and Township roads in its jurisdiction have no shoulders, and heavy rain from storm events erodes or washes out the roadways.
- The Borough of Avon-By-The-Sea reported that coastal flooding occurs even during moderate storm events.

Historical Summary of Insured Flood Losses

According to FEMA flood insurance policy records, there have been 22,004 flood losses reported in Monmouth County through the National Flood Insurance Program (NFIP) from 1972 to August 2018, up from 21,481 reported in the last plan update. NFIP loss payment statistics as of September 30, 2018 total approximately $929.6 million, up from $853 million as reported in the last plan update. Every municipal jurisdiction in Monmouth County is listed by FEMA as being an active participant in the NFIP (with Freehold Borough and Shrewsbury Township recently joining in August 2013). The name of the Floodplain Administrator (the person responsible for ensuring that development activities comply with floodplain management ordinances and NFIP regulations) for each jurisdiction is included in the Capability Assessment section of the plan and notes within each of the jurisdiction's appendix.

In addition to NFIP participation, the 16 communities of Aberdeen, Avon-By-The-Sea, Belmar, Bradley Beach, Hazlet, Keansburg, Long Branch, Manasquan, Middletown, Monmouth Beach, Neptune, Ocean, Oceanport, Sea Bright, Spring Lake, and Union Beach are listed by FEMA as Community Rating System (CRS) participating communities. Under the CRS, communities which implement floodplain management actions that go beyond the minimum requirements of the NFIP are eligible for discounts on flood insurance premiums for properties within that community. Since the last plan update, five towns including Aberdeen, Union Beach, Hazlet, Oceanport, and Manasquan have improved their CRS classification.

Figure 4.2 - 4 Monmouth County CRS Classifications & Savings



SOURCE: MONMOUTH COUNTY DIVISION OF PLANNING

Monmouth County OEM will continue to work with all jurisdictions in the County, encouraging them all to participate fully in the NFIP, and to take full advantage of additional FEMA programs such as the CRS. Jurisdictions already participating in the CRS will be encouraged to upgrade their CRS status, while non-participating jurisdictions will be encouraged to work towards eligibility. The County will also support local jurisdiction participation in the Cooperating Technical Partners Program (CTP), of which the main objective is to increase local involvement in the floodplain mapping process.

Table 4.2-12 National Flood Insurance Program (NFIP) Community Rating System (CRS) Participation in Monmouth County summarizes the CRS classifications of participating Monmouth County municipalities.

Table 4.2 - 12 National Flood Insurance Program (NFIP) Community Rating System (CRS) Participation in Monmouth County as of May 1, 2019

CRS Number	Jurisdiction	Participation Status	Date Entered CRS	Current Effective Date	CRS Class (as of May 2019)	% Discount for SFHA	% Discount for Non-SFHA
340312	Aberdeen, Township of	Current	5/1/2010	10/1/2015	8	10	5
340287	Avon-By-The-Sea, Borough of	Current	10/1/2016	10/1/2016	6	20	10
345283	Belmar, Borough of	Current	5/1/2015	5/1/2015	6	20	10

CRS Number	Jurisdiction	Participation Status	Date Entered CRS	Current Effective Date	CRS Class (as of May 2019)	% Discount for SFHA	% Discount for Non-SFHA
340289	Bradley Beach, Borough of	Current	10/1/1995	10/1/2000	7	15	5
340298	Hazlet, Township of	Current	5/1/2011	10/1/2013	6	20	10
340303	Keansburg, Borough of	Current	5/1/2015	5/1/2015	7	15	5
340307	Long Branch, City of	Current	5/1/2018	5/1/2018	7	15	5
345303	Manasquan, Borough of	Current	10/1/1992	5/1/2018	5	25	10
340313	Middletown, Township of	Current	5/1/2012	10/1/2013	6	20	10
340315	Monmouth Beach, Borough of	Current	10/1/2017	10/1/2017	8	10	5
340317	Neptune, Township of	Current	5/1/2015	5/1/2015	6	20	10
340518	Ocean, Township of	Current	5/1/2014	5/1/2014	8	20	10
340320	Oceanport, Borough of	Current	5/1/2010	10/1/2015	7	15	5
345317	Sea Bright, Borough of*	Current	10/1/1992	10/1/2018	6	20	10
340329	Spring Lake, Borough of	Current	10/1/1994	5/1/2014	6	20	10
340331	Union Beach, Borough of	Current	10/1/2003	10/1/2016	6	20	10
NOTES: FOR THE PURPOSE OF DETERMINING CRS DISCOUNTS, ALL AR AND A99 ZONES ARE TREATED AS NON-SFHAS. *ALTHOUGH SEA BRIGHT'S STATUS WAS "RESCINDED" AS OF THE LAST PLAN UPDATE, THE COMMUNITY HAS SINCE BECOME "CURRENT".							

SOURCES: FEMA APRIL 2019 NFIP FLOOD INSURANCE MANUAL; MONMOUTH COUNTY DIVISION OF PLANNING

Table 4.2 - 13 National Flood Insurance Program Statistics lists relevant NFIP statistics, including the total number of losses under the NFIP by municipal jurisdiction. It should be emphasized that this listing includes only those losses to structures that were insured through the NFIP policies. Total number of losses includes some losses in which claims were sought and not received. It is likely that many additional instances of flood losses in Monmouth County were either uninsured or not reported.

Before Superstorm Sandy had even occurred, the total value of all claims paid county-wide had increased by 42 percent between May 2008 and May 2012, ($76.8 million in May 2008 as compared to $109.5M in May 2012. At that time, many of the claims paid were due to Hurricane Irene. The impacts of Sandy are truly staggering. Between May 2008 and August 2014, the total value of all claims paid has increased from $76.8 million to $852 million. This represents about a 1009 percent increase over May 2008 values that were presented in the initial version of this HMP.

Repetitive Loss Properties

FEMA defines a Repetitive Loss (RL) property as any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-year period, since 1978. A RL property may or may not be currently insured by the NFIP. According to FEMA RL property records there are 1,645 RL properties located in Monmouth County (as of August 8, 2018). Of the 1,645 RL properties, 1,259 are non-mitigated; in other words, no changes have been made to the structure to prevent future flooding from occurring (i.e. elevation or relocation). These non-mitigated properties are associated with a total of 3,614 losses and approximately $157.5 million in claims payments under the NFIP since January 1978 (the earliest recorded date of loss).

While 46 (88 percent) of Monmouth County's 53 municipal jurisdictions identified as having one or more Repetitive Loss (RL) properties, Highlands and Sea Bright have the most RL properties [233 and 185, respectively; 418 combined (25% of all the RL properties in the County]. Total paid claims are the highest in three communities: Sea Bright ($37.95 million from 185 properties; as compared to $32.9 million from 191 properties in 2014); Monmouth Beach ($28.7 million from 148 properties; as compared to $26.5 million from 149 properties in 2014); Highlands ($26 million from 233 properties; as compared to $22.6 million from 219 properties in 2014). Paid claims per RL property are highest on average in the Borough of Red Bank where only three properties have been paid $1,487,369, or $495,790 per claim. Mitigating RL properties is a priority of the State HMP.

This plan does not show areas of the County where occasional isolated RL properties are located and show only the approximate areas covering clusters of RL properties, since the component data is subject to the 1974 Privacy Act. This legislation prohibits the public release of any information regarding individual NFIP claims or information which may lead to the identification of associated individual addresses and property owners. However, while this information is not available to the general public, the County may subsequently obtain comprehensive RL property data from FEMA for the purposes of targeted mitigation of RL areas or individual RL structures.

Since the plan update in 2015, the number of listed repetitive loss properties has increased from 1,593 as of February 2014 to 1,645 as of August 2018. FEMA has indicated that their system depends heavily on programmed address matching to identify repetitive losses and, while the software makes some allowances for misspellings and incomplete addresses, it is not perfect and sometimes legitimate address matches are missed. Sometimes repetitive loss properties go undetected for years because of address anomalies. There are FEMA contractors and FEMA regional staff who are actively working with the repetitive loss system allowing them to link addresses that they have found should be linked. When they do, new repetitive loss properties can be created even though the loss dates may have been older. Sometimes repetitive loss properties can be combined as well and may create Severe Repetitive Loss properties (SRL).

The average repetitive loss property in Monmouth County has experienced 2.9 loss events. At the extreme end, one property in the Borough of Keyport is recorded as having experienced 21 losses for a total of $695,760 in paid claims. There are six properties in the county that have had 10 or more losses and are located as follows: one in Hazlet, one in Monmouth Beach, two in Sea Bright, one in Aberdeen, and one in Keyport. These six properties have had a total of 82 losses. The following six communities have no RL properties within their borders: Allentown, Fair Haven, Freehold Borough, Matawan, Millstone, and Shrewsbury Township. The majority of all RL properties are located in the 100-year floodplain.

Severe Repetitive Loss Properties

FEMA defines a Severe Repetitive Loss (SRL) property as a residential property that is covered under an NFIP flood insurance policy and: (a) that has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or (b) for which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building; and (c) for both (a) and (b), at least two of the referenced claims must have occurred within any ten-year period, and must be greater than 10 days apart. According to FEMA repetitive loss property records (as of August 8, 2018) there are a total of 79 severe repetitive loss properties located in 17 Monmouth County communities all of which are identified as "non-mitigated". These 79 severe repetitive loss properties are associated with a total of 411 losses and $18,598,035.42 in claims payments under the NFIP since January 1978 (the earliest recorded date of loss). There is an average of 5.2 claims per property and an average payment of $235,418 per paid claim.

Table 4.2 - 13 National Flood Insurance Program Statistics

Jurisdiction	Total Policies in Force	Total Losses	Total Closed Paid Losses	Total RL Properties	Total SRL Properties	Total RL & SRL Combined	Total Mitigated Properties	Total RL Payments
Aberdeen, Township of	122	71	55	3	0	3	1	$973,573
Allenhurst, Borough of	54	21	14	2	0	2	0	$152,088
Allentown, Borough of	15	5	3	0	0	0	0	$0
Asbury Park, City of	527	70	44	6	0	6	0	$1,532,153
Atlantic Highlands, Borough of	118	97	74	6	0	6	0	$1,233,222
Avon-By-The-Sea, Borough of	415	295	247	19	1	20	9	$3,132,165
Belmar, Borough of	896	475	418	43	0	43	6	$4,580,409
Bradley Beach, Borough of	381	75	60	5	0	5	0	$216,502
Brielle, Borough of	262	214	169	10	0	10	2	$773,169
Colts Neck, Township of	64	39	26	3	0	3	1	$438,579
Deal, Borough of	165	83	50	3	1	4	0	$550,442
Eatontown, Borough of	36	21	11	3	0	3	1	$158,439
Englishtown, Borough of	35	32	28	3	0	3	0	$96,698
Fair Haven, Borough of	49	31	15	0	0	0	0	$0
Farmingdale, Borough of	17	28	21	7	0	7	0	$869,935
Freehold, Borough of	5	0	0	0	0	0	0	$0
Freehold, Township Of	117	53	34	4	0	4	0	$67,829

Jurisdiction	Total Policies in Force	Total Losses	Total Closed Paid Losses	Total RL Properties	Total SRL Properties	Total RL & SRL Combined	Total Mitigated Properties	Total RL Payments
Hazlet, Township of	492	105	73	4	2	6	0	$517,203
Highlands, Borough of	1,063	1731	1505	233	3	236	57	$26,023,725
Holmdel, Township of	49	11	9	1	0	1	0	$8,996
Howell, Township of	179	46	32	4	0	4	2	$100,971
Interlaken, Borough of	26	17	10	2	0	2	0	$74,334
Keansburg, Borough of	1,690	1315	1111	66	0	66	17	$4,498,599
Keyport, Borough of	136	164	142	10	0	10	1	$3,694,415
Lake Como, Borough of	98	38	35	2	0	2	0	$70,255
Little Silver, Borough of	336	394	343	24	1	25	1	$5,254,774
Loch Arbour, Village of	48	87	67	18	0	18	1	$984,442
Long Branch, City of	2,005	1347	1078	69	2	71	8	$8,985,066
Manalapan, Township of	182	85	61	7	0	7	1	$319,360
Manasquan, Borough of	1,493	2217	1996	167	5	172	41	$16,136,922
Marlboro, Township of	167	86	48	7	0	7	0	$97,718
Matawan, Borough of	16	23	15	0	0	0	0	$0
Middletown, Township of	2,648	1693	1429	163	5	168	42	$14,093,982
Millstone, Township of	21	8	4	0	0	0	0	$0
Monmouth Beach, Borough of	1,751	1743	1506	148	20	168	16	$28,676,838
Neptune City, Borough of	166	50	41	4	0	4	0	$808,862
Neptune, Township of	761	396	333	19	0	19	2	$3,057,767
Ocean, Township of	285	282	234	35	3	38	14	$3,687,111
Oceanport, Borough of	711	956	860	58	2	60	26	$11,998,655
Red Bank, Borough of	72	33	25	3		3	0	$1,487,369
Roosevelt, Borough of	2	4	2	1		1	0	$94,420
Rumson, Borough of	605	933	802	87	7	94	11	$17,295,364
Sea Bright, Borough of	1,096	1952	1583	185	12	197	75	$37,951,112
Sea Girt, Borough of	302	111	78	4	0	4	0	$214,542
Shrewsbury, Borough of	0	0	0	1	0	1	0	$5,628
Shrewsbury, Township of	34	10	6	0	0	0	0	$0
Spring Lake Heights, Borough of	105	44	32	111	11	122	14	$560,116
Spring Lake, Borough of	715	506	428	5	1	6	3	$11,322,696
Tinton Falls, Borough Of	60	11	4	1	0	1	0	$17,620
Union Beach, Borough of	1,148	1550	1384	83	2	85	34	$10,931,714
Upper Freehold, Township of	15	4	3	1	1	2	0	$67,301
Wall, Township of	209	81	45	4	0	4	0	$385,899

Jurisdiction	Total Policies in Force	Total Losses	Total Closed Paid Losses	Total RL Properties	Total SRL Properties	Total RL & SRL Combined	Total Mitigated Properties	Total RL Payments
West Long Branch, Borough of	40	15	7	1	0	1	0	$7,773
Monmouth County	22,004	19,658	16,600	1,645	79	1,724	386	$224,206,751

4.2.18 FLOOD: PROBABILITY OF FUTURE OCCURRENCE

Flooding will continue to have a high probability of occurrence in Monmouth County, and the probability of future occurrences in Monmouth County is certain. The probability of future flood events based on magnitude and according to best available data is illustrated in Figure 4.2-1 Special Flood Hazard Areas in Monmouth County, which indicates those areas susceptible to the 1 percent annual chance flood (100-year floodplain); the 1 percent annual chance flood with wave action (100-year coastal floodplain); and the 0.2 percent annual chance flood (500-year floodplain).

Flooding in Monmouth County is attributed mainly to tropical storms, nor'easters, and - to a lesser extent - severe thunderstorms. Usually occurring during late summer and early autumn, these storms can result in severe damage to coastal areas. Although extratropical cyclones can develop at almost any time of the year, they are more likely to occur during winter and spring. Thunderstorms are a common occurrence during the warm summer months.

4.2.19 FLOOD: POTENTIAL EFFECTS OF CLIMATE CHANGE

The frequency of intense precipitation events in Monmouth County is expected to increase in the future with climate change; this is likely to result in more riverine and flash flooding events. Within the 10 years, there have been 58 coastal flood events in Monmouth County, estimating to $10 billion in property damage. It should also be noted that anticipated sea level rise will increase the risk of damages/losses due to future coastal flooding events. Rising sea level over time will shorten the return period (increasing the frequency) of significant flood events.

Table 4.2 14 Critical Facilities, Critical Infrastructure, and Historic and Cultural Resources Vulnerable to Sea Level Rise (SLR) at +1 FT MHHW and +3 FT MHH shows the number and percentage of critical facilities, critical infrastructure, and historic and cultural resources at risk of sea level rise. The analysis was completed by georeferencing critical facility data points and intersecting NOAA's 1-FT and 3-FT Mean Higher High Water (MHHW) projections. The analysis went further to include the estimated Replacement Cost Valve (RCV) of the critical facilities by intersecting the critical facility data points, NOAA's sea level rise projections, and the estimated market value of improvements. The estimated market value data came from the State's MOD VI data and taxation rates from 2017, as per New Jersey Office of Information Technology (NJOIT)'s database. Only the jurisdictions whose critical facilities are at risk of sea level rise are included in the Table below. Municipalities in the table below are listed in order of the highest RCV for +3FT MHHW. Please note that not all municipalities are included in the following tables; only those municipalities with critical facilities vulnerable to sea level rise are listed.

Table 4.2 - 14 Critical Facilities, Critical Infrastructure, and Historic and Cultural Resources Vulnerable to Sea Level Rise (SLR) at +1 FT MHHW and +3 FT MHHW

Jurisdiction	Number of Critical Facilities at Risk of Sea Level Rise		Percentage of Critical Facilities at Risk of Sea Level Rise		Total RCV for Critical Facilities	
	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW
Aberdeen Township	1	1	4%	4%	$1,208.82	$1,208.82
Avon-by-the-Sea Borough	0	1	0%	17%	$0.00	$896,022.91
Highlands Borough	0	3	0%	33%	$0.00	$180,212.28
Monmouth Beach Borough	0	1	0%	20%	$0.00	$5,735,773.52
Sea Bright Borough	1	3	25%	75%	$0.00	$638,137.76
Monmouth County	2	9	0%	1%	$1,208.82	$7,451,355.29

Jurisdiction	Number of Critical Infrastructure at Risk of Sea Level Rise		Percentage of Critical Infrastructure at Risk of Sea Level Rise		Total RCV for Critical Infrastructure	
	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW
Wall Township	1	1	8%	8%	$46,510.95	$46,510.95
Monmouth County	1	1	2%	2%	$46,510.95	$46,510.95

Jurisdiction	Number of Historic & Cultural Resources at Risk of Sea Level Rise		Percentage of Historic & Cultural Resources at Risk of Sea Level Rise		Total RCV for Historic & Cultural Resources	
	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW
Avon-by-the-Sea Borough	9	9	30%	30%	$0.00	$0.00
Belmar Borough	5	5	33%	33%	$0.00	$0.00
Brielle Borough	4	4	17%	17%	$1,429,779.98	$1,429,779.98
Fair Haven Borough	1	1	3%	3%	$281,794.46	$281,794.46
Hazlet Township	4	4	33%	33%	$0.00	$0.00
Highlands Borough	0	3	0%	14%	$0.00	$248,839.63
Keansburg Borough	2	6	6%	17%	$0.00	$59,078.93

Jurisdiction	Number of Historic & Cultural Resources at Risk of Sea Level Rise		Percentage of Historic & Cultural Resources at Risk of Sea Level Rise		Total RCV for Historic & Cultural Resources	
	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW
Keyport Borough	6	8	3%	3%	$812,744.35	$2,099,300.93
Little Silver Borough	0	3	0%	7%	$0.00	$161,421.51
Manasquan Borough	3	8	6%	15%	$0.00	$413,110.80
Middletown Township	8	8	14%	14%	$0.00	$0.00
Monmouth Beach Borough	0	5	0%	20%	$0.00	$7,633,285.86
Neptune Township	2	3	0%	0%	$0.00	$32,624.98
Oceanport Borough	3	4	6%	8%	$0.00	$0.00
Red Bank Borough	4	6	4%	6%	$0.00	$0.00
Rumson Borough	5	5	28%	28%	$0.00	$0.00
Sea Bright Borough	3	10	13%	43%	$0.00	$493,204.45
Union Beach Borough	4	4	31%	31%	$0.00	$0.00
Wall Township	1	2	1%	2%	$0.00	$0.00
West Long Branch Borough	1	1	3%	3%	$0.00	$0.00
Monmouth County	67	101	1%	2%	$2,524,318.79	$12,852,441.52

SOURCES: NOAA OFFICE OF COASTAL MANAGEMENT, MONMOUTH COUNTY OFFICE OF GIS, NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS, NJOIT, NJ DIVISION OF TAXATION

Table 4.2-15 Total Number and RCV for General Building Stock with Risk of Sea Level Rise shows the number and percentage of general building stock with risk of sea level rise, as well as the estimated replacement cost value (RCV) of the building stock. RCV was calculated by approximating the market value of the improvements on each of the parcels in the State using MOD-IV and taxation rates from 2017[6]. Please note that not all municipalities are included in the following tables; only those municipalities with vulnerable to sea level rise are listed.

[6] NJ Office of Information Technology (NJOIT). 2017. New Jersey Real Estate MOD-IV Tax List Search Plus Database, 2017; NJ Division of Taxation. 2017. General and Effective Tax Rates by County and Municipality. https://www.state.nj.us/treasury/taxation/lpt/taxrate.shtml.

Table 4.2 - 15 Total Number and RCV for General Building Stock with Risk of Sea Level Rise

Jurisdiction	Number of General Building Stock at Risk of Sea Level Rise		Percentage of General Building Stock at Risk of Sea Level Rise		Total RCV for General Building Stock		Percentage RCV of General Building Stock	
	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW
Aberdeen Township	197	418	3.0%	6.4%	$83,387,310.94	$162,479,521.65	3.9%	7.5%
Asbury Park City	1	2	0.0%	0.0%	$0.00	$0.00	0.0%	0.0%
Atlantic Highlands Borough	27	58	1.7%	3.6%	$17,760,117.31	$39,446,379.70	2.4%	5.3%
Avon By The Sea Borough	34	122	3.7%	13.5%	$41,026,707.31	$148,686,618.89	4.5%	16.4%
Belmar Borough	49	128	1.9%	4.9%	$72,013,611.94	$184,819,728.00	4.7%	12.0%
Bradley Beach Borough	1	2	0.0%	0.1%	$0.00	$0.00	0.0%	0.0%
Brielle Borough	154	339	8.0%	17.7%	$271,279,085.31	$572,490,569.12	19.7%	41.5%
Deal Borough	12	27	1.4%	3.1%	$83,489,175.50	$286,454,860.31	4.2%	14.3%
Eatontown Borough	1	2	0.0%	0.1%	$0.00	$0.00	0.0%	0.0%
Fair Haven Borough	78	178	3.8%	8.6%	$160,684,969.66	$358,511,548.48	9.7%	21.5%
Hazlet Township	111	342	1.6%	5.1%	$23,014,327.39	$85,683,984.19	0.9%	3.3%
Highlands Borough	95	831	4.1%	36.0%	$47,421,289.88	$251,705,037.34	8.1%	42.8%
Keansburg Borough	40	947	1.3%	29.7%	$7,704,499.21	$162,240,343.41	1.6%	33.0%
Keyport Borough	96	211	4.5%	9.9%	$112,824,387.07	$262,614,890.45	17.0%	39.5%
Little Silver Borough	182	451	7.4%	18.5%	$246,121,601.06	$578,032,581.78	15.0%	35.3%
Long Branch City	185	602	2.3%	7.6%	$210,534,247.00	$636,060,616.63	5.3%	16.0%
Manasquan Borough	270	1309	8.4%	40.8%	$173,464,548.73	$903,686,690.00	8.1%	42.1%
Matawan Borough	9	23	0.4%	0.9%	$1,216,031.19	$1,964,574.56	0.1%	0.2%
Middletown Township	604	1497	2.6%	6.4%	$438,963,909.36	$1,021,407,719.41	4.2%	9.9%
Monmouth Beach Borough	242	896	15.7%	58.3%	$245,614,921.82	$872,508,075.21	21.6%	76.8%

Jurisdiction	Number of General Building Stock at Risk of Sea Level Rise		Percentage of General Building Stock at Risk of Sea Level Rise		Total RCV for General Building Stock		Percentage RCV of General Building Stock	
	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW	+1ft MHHW	+3ft MHHW
Neptune City Borough	28	66	2.1%	4.8%	$12,401,827.94	$29,076,462.13	2.7%	6.2%
Neptune Township	202	426	1.9%	3.9%	$31,737,599.11	$110,986,276.41	0.8%	2.6%
Oceanport Borough	303	789	15.9%	41.4%	$412,493,629.00	$895,509,754.89	37.3%	81.1%
Red Bank Borough	92	192	2.3%	4.9%	$153,071,108.47	$310,955,371.03	7.7%	15.6%
Rumson Borough	429	982	18.1%	41.4%	$994,818,212.95	$2,115,706,285.91	30.2%	64.2%
Sea Bright Borough	246	735	22.9%	68.5%	$240,680,410.03	$675,347,706.73	34.8%	97.7%
Sea Girt Borough	1	7	0.1%	0.6%	$0.00	$0.00	0.0%	0.0%
Shrewsbury Borough	32	66	2.2%	4.5%	$31,619,599.63	$67,388,533.25	2.9%	6.3%
Spring Lake Borough	1	2	0.1%	0.1%	$0.00	$0.00	0.0%	0.0%
Tinton Falls Borough	114	165	1.8%	2.6%	$11,508,585.00	$26,867,459.13	0.4%	1.0%
Union Beach Borough	271	742	12.0%	32.9%	$127,059,513.57	$678,565,300.65	23.1%	123.5%
Wall Township	161	344	1.7%	3.6%	$141,901,336.42	$286,134,987.22	2.6%	5.2%
West Long Branch Borough	7	13	0.3%	0.5%	$25,775,714.16	$40,250,046.51	2.0%	3.1%

SOURCES: NOAA OFFICE OF COASTAL MANAGEMENT, NJOIT, NJ DIVISION OF TAXATION

4.2.20 FLOOD: VULNERABILITY ASSESSMENT

Impacts

Near the Atlantic Ocean, Raritan Bay, Navesink River, Sandy Hook Bay, Shark River and Shrewsbury River, serious flooding problems are the result of high tidal surge and associated wave activity caused primarily by tropical storms, especially hurricanes. Other low-lying areas are vulnerable to severe flooding and flood-related damage due to the periodic flooding caused by the overflow of streams and lakes. Heavy rainfall can result in higher than normal stages of Deal Lake, affecting the Borough of Allenhurst, the City of Asbury Park, the Borough of Deal, and the Village of Loch Arbour, which frequently experiences property damage. Additional flooding in the Township of Aberdeen is attributed to tidal inundation and backwater from inadequate culverts. Due to high tidal stages on the Raritan Bay, the northern area of Aberdeen in the tidal plains of Matawan Creek, Mohingson Brook and Whale Creek is prone to flooding that affects Route35 and properties near the shoreline. Areas adjacent to Mohingson Brook, Gravelly Run and Matawan Creek are prone to flooding due to inadequate culverts.

In the Borough of Deal, the lower portion of Poplar Brook is within the tidal range of the Atlantic Ocean. Runoff from severe rain periodically can cause the upper reach of Poplar Brook to overflow its banks. Residential properties can be affected by flooding on both stretches of Poplar Brook.

In the Borough of Eatontown, at times blockage by debris and refuse on Wampum Brook, Parkers Creek, Whale Pond Brook, Husky Brook, Crystal Brook and Turtle Mill Brook can cause severe restrictions of culverts and contribute to local flooding. Most local flooding occurs upstream of State Route 35 on Parkers Creek, upstream of State Route 35 near Clinton Avenue, upstream of State Route 71 on Husky Brook at the twin 48-inch culverts under the Duncan Thecker Associates Service Road, and along the Lewis Street Bridge over Wampum Brook.

In the Township of Freehold, flooding has occurred along Manasquan River Tributary B upstream of Elton Adelphia Road, to a distance of 100 feet beyond normal channel bank. During severe conditions, Coventry Drive, which parallels the stream, has become impassable due to flooding. Debois Creek causes localized flooding where roadways cross the stream. The Strickland Road crossing has been flooded to a depth of two feet above the road surface during severe storms. The adjacent floodplain has been inundated but with no extensive property damage. Debois Creek Tributary has experienced flooding during storm conditions due to constricted channel areas in the downstream portions of the stream. Extensive erosion in the channel of the tributary has been reported.

In the Township of Holmdel, flooding occurs upstream of State Route 34 and along South Street by Willow Brook, as well as near Middle Road by Waackaack Creek.

In the Township of Howell, localized flooding problems have occurred in the area of Long Brook and Bannen Meadow Brook. Long Brook has caused flooding of adjacent property near Wyckoff Road and the State Route 33 crossing. Howell Road is prone to flooding during severe conditions. Bannen Meadow Brook has caused flooding of adjacent property near Fort Plains Road and Casino Drive. The Fort Plains Road crossing is also flooded during severe flooding conditions. The North Branch of Metedeconk River and the Manasquan River also cause flooding in Howell.

In the Township of Manalapan, considerable flooding occurs along Matchaponix Brook in the area of the corporate limits and at its junction with Pine Brook 2. Flood elevations along the lower reach of Pine Brook 2 area affected by backwater from the main branch of Matchaponix Brook. Flooding occurs along Pension Road near Clarks Mills. The housing development along Birmingham Drive, Tarrytown Road and Winthrop Drive is subject to flooding from Pine Brook 2. The area along Pine Brook Road and Pease Road is flooded regularly when Pine Brook 2 Tributary C overflows its banks. Flooding problems also exist along Milford Brook in the area of Commack Lane, Pease Road and Tennant Road. Additional problems along Milford Brook arise during heavy rains in the area of Lafayette Mills and Lafayette Mills Road.

In the Borough of Matawan, flood gates are maintained by the community on Matawan Creek at the Lake Lefferts Dam. At times, when the flood gates were not opened quickly enough during severe storm conditions, Ravine Drive has flooded to a depth of eight inches. Gravelly Brook has flooded Mill Road to a depth of six inches. The Municipal Garage, located on the floodplain of Gravelly Brook upstream of Church Street, has been flooded to a depth of eight inches, and the Church Street crossing has been flooded by Gravelly Brook to a depth of four inches. Downstream of the confluence of Gravelly Brook with Matawan Creek, the triple culvert at the Railroad Bridge causes backwater flooding of Aberdeen Road to a depth of five feet.

In the Township of Marlboro, considerable flooding occurs along Deep Run in the area of the corporate limits and Old Texas Road, a relatively flat region. A wide floodplain also occurs at Deep Run's junction with Deep Run Tributary B. Additionally, backwater effects of the culvert on Milford Brook at State Route 18 cause flooding upstream of that structure.

In the Township of Middletown, the Bayshore portion of the township lies in a poorly drained floodplain with abundant swamp and marshland. The low banks of the stream and the low relief of the surrounding terrain render this region extremely vulnerable to flooding. During periods of heavy precipitation, the creeks overtop their banks and spread their floodwaters over the broad floodplain.

In the Township of Neptune, there are several areas that experience flooding from assorted causes. In the Shark River Hills section, high tides, moon tides, and heavy rain produce flooding along low-lying roads and properties. There are residential properties and critical infrastructure (pump stations) in this area that experience flooding. The area along South Concourse Avenue also experiences flooding due to high tides, winds, moon tides, and heavy rains. The flooding impacts businesses, residents, and critical infrastructure (pump stations) in this area, and residents frequently have to be evacuated. In the Ocean Grove section of the Township, the area around Fletcher Lake frequently floods during heavy rains and high tides. Lake Alberta, located between 6th Ave and Neptune Blvd, floods often and there is a senior housing complex that is impacted during heavy rains.

In the Township of Ocean, inland flow of the ocean tidal surges in restricted by weirs in the streams flowing to the ocean, as well as by lake storage. Flooding in the township is caused mostly by local rainstorms.

In the Borough of Spring Lake Heights, flooding occurs along Wreck Pond Brook, Wreck Pond North Branch and Poly Pond Brook. In general, localized flooding may occur under severe storm conditions due to poor surface drainage.

In the Borough of Tinton Falls, low-lying areas are subject to periodic flooding caused by the overflow of Swimming River, Pine Brook 1 and Jumping Brook 2. The most severe flooding occurs at the junction of Pine Brook 1 and Swimming River.

The Borough of Union Beach lies in a poorly drained floodplain with abundant swamps and marshland. The flat gradient of the streams and low relief of the surrounding terrain makes the area extremely vulnerable to flooding. During periods of heavy rainfall, streams within the Borough can overtop and spread floodwaters across the broad floodplain. The Borough is very susceptible to flooding, as 91.3% of the Borough is located in the Special Flood Hazard Area.

In the Township of Wall, flooding in the eastern section and remaining parts of the Township is caused by streams overflowing their banks. The non-tidal sections of Shark River, Manasquan River and Wreck Pond flow in wide, meandering channels. Urbanization in the areas of Watson Creek, Judas Creek

(Upstream Reach), Roberts Swamp Brook (Upstream Reach), Poly Pond Brook and Heroys Pond Brook increase the runoff to these streams. Flooding can be aggravated by the accumulation of debris at culverts and bridges.

Exposure and Damage Estimates

In order to assess flood risk, a GIS-based analysis was used to estimate exposure to flood events using FEMA's DFIRMs in combination with local tax assessor records. To estimate exposure to flooding, the determination of value and population at-risk was calculated through GIS analysis by calculating the proportion of a parcel or census block lying within an identified flood zone (A/AE and VE), and applying that same ratio to the census block population and parcel value to estimate population at risk and value of improvements at risk, as presented in Table 4.2 - 16 Exposure to Flood Zones by Jurisdiction (2018 Values). The assessment for this plan update represents an improvement over the prior version of the plan through use of more recent assessed values (2012), in addition to more recent and more accurate flood data (preliminary DFIRMs as opposed to the earlier Q3 data, which had a much higher potential margin of error). Due to the reassessment, total assessed values in this plan update are approximately 50 percent higher than they were at the time the initial version of this plan was prepared. The table below is sorted by the percent of buildings located in the A/AE and VE Flood Zones. Jurisdictions are color-coded according to the percent of buildings in the SFHA: those in dark blue have greater than 75% of their buildings in the SFHA; those in the medium shade of blue have greater than 50% of their buildings in the SFHA; those in light blue have greater than 25% of their buildings in the SFHA.

Table 4.2 - 16 Exposure to Flood Zones by Jurisdiction (2018 Values)

Jurisdiction	Total Assessed Value of Improvements 2018 Values	Buildings Located in Flood Zone A/AE)		Buildings Located in Flood Zone (Zone VE)		Buildings Located in Flood Zone (A/AE and VE)	
		Value At-Risk	%	Value At-Risk	%	Value At-Risk	Percent
Keansburg, Borough of	$343,826,000	$332,751,545	84.50%	$3,213,537	0.82%	$335,965,082	85.32%
Union Beach, Borough of	$387,844,700	$216,439,527	75.11%	$10,892,606	3.78%	$227,332,133	78.89%
Sea Bright, Borough of	$235,586,800	$201,572,336	75.20%	$6,123,371	2.28%	$207,695,707	77.49%
Monmouth Beach, Borough of	$501,592,200	$326,948,593	64.14%	$284,668	0.06%	$327,233,261	64.20%
Manasquan, Borough of	$799,826,975	$370,872,765	45.51%	$50,372,041	6.18%	$421,244,806	51.69%
Highlands, Borough of	$342,874,400	$159,235,122	50.00%	$2,201,971	0.69%	$161,437,092	50.69%
Loch Arbour, Village of	$69,262,800	$15,058,316	34.25%	$281,258	0.64%	$15,339,574	34.89%
Oceanport, Borough of	$562,875,800	$163,073,648	27.92%	$0	0.00%	$163,073,648	27.92%
Avon-By-The-Sea, Borough of	$266,879,900	$96,198,042	24.69%	$959,595	0.25%	$97,157,637	24.93%
Belmar, Borough of	$553,347,900	$112,126,552	19.62%	$4,309,244	0.75%	$116,435,795	20.38%
Rumson, Borough of	$1,600,650,400	$300,539,362	18.90%	$10,712,125	0.67%	$311,251,487	19.58%
Brielle, Borough of	$669,338,900	$91,092,010	16.49%	$3,862,182	0.70%	$94,954,192	17.19%

Jurisdiction	Total Assessed Value of Improvements 2018 Values	Buildings Located in Flood Zone A/AE)		Buildings Located in Flood Zone (Zone VE)		Buildings Located in Flood Zone (A/AE and VE)	
		Value At-Risk	%	Value At-Risk	%	Value At-Risk	Percent
Little Silver, Borough of	$873,512,700	$123,307,184	14.64%	$0	0.00%	$123,307,184	14.64%
Farmingdale, Borough of	$109,883,900	$13,375,616	10.55%	$0	0.00%	$13,375,616	10.55%
Spring Lake, Borough of	$1,028,817,800	$122,604,672	10.39%	$1,011,588	0.09%	$123,616,260	10.48%
Sea Girt, Borough of	$732,097,100	$43,388,344	8.21%	$8,398,641	1.59%	$51,786,985	9.80%
Keyport, Borough of	$434,885,600	$37,342,996	7.85%	$6,795,237	1.43%	$44,138,233	9.28%
Atlantic Highlands, Borough of	$364,693,600	$23,495,949	8.28%	$2,456,740	0.87%	$25,952,689	9.15%
Middletown, Township of	$5,895,810,731	$476,678,684	8.50%	$20,815,231	0.37%	$497,493,915	8.87%
Hazlet, Township of	$1,215,098,000	$115,104,018	8.43%	$0	0.00%	$115,104,018	8.43%
Englishtown, Borough of	$158,314,100	$10,622,687	7.50%	$0	0.00%	$10,622,687	7.50%
Lake Como, Borough of	$140,566,300	$12,329,648	7.03%	$0	0.00%	$12,329,648	7.03%
Long Branch, City of	$2,478,681,000	$159,020,460	6.02%	$7,011,919	0.27%	$166,032,379	6.29%
Neptune, Township of	$2,431,214,700	$92,119,320	5.37%	$2,994,974	0.17%	$95,114,294	5.55%
Interlaken, Borough of	$125,000,500	$5,363,153	5.19%	$0	0.00%	$5,363,153	5.19%
Spring Lake Heights, Borough of	$525,407,200	$24,293,550	4.75%	$0	0.00%	$24,293,550	4.75%
Red Bank, Borough of	$1,194,733,400	$43,588,034	3.26%	$17,494,834	1.31%	$61,082,868	4.57%
Neptune City, Borough of	$305,279,900	$11,023,721	4.08%	$1,016,835	0.38%	$12,040,556	4.45%
Aberdeen, Township of	$1,074,509,800	$46,464,795	3.90%	$3,205,481	0.27%	$49,670,275	4.17%
Tinton Falls, Borough of	$1,691,986,800	$90,040,992	3.97%	$0	0.00%	$90,040,992	3.97%
Deal, Borough of	$822,100,400	$15,812,645	2.74%	$6,976,995	1.21%	$22,789,640	3.96%
Allentown, Borough of	$127,734,200	$5,298,388	3.65%	$0	0.00%	$5,298,388	3.65%
Ocean, Township of	$2,684,842,000	$82,112,922	3.49%	$0	0.00%	$82,112,922	3.49%
Colts Neck, Township of	$927,454,500	$65,252,437	3.45%	$0	0.00%	$65,252,437	3.45%
Wall, Township of	$3,053,292,400	$76,489,126	2.95%	$3,025,815	0.12%	$79,514,941	3.07%
Bradley Beach, Borough of	$462,112,100	$12,942,404	2.85%	$0	0.00%	$12,942,404	2.85%
Asbury Park, City of	$1,267,473,400	$23,171,428	2.50%	$2,991,996	0.32%	$26,163,424	2.82%

Jurisdiction	Total Assessed Value of Improvements 2018 Values	Buildings Located in Flood Zone A/AE)		Buildings Located in Flood Zone (Zone VE)		Buildings Located in Flood Zone (A/AE and VE)	
		Value At-Risk	%	Value At-Risk	%	Value At-Risk	Percent
Fair Haven, Borough of	$785,619,700	$5,966,412	0.90%	$12,486,679	1.88%	$18,453,091	2.78%
Upper Freehold, Township of	$851,779,300	$24,716,431	2.71%	$0	0.00%	$24,716,431	2.71%
Eatontown, Borough of	$1,314,725,700	$25,106,453	1.92%	$0	0.00%	$25,106,453	1.92%
Matawan, Borough of	$517,395,800	$10,778,158	1.91%	$0	0.00%	$10,778,158	1.91%
West Long Branch, Borough of	$889,026,200	$15,629,909	1.77%	$0	0.00%	$15,629,909	1.77%
Manalapan, Township of	$4,619,949,900	$73,755,432	1.73%	$0	0.00%	$73,755,432	1.73%
Millstone, Township of	$1,232,191,160	$18,935,228	1.69%	$0	0.00%	$18,935,228	1.69%
Shrewsbury, Borough of	$608,635,700	$9,332,215	1.69%	$0	0.00%	$9,332,215	1.69%
Marlboro, Township of	$4,435,729,800	$74,433,230	1.67%	$0	0.00%	$74,433,230	1.67%
Howell, Township of	$4,204,216,400	$58,630,432	1.64%	$0	0.00%	$58,630,432	1.64%
Freehold, Township of	$4,433,974,800	$41,058,883	0.92%	$0	0.00%	$41,058,883	0.92%
Allenhurst, Borough of	$217,949,000	$1,516,172	0.82%	$156,990	0.09%	$1,673,162	0.91%
Holmdel, Township of	$2,104,382,100	$20,973,887	0.89%	$0	0.00%	$20,973,887	0.89%
Roosevelt, Borough of	$50,136,700	$41,379	0.09%	$0	0.00%	$41,379	0.09%
Freehold, Borough of	$771,202,500	$50,603	0.01%	$0	0.00%	$50,603	0.01%
Shrewsbury, Township of	$30,450,000	$0	0.00%	$0	0.00%	$0	0.00%
Monmouth County	$63,526,773,666	$4,498,075,815	7.24%	$190,052,551	0.31%	$4,688,128,366	7.55%

NOTES: EXPOSURE CALCULATED BY GIS ANALYSIS USING LOCAL ASSESSED VALUES

To estimate potential losses resulting from the flood hazard, a HAZUS-MH analysis was conducted for both riverine and coastal flooding using FEMA's Preliminary and Effective FIRMs. HAZUS-MH estimates floodplain boundaries, potential exposure for each event frequency, and loss estimates based on probabilistic scenarios for 10%, 2%, 1%, and 0.2% Annual Chance Flood Event using a Level 2 analysis.

Table 4.2 - 17 Total Estimated Loss for the 1% Flood Event by Municipality and Land Area

Jurisdiction	Total Estimated Loss for the 1% Flood Event By Land Area
Union Beach Borough	$53,203.14
Highlands Borough	$38,696.96
Monmouth Beach Borough	$35,992.33
Keansburg Borough	$34,658.66
Oceanport Borough	$33,099.52
Manasquan Borough	$32,070.84
Sea Bright Borough	$30,825.14
Keyport Borough	$23,559.96
Rumson Borough	$22,849.16
Little Silver Borough	$17,223.47
Red Bank Borough	$13,119.16
Atlantic Highlands Borough	$10,850.57
Brielle Borough	$10,732.98
Middletown Township	$10,203.52
Long Branch City	$8,736.59
Hazlet Township	$8,252.81
Belmar Borough	$8,029.11
Aberdeen Township	$7,492.77
Avon-by-the Sea Borough	$6,643.64
Spring Lake Heights Borough	$5,909.09
Neptune Township	$5,282.05
Loch Arbour Village	$5,087.72
Fair Haven Borough	$5,071.67
Deal Borough	$4,047.26
Matawan Borough	$3,845.16
Neptune City Borough	$3,773.44
Shrewsbury Borough	$3,252.46
Spring Lake Borough	$2,989.40
Wall Township	$2,782.40
Ocean Township	$2,738.20
Allenhurst Borough	$2,512.99
Farmingdale Borough	$2,435.68
Colts Neck Township	$2,239.25
Allentown Borough	$2,235.72
Interlaken Borough	$2,076.53
Englishtown Borough	$1,793.10
Tinton Falls Borough	$1,623.06
Asbury Park City	$1,297.89
Marlboro Township	$1,113.88
Lake Como Borough	$1,080.51
Howell Township	$1,059.94
Holmdel Township	$1,057.38
Eatontown Borough	$1,037.64
Upper Freehold Township	$996.76
Freehold Township	$955.97
Manalapan Township	$923.33
Millstone Township	$884.42

Jurisdiction	Total Estimated Loss for the 1% Flood Event By Land Area
Sea Girt Borough	$731.43
West Long Branch Borough	$389.96
Bradley Beach Borough	$354.67
Roosevelt Borough	$126.46
Freehold Borough	$23.59
Shrewsbury Township	$0

SOURCE: HAZUS-MH

Table 4.2 - 18 Estimated Potential Losses From the 10%, 2%, 1%, and 0.2% Annual Chance Flood Event from Riverine Flooding

Jurisdiction	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Aberdeen, Township of	$122,335	$177,567	$255,346	$2,633,200
Allenhurst, Borough of	N/A	N/A	N/A	N/A
Allentown, Borough of	$399,364	$511,975	$627,825	$1,742,968
Asbury Park, City of	N/A	N/A	N/A	N/A
Atlantic Highlands, Borough of	N/A	N/A	N/A	N/A
Avon-By-The-Sea, Borough of	N/A	N/A	N/A	N/A
Belmar, Borough of	N/A	N/A	N/A	N/A
Bradley Beach, Borough of	N/A	N/A	N/A	N/A
Brielle, Borough of	N/A	N/A	N/A	N/A
Colts Neck, Township of	$8,174,895	$10,171,457	$11,654,355	$30,623,112
Deal, Borough of	$46,727	$53,834	$72,460	$364,796
Eatontown, Borough of	$237,528	$313,644	$358,884	$3,011,775
Englishtown, Borough of	$1,371,796	$1,778,874	$2,143,672	$6,881,949
Fair Haven, Borough of	N/A	N/A	N/A	N/A
Farmingdale, Borough of	$1,404,348	$1,749,503	$1,994,644	$4,031,847
Freehold, Borough of	N/A	N/A	N/A	N/A
Freehold, Township of	$6,179,484	$8,116,723	$10,433,242	$21,464,046
Hazlet, Township of	$1,422,872	$2,074,640	$2,600,800	$6,098,558
Highlands, Borough of	N/A	N/A	N/A	N/A
Holmdel, Township of	$4,279,168	$5,857,799	$7,460,386	$19,396,732
Howell, Township of	$17,769,888	$21,617,629	$24,509,978	$50,649,944
Interlaken, Borough of	$4,969	$5,678	$7,098	$9,937
Keansburg, Borough of	$3,049,483	$3,687,537	$4,124,943	$8,121,353
Keyport, Borough of	$138,832	$168,044	$195,484	$1,009,792
Lake Como, Borough of	N/A	N/A	N/A	N/A
Little Silver, Borough of	$1,233	$2,466	$4,315	$26,927
Loch Arbour, Village of	N/A	N/A	N/A	N/A
Long Branch, City of	$669,936	$793,479	$7,363,508	$4,315,787
Manalapan, Township of	$21,032,268	$26,048,783	$30,390,360	$61,425,237
Manasquan, Borough of	N/A	N/A	N/A	N/A
Marlboro, Township of	$1,664,746	$1,986,914	$2,342,220	$6,267,402
Matawan, Borough of	$258,745	$3,174,931	$3,493,296	$5,141,973
Middletown, Township of	$14,066,731	$17,118,272	$20,533,413	$45,495,893
Millstone, Township of	$6,637,390	$8,163,328	$9,227,738	$16,314,712
Monmouth Beach, Borough of	N/A	N/A	N/A	N/A
Neptune City, Borough of	N/A	N/A	N/A	N/A
Neptune, Township of	$4,364,935	$5,191,447	$5,803,217	$8,658,958

Jurisdiction	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Ocean, Township of	$263,103	$363,473	$604,168	$7,644,481
Oceanport, Borough of	$486,432	$563,425	$2,358,689	$3,738,932
Red Bank, Borough of	$4,615,276	$5,209,372	$6,538,570	$17,948,846
Roosevelt, Borough of	$17,570	$20,567	$22,868	$365,972
Rumson, Borough of	N/A	N/A	N/A	N/A
Sea Bright, Borough of	N/A	N/A	N/A	N/A
Sea Girt, Borough of	$330,903	$333,347	$324,382	$1,661,383
Shrewsbury, Borough of	$166,665	$229,266	$305,715	$2,197,287
Shrewsbury, Township of	N/A	N/A	N/A	N/A
Spring Lake, Borough of	$473,800	$1,137,037	$1,200,006	$877,965
Spring Lake Heights, Borough of	$1,093,643	$1,395,464	$1,634,628	$4,685,027
Tinton Falls, Borough of	$2,662,111	$5,018,595	$6,080,771	$32,284,189
Union Beach, Borough of	$0	$0	$0	$1,117
Upper Freehold, Township of	$3,435,905	$4,055,583	$4,695,811	$12,475,178
Wall, Township of	$3,043,367	$3,764,963	$4,390,324	$15,165,593
West Long Branch, Borough of	$40,095	$58,087	$114,017	$7,712,787
Monmouth County	$109,926,544	$140,913,703	$173,867,131	$202,000,251

SOURCE: HAZUS-MH

Table 4.2-19 Potential Annualized Losses from Riverine Flooding by Jurisdiction shows potential annualized property losses and annualized percent losses from riverine flooding, which is calculated by HAZUS-MH. Annualized losses is the estimated long-term value of losses to the general building stock averaged on an annual basis for a specific hazard type.

Table 4.2 - 19 Potential Annualized Losses from Riverine Flooding by Jurisdiction

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Annualized Total Building Losses Riverine Flood	Annualized Percent Loss Ratio Riverine Flood
Farmingdale, Borough of	317	$109,883,900	$157,891	0.14%
Englishtown, Borough of	311	$158,314,100	$165,326	0.13%
Keansburg, Borough of	8,946	$343,826,000	$326,653	0.09%
Millstone, Township of	377	$1,232,191,160	$735,757	0.07%
Howell, Township of	3,390	$4,204,216,400	$1,999,260	0.06%
Manalapan, Township of	1,881	$4,619,949,900	$2,442,886	0.06%
Colts Neck, Township of	732	$927,454,500	$904,792	0.05%
Upper Freehold, Township of	315	$851,779,300	$378,509	0.05%
Allentown, Borough of	163	$127,734,200	$50,233	0.04%
Matawan, Borough of	500	$517,395,800	$218,788	0.04%
Red Bank, Borough of	663	$1,194,733,400	$494,282	0.04%
Holmdel, Township of	445	$2,104,382,100	$554,597	0.03%
Middletown, Township of	10,246	$5,895,810,731	$1,578,497	0.03%
Neptune, Township of	1,627	$2,431,214,700	$470,389	0.03%
Spring Lake Heights, Borough of	325	$525,407,200	$127,076	0.03%
Freehold, Township of	1,073	$4,433,974,800	$771,972	0.02%
Hazlet, Township of	2,650	$1,215,098,000	$199,420	0.02%
Shrewsbury, Township of	0	$30,450,000	$5,251	0.02%
Tinton Falls, Borough of	736	$1,691,986,800	$439,874	0.02%
Long Branch, City of	3,301	$2,478,681,000	$154,302	0.01%

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Annualized Total Building Losses Riverine Flood	Annualized Percent Loss Ratio Riverine Flood
Oceanport, Borough of	1,499	$562,875,800	$77,159	0.01%
Sea Girt, Borough of	125	$732,097,100	$28,646	0.01%
Spring Lake, Borough of	360	$1,028,817,800	$97,451	0.01%
Wall, Township of	1,170	$3,053,292,400	$336,078	0.01%
Deal, Borough of	38	$822,100,400	$4,207	0.00%
Eatontown, Borough of	234	$1,314,725,700	$31,418	0.00%
Interlaken, Borough of	33	$125,000,500	$630	0.00%
Keyport, Borough of	1,027	$434,885,600	$16,614	0.00%
Little Silver, Borough of	784	$873,512,700	$414	0.00%
Marlboro, Township of	1,100	$4,435,729,800	$186,631	0.00%
Ocean, Township of	1,972	$2,684,842,000	$58,049	0.00%
Roosevelt, Borough of	17	$50,136,700	$1,852	0.00%
Union Beach, Borough of	4,991	$387,844,700	$0	0.00%
West Long Branch, Borough of	107	$889,026,200	$9,650	0.00%
Allenhurst, Borough of	13	$217,949,000	N/A	N/A
Asbury Park, City of	869	$1,267,473,400	N/A	N/A
Atlantic Highlands, Borough of	410	$364,693,600	N/A	N/A
Avon-By-The-Sea, Borough of	507	$266,879,900	N/A	N/A
Belmar, Borough of	1,246	$553,347,900	N/A	N/A
Bradley Beach, Borough of	185	$462,112,100	N/A	N/A
Brielle, Borough of	611	$669,338,900	N/A	N/A
Fair Haven, Borough of	154	$785,619,700	N/A	N/A
Freehold, Borough of	1	$771,202,500	N/A	N/A
Highlands, Borough of	2,641	$342,874,400	N/A	N/A
Lake Como, Borough of	95	$140,566,300	N/A	N/A
Loch Arbour, Village of	75	$69,262,800	N/A	N/A
Manasquan, Borough of	2,440	$799,826,975	N/A	N/A
Monmouth Beach, Borough of	2,132	$501,592,200	N/A	N/A
Neptune City, Borough of	273	$305,279,900	N/A	N/A
Rumson, Borough of	1,360	$1,600,650,400	N/A	N/A
Sea Bright, Borough of	1,254	$235,586,800	N/A	N/A
Shrewsbury, Borough of	99	$608,635,700	N/A	N/A
Aberdeen, Township of	2,997	$1,074,509,800	N/A	N/A

SOURCE: HAZUS-MH
*EXPOSURE CALCULATED BY GIS ANALYSTS USING LOCAL ASSESSED VALUES

As noted above, this analysis estimates damages from riverine sources, therefore the risks and damages in this section for coastal communities may appear underestimated when read in isolation from the accompanying sections estimating damages from storm surge, wave action, and erosion.

For the subset of structures identified as Repetitive Loss Properties (see Section 3a), a simple review of the history of paid claims suggests an annualized loss of approximately $5.6 million for these 1,618 properties. Without efforts to mitigate these and other individual properties at risk from frequent flooding, annual repetitive losses can be expected to remain at this order of magnitude, and even to increase, as structures that have up until now only been flooded once become flooded repeatedly and hence meet the definition of "Repetitive Loss Property". A more detailed assessment of potential future losses suffered by these properties would require a comprehensive survey of each individual repetitive loss property, which was outside the scope of this plan. However, since the last plan was prepared, many more communities maintain a detailed inventory of repetitive loss properties, and targeted mitigation is something that has been considered by many jurisdictions for this first plan update.

In accordance with FEMA guidance, all analyses in this plan have been conducted using the best readily available data. However, in the opinion of some members of the Planning Committee, in particular County Engineering staff, the extent of property damage or risk due to potential stream flooding may be underestimated by this level of analysis, for the following reasons:

With a few exceptions, the countywide FIS and FIRMs are primarily based on hydrologic and hydraulic analyses completed for each municipality during the late 1970s/early 1980s. For many municipalities, these analyses were conducted before the intense development of the 1980s and 1990s occurred. The analyses assume uniform conveyance throughout the stream corridor and do not necessarily account for changes in channel width or depth caused by siltation. Encroachments into the floodplain and or floodway could increase the flood elevation and therefore, widen the delineations of the 1%, 0.2% annual chance floodplains and 1% annual chance floodway depicted on the FIRMs.

Since the initial FEMA FIS, the State's Flood Hazard Area and Freshwater Wetlands rules have been established, regulating development in floodplains and floodways. While these regulations have served to guide appropriate development trends within these sensitive areas, they have been considered by some to be an obstacle for many local government agencies in implementing systematic stream-cleaning and maintenance of stormwater facilities. As a result, many stream segments throughout Monmouth County are silted in and/or blocked by debris and flood control basins are not functioning as designed.

Table 4.2 - 20 Number and Percentage of Critical Facilities with Flood Risk by Flood Zone and Jurisdiction shows the number and percentage of critical facilities with flood risk; Table 4.2 – 21 Number and Percentage of Critical Infrastructure with Flood Risk by Flood Zone and Jurisdiction shows the number and percentage of critical infrastructure with flood risk; Table 4.2 – 22 Number and Percentage of Historic and Cultural Resources with Flood Risk by Flood Zone and Jurisdiction shows the number and percentage of historic and cultural resources with flood risk. Flood risk was attributed to those georeferenced critical facilities that intersected with a composite of the FEMA FIRMS and PFIRMS in ArcMap. A composite was used to ensure the most recent data and best available data on flood boundaries was used. Jurisdictions are color-coded according to the percent of critical facilities in the SFHA: those in red have greater than 75% of their critical facilities in the SFHA; those in orange have greater than 50% of their critical facilities in the SFHA; those in yellow have greater than 25% of their critical facilities in the SFHA. Roosevelt Borough and Shrewsbury Township are not included in the following table as none of their critical facilities are located in the SFHA. Table 4.2 - 20 Number and Percentage of Critical Facilities with Flood Risk by Flood Zone and Jurisdiction is sorted by the percent of buildings located in the A/AE and VE Flood Zones. Jurisdictions are color-coded according to the percent of critical facilities in the SFHA: those in dark blue have greater than 75% of their critical facilities in the SFHA; those in the medium shade of blue have greater than 50% of their critical facilities in the SFHA; those in light blue have greater than 25% of their critical facilities in the SFHA.

Table 4.2 - 20 Number and Percentage of Critical Facilities with Flood Risk by Flood Zone and Jurisdiction

Jurisdiction	Number of Critical Facilities with Flood Risk			Percentage of Critical Facilities with Flood Risk		
	in SFHA	in Zone A	in Zone V	in SFHA	in Zone A	in Zone V
Monmouth Beach Borough	5	5	0	50%	50%	0%
Keansburg Borough	14	14	0	48%	48%	0%
Union Beach Borough	8	8	0	38%	38%	0%
Highlands Borough	6	6	0	33%	33%	0%
Sea Bright Borough	4	4	0	24%	24%	0%
Oceanport Borough	3	3	0	20%	20%	0%
Belmar Borough	3	3	0	13%	13%	0%
Hazlet Township	5	5	0	11%	11%	0%
Avon-by-the-Sea Borough	2	2	0	11%	11%	0%
Neptune City Borough	1	1	0	9%	9%	0%
Keyport Borough	2	2	0	7%	7%	0%
Rumson Borough	2	2	0	6%	6%	0%
Middletown Township	10	10	0	6%	6%	0%
Brielle Borough	1	1	0	5%	5%	0%
Red Bank Borough	3	3	0	4%	4%	0%
Atlantic Highlands Borough	1	1	0	4%	4%	0%
Little Silver Borough	1	1	0	4%	4%	0%
Spring Lake Borough	1	1	0	3%	3%	0%
Holmdel Township	1	1	0	2%	2%	0%
Long Branch City	1	1	0	1%	1%	0%
Wall Township	1	1	0	1%	1%	0%
Allenhurst Borough	0	0	0	0%	0%	0%
Allentown Borough	0	0	0	0%	0%	0%
Asbury Park City	0	0	0	0%	0%	0%
Bradley Beach Borough	0	0	0	0%	0%	0%
Colts Neck Township	0	0	0	0%	0%	0%
Deal Borough	0	0	0	0%	0%	0%
Eatontown Borough	0	0	0	0%	0%	0%
Englishtown Borough	0	0	0	0%	0%	0%
Fair Haven Borough	0	0	0	0%	0%	0%
Farmingdale Borough	0	0	0	0%	0%	0%
Freehold Borough	0	0	0	0%	0%	0%
Freehold Township	0	0	0	0%	0%	0%
Howell Township	0	0	0	0%	0%	0%
Interlaken Borough	0	0	0	0%	0%	0%
Lake Como Borough	0	0	0	0%	0%	0%
Loch Arbour Village	0	0	0	0%	0%	0%
Manalapan Township	0	0	0	0%	0%	0%
Manasquan Borough	0	0	0	0%	0%	0%
Marlboro Township	0	0	0	0%	0%	0%
Matawan Borough	0	0	0	0%	0%	0%
Millstone Township	0	0	0	0%	0%	0%
Neptune Township	0	0	0	0%	0%	0%
Ocean Township	0	0	0	0%	0%	0%
Roosevelt Borough	0	0	0	0%	0%	0%
Sea Girt Borough	0	0	0	0%	0%	0%
Shrewsbury Borough	0	0	0	0%	0%	0%
Shrewsbury Township	0	0	0	0%	0%	0%

Jurisdiction	Number of Critical Facilities with Flood Risk			Percentage of Critical Facilities with Flood Risk		
	in SFHA	in Zone A	in Zone V	in SFHA	in Zone A	in Zone V
Spring Lake Heights Borough	0	0	0	0%	0%	0%
Tinton Falls Borough	0	0	0	0%	0%	0%
Upper Freehold Township	0	0	0	0%	0%	0%
West Long Branch Borough	0	0	0	0%	0%	0%
Aberdeen Township	1	0	1	3%	0%	3%
Monmouth County	76	19	57	4%	4%	0%

SOURCE: FEMA, MONMOUTH COUNTY OFFICE OF GIS, NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS

Table 4.2 - 21 Number and Percentage of Critical Infrastructure with Flood Risk by Flood Zone and Jurisdiction

Jurisdiction	Number of Critical Infrastructure with Flood Risk			Percentage of Critical Infrastructure with Flood Risk		
	in SFHA	in Zone A	in Zone V	in SFHA	in Zone A	in Zone V
Atlantic Highlands Borough	1	1	0	4%	4%	0%
Red Bank Borough	1	1	0	1%	1%	0%
Wall Township	1	0	1	1%	0%	1%
Aberdeen Township	0	0	0	0%	0%	0%
Allenhurst Borough	0	0	0	0%	0%	0%
Allentown Borough	0	0	0	0%	0%	0%
Asbury Park City	0	0	0	0%	0%	0%
Avon-by-the-Sea Borough	0	0	0	0%	0%	0%
Belmar Borough	0	0	0	0%	0%	0%
Bradley Beach Borough	0	0	0	0%	0%	0%
Brielle Borough	0	0	0	0%	0%	0%
Colts Neck Township	0	0	0	0%	0%	0%
Deal Borough	0	0	0	0%	0%	0%
Eatontown Borough	0	0	0	0%	0%	0%
Englishtown Borough	0	0	0	0%	0%	0%
Fair Haven Borough	0	0	0	0%	0%	0%
Farmingdale Borough	0	0	0	0%	0%	0%
Freehold Borough	0	0	0	0%	0%	0%
Freehold Township	0	0	0	0%	0%	0%
Hazlet Township	0	0	0	0%	0%	0%
Highlands Borough	0	0	0	0%	0%	0%
Holmdel Township	0	0	0	0%	0%	0%
Howell Township	0	0	0	0%	0%	0%
Interlaken Borough	0	0	0	0%	0%	0%
Keansburg Borough	0	0	0	0%	0%	0%
Keyport Borough	0	0	0	0%	0%	0%
Lake Como Borough	0	0	0	0%	0%	0%
Little Silver Borough	0	0	0	0%	0%	0%
Loch Arbour Village	0	0	0	0%	0%	0%
Long Branch City	0	0	0	0%	0%	0%
Manalapan Township	0	0	0	0%	0%	0%
Manasquan Borough	0	0	0	0%	0%	0%
Marlboro Township	0	0	0	0%	0%	0%
Matawan Borough	0	0	0	0%	0%	0%
Middletown Township	0	0	0	0%	0%	0%
Millstone Township	0	0	0	0%	0%	0%

Jurisdiction	Number of Critical Infrastructure with Flood Risk			Percentage of Critical Infrastructure with Flood Risk		
	in SFHA	in Zone A	in Zone V	in SFHA	in Zone A	in Zone V
Monmouth Beach Borough	0	0	0	0%	0%	0%
Neptune City Borough	0	0	0	0%	0%	0%
Neptune Township	0	0	0	0%	0%	0%
Ocean Township	0	0	0	0%	0%	0%
Oceanport Borough	0	0	0	0%	0%	0%
Roosevelt Borough	0	0	0	0%	0%	0%
Rumson Borough	0	0	0	0%	0%	0%
Sea Bright Borough	0	0	0	0%	0%	0%
Sea Girt Borough	0	0	0	0%	0%	0%
Shrewsbury Borough	0	0	0	0%	0%	0%
Shrewsbury Township	0	0	0	0%	0%	0%
Spring Lake Borough	0	0	0	0%	0%	0%
Spring Lake Heights Borough	0	0	0	0%	0%	0%
Tinton Falls Borough	0	0	0	0%	0%	0%
Union Beach Borough	0	0	0	0%	0%	0%
Upper Freehold Township	0	0	0	0%	0%	0%
West Long Branch Borough	0	0	0	0%	0%	0%
Monmouth County	3	2	1	0%	0%	0%

Table 4.2 - 22 **Number and Percentage of Historic and Cultural Resources with Flood Risk by Flood Zone and Jurisdiction**

Jurisdiction	Number of Historic and Cultural Resources with Flood Risk			Percentage of Historic and Cultural Resources with Flood Risk		
	in SFHA	in Zone A	in Zone V	in SFHA	in Zone A	in Zone V
Allentown Borough	11	11	0	183%	183%	0%
Upper Freehold Township	19	19	0	158%	158%	0%
Sea Bright Borough	23	23	0	135%	135%	0%
Monmouth Beach Borough	13	13	0	130%	130%	0%
Keansburg Borough	34	33	1	117%	114%	3%
Neptune Township	79	75	4	104%	99%	5%
Loch Arbour Village	5	4	1	100%	80%	20%
Keyport Borough	27	16	11	90%	53%	37%
Avon-by-the-Sea Borough	17	13	4	89%	68%	21%
Manasquan Borough	20	18	2	67%	60%	7%
Interlaken Borough	4	4	0	57%	57%	0%
Union Beach Borough	12	9	3	57%	43%	14%
Highlands Borough	9	9	0	50%	50%	0%
Brielle Borough	9	9	0	47%	47%	0%
Spring Lake Borough	13	10	3	42%	32%	10%
Belmar Borough	10	5	5	42%	21%	21%
Oceanport Borough	5	5	0	33%	33%	0%
Asbury Park City	18	6	12	32%	11%	21%
Bradley Beach Borough	6	5	1	30%	25%	5%
Little Silver Borough	8	8	0	30%	30%	0%
Atlantic Highlands Borough	7	6	1	26%	22%	4%
Spring Lake Heights Borough	3	3	0	25%	25%	0%
Colts Neck Township	13	13	0	24%	24%	0%
Sea Girt Borough	4	3	1	20%	15%	5%
Howell Township	13	13	0	19%	19%	0%

Jurisdiction	Number of Historic and Cultural Resources with Flood Risk			Percentage of Historic and Cultural Resources with Flood Risk		
	in SFHA	in Zone A	in Zone V	in SFHA	in Zone A	in Zone V
Allenhurst Borough	2	1	1	18%	9%	9%
Englishtown Borough	2	2	0	17%	17%	0%
Farmingdale Borough	2	2	0	17%	17%	0%
Lake Como Borough	1	1	0	14%	14%	0%
Hazlet Township	6	6	0	13%	13%	0%
Long Branch City	8	6	2	12%	9%	3%
Manalapan Township	8	8	0	12%	12%	0%
West Long Branch Borough	3	3	0	12%	12%	0%
Red Bank Borough	7	7	0	10%	10%	0%
Matawan Borough	3	3	0	9%	9%	0%
Aberdeen Township	3	3	0	9%	9%	0%
Deal Borough	1	1	0	9%	9%	0%
Wall Township	6	5	1	8%	7%	1%
Ocean Township	4	4	0	8%	8%	0%
Holmdel Township	5	5	0	8%	8%	0%
Tinton Falls Borough	6	6	0	7%	7%	0%
Middletown Township	12	12	0	7%	7%	0%
Eatontown Borough	2	2	0	7%	7%	0%
Rumson Borough	2	2	0	6%	6%	0%
Marlboro Township	5	5	0	6%	6%	0%
Millstone Township	7	7	0	5%	5%	0%
Fair Haven Borough	1	1	0	5%	5%	0%
Shrewsbury Borough	1	1	0	2%	2%	0%
Freehold Township	1	1	0	1%	1%	0%
Freehold Borough	0	0	0	0%	0%	0%
Neptune City Borough	0	0	0	0%	0%	0%
Roosevelt Borough	0	0	0	0%	0%	0%
Shrewsbury Township	0	0	0	0%	0%	0%
Monmouth County	480	427	53	24%	21%	3%

Table 4.2 – 23 Total Replacement Cost Value (RCV) for Critical Facilities with Flood Risk by Flood Zone and Jurisdiction summarizes the replacement cost value (RCV) of each jurisdiction's critical facilities sorted from largest RCV to smallest. First, we approximated the market value of improvements on each of the parcels in the state using MOD-IV and taxation rates from 2017 (NJ Office of Information Technology (NJOIT), 2017; NJ Division of Taxation, 2017). Georeferenced critical facility data points were then intersected with the parcel layer to attribute the corresponding market value for improvements to each critical facility. Some critical facilities had been geolocated to the nearest road centerline and thus were not captured when intersected with parcels. As a proxy, we calculated the median market value of improvements from the critical facilities geolocated on their proper parcels and attributed this median value to all other critical facilities.

Table 4.2 - 23 Total Replacement Cost Value (RCV) for Critical Facilities with Flood Risk by Flood Zone and Jurisdiction

Jurisdiction	Total RCV for Critical Facilities with Flood Risk		
	in SFHA	in Zone A	in Zone V
Union Beach Borough	$24,815,375	$24,601,418	$213,957
Red Bank Borough	$24,317,475	$24,317,475	$0
Keansburg Borough	$23,462,973	$23,249,016	$213,957
Sea Girt Borough	$22,416,506	$22,202,549	$213,957
Asbury Park City	$22,051,150	$202,559	$21,848,591
Manasquan Borough	$21,039,312	$20,611,398	$427,913
Keyport Borough	$11,354,290	$10,553,928	$800,362
Middletown Township	$11,017,109	$11,017,109	$0
Monmouth Beach Borough	$8,102,685	$8,102,685	$0
Belmar Borough	$7,931,816	$2,992,359	$4,939,456
Hazlet Township	$7,113,110	$7,113,110	$0
Rumson Borough	$7,103,744	$7,103,744	$0
Spring Lake Borough	$7,085,867	$2,115,428	$4,970,439
Bradley Beach Borough	$4,765,172	$2,382,586	$2,382,586
Colts Neck Township	$4,510,076	$4,510,076	$0
Avon-by-the-Sea Borough	$3,842,186	$2,350,855	$1,491,330
Sea Bright Borough	$3,419,575	$3,419,575	$0
Highlands Borough	$3,070,657	$3,070,657	$0
Neptune Township	$2,368,574	$888,452	$1,480,122
Oceanport Borough	$2,176,356	$2,176,356	$0
Wall Township	$1,885,044	$1,624,577	$260,468
Holmdel Township	$1,583,593	$1,583,593	$0
Brielle Borough	$1,450,566	$1,450,566	$0
Atlantic Highlands Borough	$1,442,762	$1,442,762	$0
Ocean Township	$898,092	$898,092	$0
West Long Branch Borough	$898,092	$898,092	$0
Loch Arbour Village	$855,827	$641,870	$213,957
Long Branch City	$707,565	$493,608	$213,957
Little Silver Borough	$679,239	$679,239	$0
Manalapan Township	$641,870	$641,870	$0
Tinton Falls Borough	$531,110	$531,110	$0
Interlaken Borough	$427,913	$427,913	$0
Marlboro Township	$427,913	$427,913	$0
Millstone Township	$427,913	$427,913	$0
Spring Lake Heights Borough	$427,913	$427,913	$0
Aberdeen Township	$215,166	$213,957	$1,209
Allenhurst Borough	$213,957	$213,957	$0
Eatontown Borough	$213,957	$213,957	$0
Lake Como Borough	$213,957	$213,957	$0
Neptune City Borough	$213,957	$213,957	$0
Shrewsbury Borough	$213,957	$213,957	$0
Matawan Borough	$42,720	$42,720	$0
Englishtown Borough	$0	$0	$0
Freehold Township	$0	$0	$0
Allentown Borough	$0	$0	$0
Deal Borough	$0	$0	$0
Fair Haven Borough	$0	$0	$0
Farmingdale Borough	$0	$0	$0

Jurisdiction	Total RCV for Critical Facilities with Flood Risk		
	in SFHA	in Zone A	in Zone V
Freehold Borough	$0	$0	$0
Howell Township	$0	$0	$0
Roosevelt Borough	$0	$0	$0
Upper Freehold Township	$0	$0	$0
Monmouth County	$236,577,090	$196,904,830	$39,672,260

SOURCE: FEMA, MONMOUTH COUNTY OFFICE OF GIS, NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS, NJOIT, NJ DIVISION OF TAXATION

4.2.21 FLOOD: POTENTIAL FOR FUTURE DEVELOPMENT TO IMPACT HAZARD VULNERABILITY

Infill development and redevelopment would not be likely to substantially increase a jurisdiction's overall exposure to flooding because existing structures would be replaced with new structures, and the new structures would be built to higher codes and standards offering a certain degree of protection from the hazard. Greenfield development would be more likely, however, to have the potential to substantially increase a jurisdiction's overall vulnerability to the hazard because a new structure would be placed on previously undeveloped land.

All of Monmouth County's jurisdictions have mapped flood hazard areas including the Regulatory Floodway, Zone VE, and Zone A/AE; 51 municipalities have potentially developable undeveloped parcels in mapped flood hazard areas. The total area of these parcels is approximately 11,266 acres. In other words, nearly 35 percent of the County's potentially developable undeveloped land is in areas potentially susceptible to flooding under existing conditions. By 2050, sea level rise could increase this acreage by about one percent to 11,577 acres. Table 4.2-24 Potential for Future Development to Impact Flood Hazard Vulnerability presents a snapshot of the flood hazard, future development trends, the acreage of potentially developable parcels subject to flooding under existing conditions, the acres of potentially developable undeveloped parcels that could affected by sea level rise by the year 2050, and the potential for future development of undeveloped parcels to substantially increase flood hazard vulnerability under existing and future conditions.

Jurisdictions with a potential for future development trends to substantially increase flood hazard vulnerability under existing conditions should: (a) include flood mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development.

Table 4.2 - 24 Potential for Future Development to Impact Flood Hazard Vulnerability

Jurisdiction	Flood Hazard Areas Present[7]	Relative Population Trend (2010-2040)[8]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Flood Areas	Percent of Potentially Developable Undeveloped Land in Mapped Flood Areas	Local Characterization of Development Trends[9]	PFD on Undeveloped Parcels in Mapped Flood Hazard Areas	PFD on Undeveloped Parcels in Mapped Flood Areas to Substantially Increase Dam Failure hazard Vulnerability Under Existing SFHA
Aberdeen, Township of	H	Substantial increase	415	185	0.447	Mix of greenfield development, infill and redevelopment	•	•
Allenhurst, Borough of	H	Negligible increase	4	1	0.179	Little if any development expected	•	
Allentown, Borough of	H	Substantial increase	6	4	0.614	Little if any development expected	•	
Asbury Park, City of	H	Moderate increase	39	6	0.146	Mix of greenfield development, infill and redevelopment	•	
Atlantic Highlands, Borough of	H	Negligible increase	60	10	0.169	Mix of greenfield development, infill and redevelopment	•	•
Avon-by-the-Sea, Borough of	H	Low level increase	7	5	0.655	Little if any development expected	•	
Belmar, Borough of	H	Moderate increase	13	3	0.232	Mix of greenfield development, infill and redevelopment	•	
Bradley Beach, Borough of	H	Low level increase	14	0.5	0.035	Mix of greenfield development, infill and redevelopment	•	
Brielle, Borough of	H	Negligible increase	131	70	0.533	Mix of greenfield development, infill and redevelopment	•	•

7 High (H), Medium (M), or Low (L)

8 Relative population trend, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.

9 Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Flood Hazard Areas Present[7]	Relative Population Trend (2010-2040)[8]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Flood Areas	Percent of Potentially Developable Undeveloped Land in Mapped Flood Areas	Local Characterization of Development Trends[9]	PFD on Undeveloped Parcels in Mapped Flood Hazard Areas	PFD on Undeveloped Parcels in Mapped Flood Areas to Substantially Increase Dam Failure hazard Vulnerability Under Existing SFHA
Colts Neck, Township of	H	Substantial increase	793	209	0.264	Predominantly greenfield development	•	•
Deal, Borough of	H	Low level increase	40	11	0.282	Little if any development expected	•	•
Eatontown, Borough of	H	Substantial increase	347	69	0.198	Mix of greenfield development, infill and redevelopment	•	•
Englishtown, Borough of	H	Moderate increase	77	53	0.687	Mix of greenfield development, infill and redevelopment	•	•
Fair Haven, Borough of	H	Substantial increase	25	8	0.321	Mix of greenfield development, infill and redevelopment	•	
Farmingdale, Borough of	H	Moderate increase	69	54	0.782	Mix of greenfield development, infill and redevelopment	•	•
Freehold, Borough of	H	Negligible increase	0	0	0		•	•
Freehold, Township of	H	Substantial increase	2,622	862	0.329	Mix of greenfield development, infill and redevelopment	•	•
Hazlet, Township of	H	Substantial increase	249	151	0.605	Predominantly greenfield development	•	•
Highlands, Borough of	H	Negligible increase	58	31	0.531	Mix of greenfield development, infill and redevelopment	•	•
Holmdel, Township of	H	Moderate increase	593	123	0.207	Mix of greenfield development, infill and redevelopment	•	•

Jurisdiction	Flood Hazard Areas Present[7]	Relative Population Trend (2010-2040)[8]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Flood Areas	Percent of Potentially Developable Undeveloped Land in Mapped Flood Areas	Local Characterization of Development Trends[9]	PFD on Undeveloped Parcels in Mapped Flood Hazard Areas	PFD on Undeveloped Parcels in Mapped Flood Areas to Substantially Increase Dam Failure hazard Vulnerability Under Existing SFHA
Howell, Township of	H	Low level increase	6,606	2,245	0.34	Predominantly greenfield development	•	
Interlaken, Borough of	H	Substantial increase	7	3	0.507	Mix of greenfield development, infill and redevelopment	•	•
Keansburg, Borough of	H	Moderate increase	85	70	0.825	Little to no development expected	•	•
Keyport, Borough of	H	Substantial increase	68	51	0.749	Mix of greenfield development, infill and redevelopment	•	
Lake Como, Borough of	H	Moderate increase	8	2	0.275	Mix of greenfield development, infill and	•	•
Little Silver, Borough of	H	Negligible increase	54	21	0.385	Little to no development expected	•	
Loch Arbour, Village of	H	Substantial increase	2	2	0.857	Mix of greenfield development, infill and redevelopment	•	•
Long Branch, City of	H	Substantial increase	288	101	0.349	Little to no development expected	•	•
Manalapan, Township of	H	Moderate increase	3,194	964	0.302	Mix of greenfield development, infill and redevelopment	•	•
Manasquan, Borough of	H	Substantial increase	39	31	0.796	Predominantly greenfield development	•	•
Marlboro, Township of	H	Substantial increase	2,014	722	0.359	Mix of greenfield development, infill and redevelopment	•	•
Matawan, Borough of	H	Low level increase	140	85	0.604	Predominantly greenfield development	•	•

Jurisdiction	Flood Hazard Areas Present[7]	Relative Population Trend (2010-2040)[8]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Flood Areas	Percent of Potentially Developable Undeveloped Land in Mapped Flood Areas	Local Characterization of Development Trends[9]	PFD on Undeveloped Parcels in Mapped Flood Hazard Areas	PFD on Undeveloped Parcels in Mapped Flood Areas to Substantially Increase Dam Failure hazard Vulnerability Under Existing SFHA
Middletown, Township of	H	Moderate increase	2,313	877	0.379	Mix of greenfield development, infill and redevelopment	•	•
Millstone Township	H	Negligible increase	3,169	1,107	0.349	Mix of greenfield development, infill and redevelopment	•	•
Monmouth Beach Borough	H	Negligible increase	57	55	0.959	Mix of greenfield development, infill and redevelopment	•	•
Neptune City, Borough of	M	Negligible increase	38	15	0.384	Mix of greenfield development, infill and redevelopment	•	•
Neptune, Township of	H	Substantial increase	833	286	0.343	Mix of greenfield development, infill and redevelopment	•	•
Ocean, Township of	H	Negligible increase	1,009	390	0.386	Mix of greenfield development, infill and redevelopment	•	•
Oceanport, Borough of	H	Low level increase	218	180	0.824	Mix of greenfield development, infill and redevelopment	•	•
Red Bank, Borough of	M	Substantial increase	79	14	0.177	Little to no development expected	•	•
Roosevelt, Borough of	L	Low level increase	65	11	0.174	Mix of greenfield development, infill and redevelopment	•	•
Rumson, Borough of	H	Moderate increase	126	67	0.532	Mix of greenfield development, infill and redevelopment	•	•

Jurisdiction	Flood Hazard Areas Present[7]	Relative Population Trend (2010-2040)[8]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Flood Areas	Percent of Potentially Developable Undeveloped Land in Mapped Flood Areas	Local Characterization of Development Trends[9]	PFD on Undeveloped Parcels in Mapped Flood Hazard Areas	PFD on Undeveloped Parcels in Mapped Flood Areas to Substantially Increase Dam Failure hazard Vulnerability Under Existing SFHA
Sea Bright, Borough of	H	Substantial increase	38	38	0.995	Little to no development expected	•	
Sea Girt, Borough of	H	Moderate increase	20	2	0.081	Mix of greenfield development, infill and redevelopment	•	•
Shrewsbury, Borough of	H	Substantial increase	126	40	0.314	Little to no development expected	•	
Shrewsbury, Township of	L	Substantial increase	0	0	0	Mix of development, infill and redevelopment	•	
Spring Lake, Borough of	H	Negligible increase	17	4	0.267	Little to no development expected	•	•
Spring Lake Heights, Borough of	M	Low level increase	113	7	0.062	Predominantly greenfield development	•	•
Tinton Falls, Borough of	M	Substantial increase	1,670	475	0.285	Mix of greenfield development, infill and redevelopment	•	•
Union Beach, Borough of	H	Low level increase	278	277	0.994	Predominantly greenfield development	•	•
Upper Freehold, Township of	H	Negligible increase	1,508	530	0.351	Predominantly greenfield development	•	•
Wall, Township of	M	Moderate increase	2,446	706	0.289	Mix of greenfield development, infill and redevelopment	•	•
West Long Branch, Borough of	M	Substantial increase	84	37	0.436	Mix of greenfield development, infill and redevelopment	•	•
Monmouth, County of:	H	Moderate increase	32,274	11,270	0.349	Mix of greenfield development, infill and redevelopment	•	•

Table 4.2 - 25 Potential for Future Development to Impact Flood Hazard Vulnerability in SFHA 2050 lists acres of potentially developable undeveloped parcels affected by sea level rise according to NOAA's SRL projections, which are mapped in the Appendix Volume I – Jurisdictional Information. Jurisdictions with a potential for future development trends to substantially increase flood hazard vulnerability under future conditions (with sea level rise) should: (a) include sea level rise mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development.

Table 4.2 - 25 Potential for Future Development to Impact Flood Hazard Vulnerability in SFHA 2050

Jurisdiction	Acres of Potentially Developable Undeveloped Parcels Affected by Sea Level Rise[10]	Potential for Future Development on Undeveloped Parcels in Mapped Flood Areas to substantially increase flood hazard vulnerability under SFHA 2050
Aberdeen, Township of	2	•
Allenhurst, Borough of	1	
Allentown, Borough of	0	
Asbury Park, City of	6	•
Atlantic Highlands, Borough of	8	•
Avon-by-the-Sea, Borough of	1	
Belmar, Borough of	6	
Bradley Beach, Borough of	7	
Brielle, Borough of	2	•
Colts Neck, Township of	0	•
Deal, Borough of	7	•
Eatontown, Borough of	0	•
Englishtown, Borough of	0	•
Fair Haven, Borough of	0	
Farmingdale, Borough of	0	•
Freehold, Borough of	0	•
Freehold, Township of	0	•
Hazlet, Township of	5	•
Highlands, Borough of	0	•
Holmdel, Township of	0	•
Howell, Township of	0	
Interlaken, Borough of	0	•
Keansburg, Borough of	15	•
Keyport, Borough of	1	
Lake Como, Borough of	1	•
Little Silver, Borough of	2	
Loch Arbour, Village of	0	•
Long Branch, City of	69	•
Manalapan, Township of	0	•
Manasquan, Borough of	0	•

[10] SFHA 2050 = Special Flood Hazard Areas modeled for year 2050 with Sea Level Rise incorporated (high)

Jurisdiction	Acres of Potentially Developable Undeveloped Parcels Affected by Sea Level Rise[10]	Potential for Future Development on Undeveloped Parcels in Mapped Flood Areas to substantially increase flood hazard vulnerability under SFHA 2050
Marlboro, Township of	0	•
Matawan, Borough of	0	•
Middletown, Township of	23	•
Millstone Township	0	•
Monmouth Beach Borough	1	•
Neptune City, Borough of	2	•
Neptune, Township of	14	•
Ocean, Township of	0	•
Oceanport, Borough of	8	•
Red Bank, Borough of	0	•
Roosevelt, Borough of	0	•
Rumson, Borough of	10	•
Sea Bright, Borough of	0	
Sea Girt, Borough of	4	•
Shrewsbury, Borough of	0	
Shrewsbury, Township of	0	
Spring Lake, Borough of	5	•
Spring Lake Heights, Borough of	0	•
Tinton Falls, Borough of	0	•
Union Beach, Borough of	1	•
Upper Freehold, Township of	0	•
Wall, Township of	110	•
West Long Branch, Borough of	0	

As part of this HMP update, the Project Team analyzed future potential development at risk of flooding by computing vacant, private, upland acreage located within and outside the SHFA. The Project Team used County tax data to calculate the total parcel acreage for each municipality and compared total acreage to the acreage of vacant, private (excluding farmland preservation and open space), upland (excluding water and wetlands) located within and outside the SFHA. Vacant land is determined by the County's MOD IV parcel data, not aerial interpretation. Table 4.2 - 26 Potential Developable Land Within SFHA displays each municipality's potential developable land located within an outside the SFHA, ranked by most vulnerable to flooding to least vulnerable.

Table 4.2 - 26 Developable Land Within SFHA

Municipality	Total Parel Acres	Total Acres of Vacant, Private, Upland Inside SFHA	Percentage	Total Acres of Vacant, Private, Upland Outside SFHA	Percentage
Middletown, Township of	4499.94	72.64	1.61%	331.76	0.00%
Long Branch, City of	956.05	57.79	6.04%	213.31	0.01%
Manalapan, Township of	5138.05	49.73	0.97%	1295.88	0.00%
Union Beach, Borough of	320.61	48.84	15.23%	3.77	0.05%
Sea Bright, Borough of	152.06	47.98	31.55%	2.84	0.21%
Monmouth Beach Borough	123.46	41.94	33.97%	22.36	0.28%
Howell, Township of	10761.65	33.14	0.31%	1581.44	0.00%
Keansburg, Borough of	161.44	29.52	18.29%	1.26	0.11%
Rumson, Borough of	430.68	28.78	6.68%	33.39	0.02%
Brielle, Borough of	343.83	24.54	7.14%	75.91	0.02%
Oceanport, Borough of	540.47	22.92	4.24%	48.09	0.01%
Colts Neck, Township of	5284.99	17.10	0.32%	269.07	0.00%
Hazlet, Township of	1016.89	16.11	1.58%	84.52	0.00%
Marlboro, Township of	4067.46	15.10	0.37%	775.37	0.00%
Aberdeen, Township of	919.94	14.22	1.55%	193.47	0.00%
Neptune, Township of	1536.36	11.82	0.77%	249.60	0.00%
Freehold, Township of	5739.53	11.69	0.20%	910.43	0.00%
Highlands, Borough of	137.51	11.62	8.45%	16.94	0.06%
Atlantic Highlands, Borough of	466.43	11.38	2.44%	84.83	0.01%
Tinton Falls, Borough of	4369.22	10.49	0.24%	742.95	0.00%
Keyport, Borough of	356.65	9.88	2.77%	17.99	0.01%
Manasquan, Borough of	166.81	7.21	4.32%	3.50	0.03%
Little Silver, Borough of	189.89	6.73	3.54%	12.09	0.02%
Millstone Township	3743.04	6.59	0.18%	733.70	0.00%
Shrewsbury, Borough of	442.59	5.96	1.35%	46.51	0.00%
Upper Freehold, Township of	12579.34	4.87	0.04%	404.49	0.00%
Englishtown, Borough of	156.06	4.37	2.80%	25.21	0.02%
Ocean Township	1696.42	4.11	0.24%	171.59	0.00%
Deal, Borough of	117.73	3.67	3.12%	32.57	0.03%
Wall, Township of	5539.34	3.58	0.06%	686.92	0.00%
West Long Branch, Borough of	507.08	3.22	0.63%	34.64	0.00%
Asbury Park, City of	252.60	2.71	1.07%	37.58	0.00%
Matawan, Borough of	352.55	2.60	0.74%	24.10	0.00%
Eatontown, Borough of	1997.62	2.29	0.11%	162.26	0.00%
Belmar, Borough of	78.71	2.11	2.68%	7.91	0.03%

Municipality	Total Parel Acres	Total Acres of Vacant, Private, Upland Inside SFHA	Percentage	Total Acres of Vacant, Private, Upland Outside SFHA	Percentage
Red Bank, Borough of	337.15	1.85	0.55%	48.43	0.00%
Spring Lake Heights, Borough of	258.69	1.66	0.64%	9.86	0.00%
Fair Haven, Borough of	70.62	1.42	2.01%	12.90	0.03%
Spring Lake, Borough of	68.72	1.34	1.95%	11.73	0.03%
Avon-by-the-Sea, Borough of	38.73	1.26	3.26%	2.47	0.08%
Sea Girt, Borough of	257.02	1.09	0.42%	7.72	0.00%
Neptune City, Borough of	173.37	0.85	0.49%	6.13	0.00%
Allentown, Borough of	71.13	0.47	0.65%	3.89	0.01%
Farmingdale, Borough of	120.81	0.46	0.38%	3.58	0.00%
Holmdel, Township of	2242.44	0.40	0.02%	433.52	0.00%
Bradley Beach, Borough of	57.85	0.25	0.44%	1.80	0.01%
Lake Como, Borough of	24.49	0.22	0.90%	5.38	0.04%
Loch Arbour, Village of	7.31	0.21	2.82%	0.37	0.39%
Interlaken, Borough of	19.08	0.02	0.11%	1.68	0.01%
Allenhurst, Borough of	23.69	0.00	0.00%	2.00	0.00%
Freehold, Borough of	452.55	0.00	0.00%	60.18	0.00%
Roosevelt, Borough of	185.74	0.00	0.00%	0.49	0.00%
Shrewsbury, Township of	38.57	0.00	0.00%	0.00	0.00%

SOUCES: NJGIN, FEMA, NJDEP, MOD-VI PARCEL DATA

4.2.22 TSUNAMI: HAZARD DESCRIPTION

FEMA and NOAA state that tsunamis are a series of traveling ocean waves created by sudden displacements of the ocean floor (earthquakes) or volcanic activity. A tsunami can move hundreds of miles per hour in the open ocean and crash into land with waves exceeding 100 feet in height (FEMA 2009). A tsunami consists of a series of high-energy waves that travel outward, like pond ripples, from the area where the tsunami originated. The sequence of tsunami waves arrives at the shoreline over an extended period of time and build height as it gets closer (FEMA, 2007; Humboldt County Hazard Mitigation Plan, 2008). A tsunami approaching the shoreline may take three forms: non-breaking waves that act as a rapidly rising tide; a large, turbulent wall-like wave (bore); or a series of partially developed waves (Humboldt County Hazard Mitigation Plan 2008).

A rare form of a tsunami, called Meteotsunami, has also affected Monmouth County. Unlike tsunamis triggered by seismic activity, meteotsunamis are driven by air-pressure disturbances often associated with fast-moving weather events. The storm generates a wave that moves towards the shore and is amplified by a shallow continental shelf and inlet, bay, or other coastal feature (NOAA, 2019).

4.2.23 TSUNAMI: LOCATION

According to a document titled U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves, the United States Atlantic Coast and the Gulf Coast have experienced very few tsunamis in the last 200 years. NOAA's National Geophysical Data Center (NGDC) compiled a listing of all tsunamis and tsunami-like waves of the eastern United States and Canada. Forty-nine potential tsunami events have been identified as possibly impacting the East Coast of the United States between 1668 and 2008. Of these events, eight were categorized as definite or probable tsunamis (NOAA NGDC, 2013). No mega tsunamis have occurred in the Atlantic or Pacific Oceans in recorded history and therefore the risk of tsunami remains low in Monmouth County.

4.2.24 TSUNAMI: EXTENT

When a major undersea earthquake occurs near the coast at a shallow depth, a destructive tsunami can be generated. This tsunami could impact near-by coasts within minutes and could travel across entire ocean basins causing damage 1,000 miles away. To notify distant coastal areas, internationally coordinated tsunami warning systems have been established to provide warning to countries regarding regional-to-distant tsunamis. This information is provided to emergency officials, and as appropriate, directly to the public (International Tsunami Information Centre 2008).

NOAA extensively monitors the Pacific Ocean for tsunamis that could impact Hawaii, Alaska, California, Oregon, and Washington. NOAA's Deep-ocean Assessment and Report Tsunamis (DART) program is part of the United States National Tsunami Hazard Mitigation Program and includes seismic networks, tsunami detection buoys and tidal gauges (Maine Geological Survey 2008).

In the Atlantic Ocean, there is no tsunami monitoring program. Although a monitoring program does not exist, the United States Geological Survey (USGS) operates the United States National Seismograph Network, which is part of the Global Seismic Network that monitors seismic activity around the world. These networks detect seismic events that are capable of producing a tsunami. Soon after an earthquake occurs, activity is recorded by seismographs and sent via satellite to the United States National Seismograph Network in Colorado. There, it is analyzed and warnings, if needed, are issued (Maine Geological Survey 2008).

4.2.25 TSUNAMI: PREVIOUS OCCURRENCES AND LOSSES

While the probability of a large tsunami impacting the coast of New Jersey is very small due to the position along the trailing edge of the North Atlantic Plate, the Mid-Atlantic region has been subjected to minor tsunami action over the past 250 years and perhaps significant tsunami action over the last geologic period.

Lockridge, et al. (2002) analyzed tsunami and tsunami-like waves that have impacted the East Coast of the United States. NOAA's NGDC compiled a listing of all tsunamis and tsunami-like waves of the eastern United States and Canada. Thirty-nine potential tsunami events have been identified as possibly impacting the East Coast of the United States since 1668. Of these events, four are categorized as definite or probable tsunamis.

The NGDC identified seven potential tsunami events that may have impacted the State of New Jersey. Of those seven events, two were categorized as a probable tsunami. Table 4.2-27 Previous Occurrences and Losses in New Jersey, 1821-2017 describes potential tsunami events that have impacted the State of New Jersey. The most recent tsunami event occurred in 2013 and was a Meteotsunami that was caused by a strong weather system that moved from across the eastern U.S. that day.

Table 4.2 - 27 Previous Occurrences and Losses in New Jersey 1821- 2017

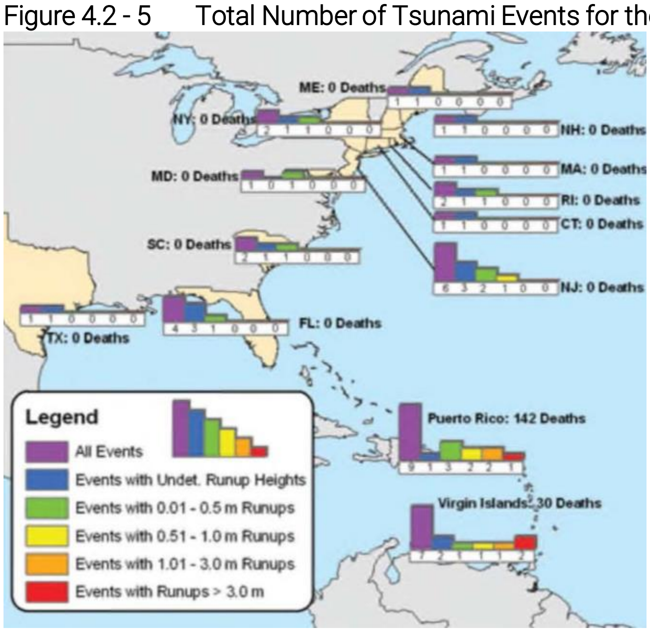
Event Date	Source Location	County	Description/Losses
September 3, 1821	North Carolina	Statewide	A hurricane passed over the Outer Banks of North Carolina and over the Delmarva Peninsula. It entered Cape May County where it followed a path similar to that of where the Garden State Parkway is today. Miles of sandbars were exposed the next morning. A dull roar approached and then a solid mass of wind and rain came tearing great pines from the ground and moving houses from their foundations. A wall of water struck that carried away people and animals.
August 10, 1884	Philadelphia, PA	Statewide	A 5.6 earthquake generated a tsunami that was reported from Philadelphia, Trenton, and Highlands. In Trenton, the water in the city reservoir was agitated and a small tidal wave was noticed on the canal and feeder. In Highlands, two men were fishing and felt as if the water was had gone out from under their boat and it was grating on the sand.
September 8, 1889	Asbury Park, NJ	Monmouth	This event occurred during the Mudhen Hurricane. Unusually high waves were reported between September 8 and 10 in the Mid-Atlantic Coast. In New Jersey, these waves were reported in Asbury Park, Atlantic City, Sea Isle City, Coney Island, Long Island, Staten Island and other exposed points.
September 1, 1895	High Bridge, NJ	Hunterdon	A 4.3 earthquake centered near High Bridge was felt over a large area to the northeast and southwest. The earthquake was felt from Maine to Virginia. The earthquake knocked articles from shelves and rocked buildings in several towns in New Jersey, Pennsylvania, and New York. In Asbury Park, NJ, plaster was knocked from walls. The earthquake caused a tsunami-like wave on Long Island. There was one run-up associated with this event. It caused one injury.
June 9, 1913	Longport, NJ	Atlantic	It was reported that heavy tides were associated with this event. There were no reports of storms or earthquakes in the northeast United States on this date. Damage in Longport occurred at the Thoroughfare waterfront when a 250-foot section of the embankment at 23rd Street was carried away. The washout extended to within 15 feet of the nearby rail line. The tide tore away the wharf at the Schurch chandlery store and it undermined the soil from the building. The Lavine Wharf was completely torn away. This event caused $10,000 in damage. There was one injury associated with this event.
August 19, 1931	Atlantic City, NJ	Atlantic	There was a sudden and brief onset of 3-meter waves in Atlantic City. Reports state that the surf was rough the day of the event and the waves rolled in shortly before noon. The waves arrived during high tide. There were other high wave events in the region, causing four people to drown. The weather bureau attributed this event to a tropical storm north of Puerto Rico.
June 13, 2013	East Coast	Ocean	A rare type of tsunami called a "Meteotsunami" hit the New Jersey coast. It was caused by a strong weather system that moved from across the eastern U.S. that day. The weather system caused a jump in air pressure, which created the wave. The impacts were greatest in Barnegat Light. An approximately 6-foot wave knocked three people off the inlet jetty, injuring at least two of them. No coastline damage was reported.

SOURCE: LOCKRIDGE ET AL. 2002; NOAA, 2017

According to the 2008 NOAA study (U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves), tsunami events and losses were summarized for the Atlantic Region. Figure 4.2-5 Total Number of Tsunami Events for the United States and Territories shows the number of tsunami events and total number of events causing run-up heights from 0.1 meters to greater than three meters for the United States and its territories in the Atlantic, Gulf Coast, Puerto Rico, and the United States Virgin Islands.

The table indicates that New Jersey has experienced seven tsunami events with any observed run-up. Run-up is a measurement of the height of the water onshore observed above a reference sea level. Tsunami run-up occurs when a peak in the tsunami wave travels from the near-shore region onto shore. There were no reported deaths or injuries associated with these events.

Figure 4.2 - 5 Total Number of Tsunami Events for the United States and Territories



SOURCE: DUNBAR AND WEAVER 2008

4.2.26 TSUNAMI: PROBABILITY OF FUTURE OCCURRENCE

Tsunamis will continue to have a low probability of occurrence for Monmouth County.

4.2.27 TSUNAMI: VULNERABILITY ASSESSMENT

Impacts

When a tsunami event occurs, the first information available about the source of the tsunami is based only on the available seismic information for the earthquake event. As the tsunami wave propagates across the ocean and successively reaches the DART stations, these systems report sea level measurement information back to the Tsunami Warning Centers. The centers process the information and produce a new and more refined estimate of the tsunami source. The result is an increasingly accurate forecast of the tsunami that can be used to issue watches, warnings, or evacuations.

Aside from the tremendous hydraulic force of the tsunami waves themselves, floating debris carried by a tsunami can endanger human lives and batter inland structures. Ships moored at piers and in harbors often are swamped and sunk or are left battered and stranded high on the shore. Breakwaters and piers collapse, sometimes from scouring actions that sweep away their foundation and sometimes because of the direct wave impact. Railroad yards and oil tanks situated near the waterfront are particularly vulnerable. Oil fires frequently result and can be spread by the waves.

Port facilities, naval facilities, fishing fleets, and public utilities are often the backbone of the economy of the affected areas. These resources generally receive the most severe damage. Until debris can be cleared, wharves and piers rebuilt, utilities restored, and fishing fleets reconstituted, communities may find themselves without fuel, food, and employment. Wherever water transport is a vital means of supply, disruption of coastal systems caused by tsunamis can have far-reaching economic effects.

Exposure and Damages

There are no defined stormwater, tsunami or ice jam hazard areas identified at this time. Therefore, the vulnerability to these hazards is discussed in a qualitative nature below. As tsunami inundation or hazard areas are developed, they will be used to conduct a spatial analysis to identify the most vulnerable residents and structures in the tsunami hazard zone and be used to focus public education and outreach efforts on these communities. Further, tsunami inundation maps will provide information needed to create evacuation maps.

4.2.28 STORM SURGE: HAZARD DESCRIPTION

A storm surge is a large dome of water often 50 to 100 miles wide and rising anywhere from four to five feet in a Category 1 hurricane up to more than 30 feet in a Category 5 storm. Storm surge heights and associated waves are also dependent upon the shape of the offshore continental shelf (narrow or wide) and the depth of the ocean bottom (bathyrnetry). A narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water close to the shoreline, tends to produce a lower surge but higher and more powerful storm waves. Storm surge arrives ahead of a storm's actual landfall and the more intense the hurricane is, the sooner the surge arrives. Storm surge can be devastating to coastal regions, causing severe beach erosion and property damage along the immediate coast. Further, water rise caused by storm surge can be very rapid, posing a serious threat to those who have not yet evacuated flood-prone areas. Storm surge can be exacerbated if occurring at or near high tide.

4.2.29 STORM SURGE: LOCATION

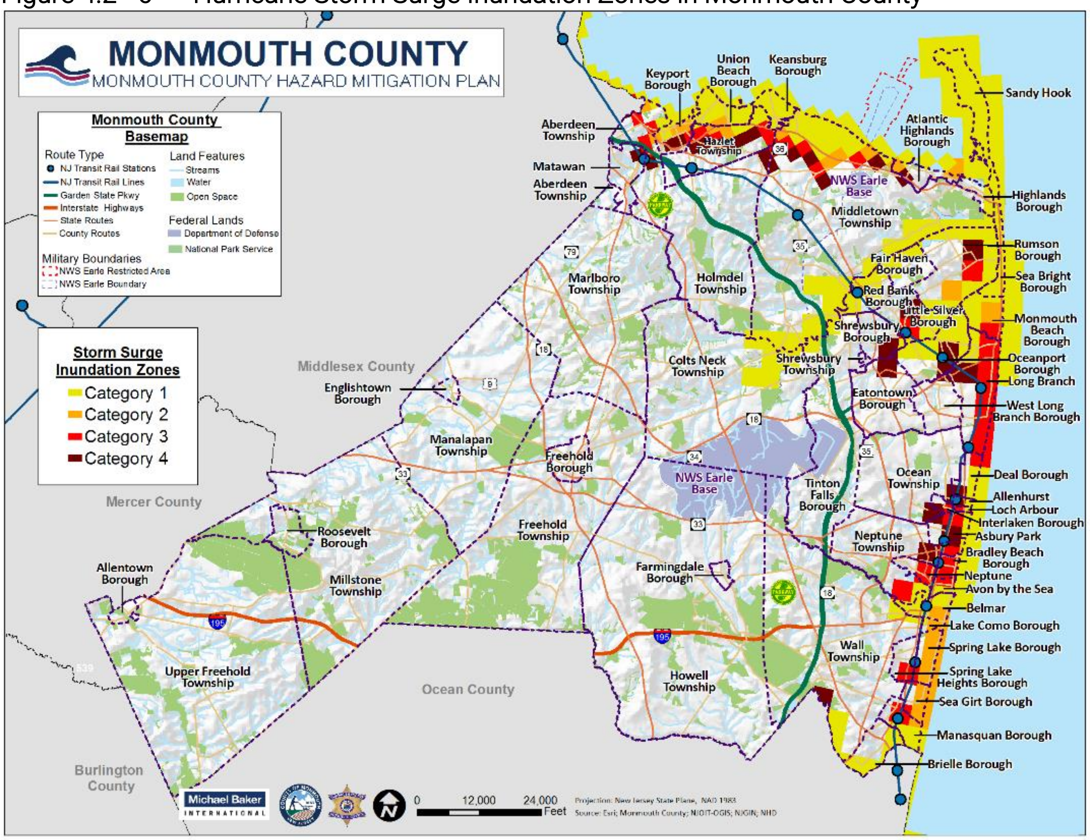
There are many areas in Monmouth County subject to potential storm surge inundation as modeled and mapped by the U.S. Army Corps of Engineers (USACE). **Figure 4.2 – 6 Hurricane Storm Surge Inundation Zones in Monmouth County** illustrates inundation zones storm surges associated with hurricanes of Category 1 to 4 for Monmouth County derived from georeferenced Sea, Lake and Overland Surge from Hurricanes (SLOSH) data produced by the USACE in coordination with NOAA[11]. SLOSH is a modeling tool used to estimate storm surge for coastal areas resulting from historical, hypothetical or predicted hurricanes taking into account maximum expected levels for pressure, size, forward speed, track and winds. Therefore, the SLOSH data is best used for defining the potential maximum surge associated

[11] This data represents a polygon feature set in Monmouth County showing the limits of potential flooding from Category 1-4 hurricanes. The data was compiled by the U.S. Army Corps of Engineers as part of a Hurricane Evacuation Study (HES) in 2005-2006 (http://www.nap.usace.army.mil/HES/nj/index.html). The USACE gathered 2003 contour lines data from Monmouth County as part of its calculations in using the National Weather Service- National Hurricane Center's SLOSH model (Sea, Lake and Overland Surges from Hurricanes)

with various storm intensities for any particular location. Storm surge arrives prior to a hurricane's landfall, and the greater the hurricane's intensity, the sooner the surge arrives. In 2016, Monmouth County used the SLOSH models to create their own awareness program, Know Your Zone. This educational campaign informs residents, businesses, and visitors of the County of the new hurricane evacuation zones and their vulnerability to storm surge, especially in those high-risk communities.

As shown in the **Figure 4.2-6 Hurricane Storm Surge Inundation Zones in Monmouth County**, all of the County's coastal jurisdictions are at high risk to storm surge inundation. While non-coastal areas may not be directly impacted by storm surge inundation, they might experience flooding caused by storm surge and extremely high tides that can affect the drainage of areas further inland. In total, 41 (77 percent) of municipal jurisdictions have been identified as being at risk to the storm surge hazard in Monmouth County.

Figure 4.2 - 6 Hurricane Storm Surge Inundation Zones in Monmouth County



SOURCE: NOAA

4.2.30 STORM SURGE: EXTENT

The magnitude or severity of the storm surge hazard is generally related to the associated winds resulting from coastal storms (i.e. hurricanes, tropical storms, nor'easters). NOAA's Coastal Inundation Dashboard is used to measure the extent of storm surge.

4.2.31 STORM SURGE: PREVIOUS OCCURRENCES AND LOSSES

Before Superstorm Sandy, there is very limited data available for historical weather events that have caused storm surge inundation in Monmouth County. According to NCDC records, Monmouth County experienced a storm surge event in February 2006 that accounted for an estimated $900,000 in property damages, as described below. Storm surge has been a major factor associated with other weather events affecting Monmouth County, particularly nor'easters.

February 12, 2006. The major winter storm that affected New Jersey had a major impact on the New Jersey shore. Strong onshore winds along with high tides produced coastal flooding along with beach erosion. Across coastal Monmouth County, minor to locally moderate coastal flooding was reported across many areas. In the Monmouth Beach area, a storm surge flooded the Patten Avenue Bridge along with some other streets during the early morning, where some cars were overtaken by water.

Hurricane Irene 2011 and **Superstorm Sandy 2012.** Storm surge associated with Hurricane's Irene and Sandy was extensive and devastating for most coastal and Bayshore communities during Sandy. This is discussed in detail in the section on Hurricanes and Tropical Storms.

Other notable reports of historical storm surge events include the following, as identified by the Planning Committee:

- The Borough of Allenhurst lost numerous beach buildings to storm surge during the 1992 nor'easter event.
- The Borough of Bradley Beach has experienced significant flooding issues due to storm surge in the past.
- Little Silver Borough indicated that the storm surge associated with the 1992 nor'easter was measured at a height of 11 feet and caused major coastal flooding along the waterfront.

4.2.32 STORM SURGE: PROBABILITY OF FUTURE OCCURRENCE

The probability of a named storm making landfall in the vicinity of Monmouth County is 13 percent but is less for events that cause significant storm surge (dependent on storm speed, direction, tides, etc.). However, less severe to moderate storm surge events typically associated with nor'easters and less intense coastal storms are more likely to occur, and in the case of nor'easters will last longer and possibly cause more damage than fast-moving hurricanes. Additionally, the long-term rise in sea level can be expected to impact the occurrence of significant storm surges and hence future damages from coastal flooding in Monmouth County. Rising sea levels over time will shorten the return period (or exceedance interval) and hence increase the frequency of significant storm surge events. To take a hypothetical example, a one-foot rise in sea level over 50 years could result in a storm surge event with a current annual occurrence probability of 2% (a "50-year" event) becoming an event of 10% annual probability (a "10-year" event).

4.2.33 STORM SURGE: POTENTIAL EFFECTS OF CLIMATE CHANGE

The frequency and intensity of coastal storms and severe weather events is expected to increase in the future due to climate change. In the years to come, it is anticipated that Monmouth County will observe drastic changes in storm character, intensity, frequency, and storm tracking. Hurricanes are likely to become more intense with rising sea water temperatures. Coastal erosion rates are likely to increase with rising sea-level, to levels higher than those rates that have been observed over the last century. Storm effects will be more extensive in the future. The following types of impacts can be anticipated in Monmouth County's future as a result of climate change and sea level rise: inundation of low-lying areas; increased frequency and extent of storm-related flooding; wetland loss; saltwater intrusion into estuaries and freshwater aquifers; land loss through submergence and erosion of lands in coastal areas; migration of coastal landforms and habitats; increased salinity in estuaries and coastal fresh; impacts to human populations (property losses, more frequent flood damage, more frequent flooding of roadways and urban centers, risks to people as the population of coastal areas increases); more buildings and infrastructure exposed; currently exposed buildings and infrastructure could be subject to potentially greater losses as water levels increase, and continued rapid coastal development exacerbates the impacts of sea level rise; impacts on gravity flow stormwater systems; impacts on non-coastal areas. Impacts of climate change and sea level rise can affect all parts of a community, including: transportation infrastructure (ports, marinas, airports, roads, bridges, railways); public infrastructure (stormwater and wastewater management systems, drinking water supply and distribution systems, power utility systems, communications systems); public facilities (i.e., police, fire, ambulance, hospitals, schools, daycare centers, adult living facilities, historic landmarks, government buildings, libraries, parks, etc.); economic viability of a community - particularly for communities where tourism tends to drive local economies, as is the case in many of Monmouth County's coastal communities. Climate change and sea level rise could lead to a potential loss of assets that support tourism (i.e., beaches themselves as well beach access points, lodging, restaurants, marinas, fishing habitats, ecotourism, etc.).

4.2.34 STORM SURGE: VULNERABILITY ASSESSMENT

Impacts

Storm surge can be devastating to coastal regions, causing flooding, severe beach erosion, and property damage along the immediate coast. Furthermore, water can rise very rapidly due to storm surge, posing a serious threat to people remaining in inundation areas.

Exposure and Damage Estimates

Storm surge is a flood hazard which is related to hurricanes, which differs from coastal flood events. Only storm surge related to hurricanes is analyzed in this section. Due to data limitations, analysis for ordinary coastal flooding events not associated with hurricanes could not be modeled in this risk assessment. In order to assess storm surge risk, two distinct vulnerability assessment approaches were applied for Monmouth County in order to assess exposure and potential losses to storm surge hazard events. This includes a GIS-based analysis to estimate exposure and HAZUS-MH to estimate potential losses for storm surge events.

Coastal flood inundation zone maps were derived from georeferenced data produced by the National Oceanic and Atmospheric Administration (NOAA). Storm surge data was provided from NOAA Sea, Lake and Overland Surges from Hurricanes (SLOSH) data (2006). SLOSH is a modeling tool used to estimate storm surge resulting from historical, hypothetical or predicted hurricanes. In this analysis, color- coded storm surge inundation areas were created and overlaid with parcel and census block data, defining the potential maximum surge for coastal locations in Monmouth County. For Monmouth County, the New York (NY2) SLOSH basin was used.

To estimate exposure to storm surge, the determination of value and population at-risk was calculated through GIS analysis by calculating the proportion of a parcel or census block lying within an identified storm surge zone (Category 1-4 storm events), and applying that same ratio to the census block population and parcel value to estimate population at risk and value of improvements at risk, as presented in **Table 4.2-28 Exposure in Storm Surge Areas by Jurisdiction**. Five jurisdictions are 100 percent exposed to storm surge: Keansburg, Loch Arbour, Monmouth Beach, Sea Bright, and Union Beach. Twelve jurisdictions have no improved property exposed to storm surge. Jurisdictions are color-coded according to the percent of buildings in the SFHA: those in dark blue have greater than 75% of their buildings in the SFHA; those in the medium shade of blue have greater than 50% of their buildings in the SFHA; those in light blue have greater than 25% of their buildings in the SFHA.

Table 4.2 - 28 Exposure in Storm Surge Areas by Jurisdiction (2018 Values)

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located in Category 1-4 Storm Surge Areas*	Percent of Total Building Value Exposed to Surge
Keansburg, Borough of	10,105	$343,826,000	$393,782,623	100.00%
Loch Arbour, Village of	194	$69,262,800	$43,964,818	100.00%
Monmouth Beach, Borough of	3,279	$501,592,200	$509,731,405	100.00%
Sea Bright, Borough of	1,414	$235,586,800	$268,030,710	100.00%
Union Beach, Borough of	6,245	$387,844,700	$288,161,877	100.00%
Belmar, Borough of	5,750	$553,347,900	$566,789,888	99.20%
Avon-By-The-Sea, Borough of	1,829	$266,879,900	$383,429,812	98.40%
Lake Como, Borough of	1,609	$140,566,300	$163,293,100	93.12%
Sea Girt, Borough of	1,520	$732,097,100	$483,183,139	91.47%
Bradley Beach, Borough of	3,788	$462,112,100	$400,929,137	88.35%
Manasquan, Borough of	4,862	$799,826,975	$711,352,880	87.29%
Oceanport, Borough of	4,721	$562,875,800	$499,778,269	85.57%
Interlaken, Borough of	649	$125,000,500	$78,362,097	75.89%
Spring Lake, Borough of	2,060	$1,028,817,800	$862,005,595	73.07%
Asbury Park, City of	11,274	$1,267,473,400	$583,563,435	62.99%
Long Branch, City of	18,701	$2,478,681,000	$1,527,802,728	57.84%
Allenhurst, Borough of	403	$217,949,000	$104,392,891	56.65%
Highlands, Borough of	2,779	$342,874,400	$178,112,497	55.93%
Rumson, Borough of	3,970	$1,600,650,400	$885,822,692	55.71%
Little Silver, Borough of	3,090	$873,512,700	$449,644,784	53.39%
Neptune City, Borough of	2,649	$305,279,900	$140,452,387	51.86%
Brielle, Borough of	2,181	$669,338,900	$254,268,555	46.04%
Keyport, Borough of	3,548	$434,885,600	$183,425,844	38.56%
Neptune, Township of	9,413	$2,431,214,700	$636,714,664	37.12%
Atlantic Highlands, Borough of	1,236	$364,693,600	$81,800,609	28.84%
Spring Lake Heights, Borough of	1,474	$525,407,200	$141,598,370	27.69%
Hazlet, Township of	6,736	$1,215,098,000	$369,369,674	27.06%
Deal, Borough of	136	$822,100,400	$122,446,063	21.25%
Shrewsbury, Borough of	891	$608,635,700	$102,521,547	18.56%
Fair Haven, Borough of	1,011	$785,619,700	$113,983,854	17.17%
West Long Branch, Borough of	1,513	$889,026,200	$151,608,715	17.13%

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located in Category 1-4 Storm Surge Areas*	Percent of Total Building Value Exposed to Surge
Middletown, Township of	17,876	$5,895,810,731	$956,929,375	17.06%
Eatontown, Borough of	1,223	$1,314,725,700	$188,374,201	14.44%
Red Bank, Borough of	858	$1,194,733,400	$69,189,167	5.18%
Ocean, Township of	1,686	$2,684,842,000	$99,458,836	4.23%
Aberdeen, Township of	2,044	$1,074,509,800	$42,530,763	3.57%
Wall, Township of	1,646	$3,053,292,400	$86,795,703	3.35%
Matawan, Borough of	484	$517,395,800	$7,128,608	1.26%
Tinton Falls, Borough of	430	$1,691,986,800	$13,953,265	0.61%
Holmdel, Township of	315	$2,104,382,100	$4,930,564	0.21%
Howell, Township of	473	$4,204,216,400	$222,755	0.01%
Allentown, Borough of	0	$127,734,200	$0	0.00%
Colts Neck, Township of	0	$927,454,500	$0	0.00%
Englishtown, Borough of	0	$158,314,100	$0	0.00%
Farmingdale, Borough of	0	$109,883,900	$0	0.00%
Freehold, Borough of	0	$771,202,500	$0	0.00%
Freehold, Township of	0	$4,433,974,800	$0	0.00%
Manalapan, Township of	0	$4,619,949,900	$0	0.00%
Marlboro, Township of	0	$4,435,729,800	$0	0.00%
Millstone, Township of	0	$1,232,191,160	$0	0.00%
Roosevelt, Borough of	0	$50,136,700	$0	0.00%
Shrewsbury, Township of	0	$30,450,000	$0	0.00%
Upper Freehold, Township of	0	$851,779,300	$0	0.00%
Monmouth County	142,143	$63,526,773,666	$13,144,104,601	21.18%

*EXPOSURE CALCULATED BY GIS ANALYSTS USING LOCAL ASSESSED VALUES

To analyze potential losses, color-coded storm surge inundation areas were created and overlaid with census block data, defining the potential maximum surge for coastal locations for each category of hurricane, as well as exposed structures located in those areas. A GIS analysis was conducted to verify that the surge boundaries and depths estimated reasonably correspond with the boundaries in the NOAA data, and HAZUS-MH inventory was used to estimate potential losses.

For developing the depth grid files, the SLOSH data was used in combination with ground elevation data from the USGS National Elevation Dataset (NED). The MOM value (Maximum of the Maximum Envelopes of Water; a composite measure that expresses the maximum flood elevation) for Categories 1, 2, 3 and 4 from the SLOSH data was used to determine the "surge" or water elevation. A GRID digital map of flood elevation was produced from the SLOSH shapefile data. A simple GIS operation of subtraction was performed with the ground elevation data set to determine the water depth.

HAZUS-MH was used to estimate potential losses in Monmouth County resulting from potential storm surge events. The flood depth estimates from the SLOSH shapefile data were imported into HAZUS to conduct a Level 2 HAZUS analysis. **Table 4.2 - 29 Estimated Potential Losses from Category 1, 2, 3 and 4 Storm Event**s shows estimated potential losses for Category 1, 2, 3 and 4 storm surge event scenarios for each jurisdiction. Similar to other HAZUS analysis, the values from HAZUS were adjusted to reflect the current assessed values for structures in each of the communities.

Table 4.2 - 29 Estimated Potential Losses from Category 1, 2, 3 and 4 Storm Surge Events

Jurisdiction	Potential Total Building Losses			
	Category 1 Event	Category 2 Event	Category 3 Event	Category 4 Event
Aberdeen, Township of	$8,296,213	$15,441,601	$25,974,486	$42,530,763
Allenhurst, Borough of	$7,883	$12,935,439	$42,428,282	$104,392,891
Allentown, Borough of	N/A	N/A	N/A	N/A
Asbury Park, City of	$14,242,126	$170,161,993	$395,024,008	$583,563,435
Atlantic Highlands, Borough of	$19,809,985	$43,024,022	$65,465,849	$81,800,609
Avon-By-The-Sea, Borough of	$85,172,790	$237,085,118	$362,068,087	$383,429,812
Belmar, Borough of	$84,126,810	$392,699,818	$547,606,724	$566,789,888
Bradley Beach, Borough of	$8,941,504	$112,228,504	$277,848,143	$400,929,137
Brielle, Borough of	$101,849,679	$167,547,967	$214,166,925	$254,268,555
Colts Neck, Township of	$0	$0	$0	$0
Deal, Borough of	$1,671,112	$10,839,088	$48,155,944	$122,446,063
Eatontown, Borough of	$444,384	$713,649	$11,545,755	$188,374,201
Englishtown, Borough of	N/A	N/A	N/A	N/A
Fair Haven, Borough of	$9,256,605	$24,947,200	$50,981,373	$113,983,854
Farmingdale, Borough of	N/A	N/A	N/A	N/A
Freehold, Borough of	N/A	N/A	N/A	N/A
Freehold, Township of	N/A	N/A	N/A	N/A
Hazlet, Township of	$65,776,106	$116,181,447	$234,076,575	$369,369,674
Highlands, Borough of	$158,821,335	$174,007,410	$175,253,058	$178,112,497
Holmdel, Township of	$350,574	$705,991	$2,011,213	$4,930,564
Howell, Township of	N/A	N/A	N/A	N/A
Interlaken, Borough of	$4,521,429	$17,063,163	$47,612,458	$78,362,097
Keansburg, Borough of	$301,490,910	$382,321,668	$393,024,828	$393,782,623
Keyport, Borough of	$17,742,351	$42,449,341	$91,021,064	$183,425,844
Lake Como, Borough of	$13,116,752	$37,200,636	$102,532,584	$163,293,100
Little Silver, Borough of	$175,555,770	$268,327,229	$356,864,541	$449,644,784
Loch Arbour, Village of	$8,476,962	$28,069,486	$38,083,209	$43,964,818
Long Branch, City of	$381,555,089	$693,888,241	$947,406,095	$1,527,802,728
Manalapan, Township of	N/A	N/A	N/A	N/A
Manasquan, Borough of	$377,670,505	$510,772,429	$613,646,127	$711,352,880
Marlboro, Township of	N/A	N/A	N/A	N/A
Matawan, Borough of	$0	$1,031,903	$6,211,236	$7,128,608
Middletown, Township of	$407,303,554	$591,212,071	$790,374,120	$956,929,375
Millstone, Township of	N/A	N/A	N/A	N/A
Monmouth Beach, Borough of	$441,358,368	$491,535,773	$509,731,405	$509,731,405
Neptune City, Borough of	$6,918,016	$43,050,599	$98,535,946	$140,227,154
Neptune, Township of	$64,867,969	$172,246,317	$412,542,462	$636,714,664
Ocean, Township of	$2,394,221	$10,213,167	$43,650,618	$99,458,836
Oceanport, Borough of	$256,495,090	$350,582,357	$461,035,579	$499,778,269
Red Bank, Borough of	$26,752,664	$36,046,657	$58,775,318	$69,189,167
Roosevelt, Borough of	N/A	N/A	N/A	N/A
Rumson, Borough of	$368,828,215	$552,439,876	$742,833,174	$885,822,692
Sea Bright, Borough of	$245,446,536	$267,831,492	$268,030,710	$268,030,710
Sea Girt, Borough of	$24,298,306	$136,709,473	$349,094,021	$483,183,139
Shrewsbury, Borough of	$9,152,547	$30,092,186	$63,422,765	$102,521,547

Jurisdiction	Potential Total Building Losses			
	Category 1 Event	Category 2 Event	Category 3 Event	Category 4 Event
Shrewsbury, Township of	N/A	N/A	N/A	$6,508
Spring Lake, Borough of	$117,676,653	$242,588,786	$489,852,273	$862,005,595
Spring Lake Heights, Borough of	$4,433,589	$30,295,458	$78,987,343	$141,598,370
Tinton Falls, Borough of	$789,102	$1,645,098	$6,053,799	$13,953,265
Union Beach, Borough of	$143,508,566	$250,571,927	$283,180,185	$288,161,877
Upper Freehold, Township of	N/A	N/A	N/A	N/A
Wall, Township of	$9,183,066	$17,785,033	$37,189,036	$86,795,703
West Long Branch, Borough of	$4,235,722	$9,911,130	$36,848,260	$151,608,715
Monmouth County	$3,969,395,941	$6,694,400,742	$9,779,145,576	$13,149,612,661

SOURCE: HAZUS-MH

Table 4.2 - 30 Potential Annualized Losses from Storm Surge by Jurisdiction shows potential annualized property losses, or estimated damages over a period of time, and percent loss ratios, the percentage of loss, resulting from storm surge by jurisdiction.

Table 4.2 - 30 Potential Annualized Losses from Storm Surge by Jurisdiction (2018 Values)

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Buildings Exposed to Surge (2018 Values)	Total Annualized Expected Property Losses (2018 Values)	Annualized Percent Loss Ratio
Keansburg, Borough of	10,105	$393,782,623	$17,917,109	4.55%
Union Beach, Borough of	6,245	$288,161,877	$13,024,916	4.52%
Sea Bright, Borough of	1,414	$268,030,710	$10,426,395	3.89%
Manasquan, Borough of	4,862	$711,352,880	$15,863,169	2.23%
Highlands, Borough of	2,779	$178,112,497	$3,312,893	1.86%
Monmouth Beach, Borough of	3,279	$509,731,405	$8,002,783	1.57%
Avon-By-The-Sea, Borough of	1,829	$383,429,812	$5,252,988	1.37%
Belmar, Borough of	5,750	$566,789,888	$6,631,441	1.17%
Rumson, Borough of	3,970	$885,822,692	$9,832,632	1.11%
Brielle, Borough of	2,181	$254,268,555	$2,796,954	1.10%
Spring Lake, Borough of	2,060	$862,005,595	$7,240,847	0.84%
Allenhurst, Borough of	403	$104,392,891	$845,582	0.81%
Loch Arbour, Village of	194	$43,964,818	$356,115	0.81%
Interlaken, Borough of	649	$78,362,097	$517,190	0.66%
Lake Como, Borough of	1,609	$163,293,100	$963,430	0.59%
Oceanport, Borough of	4,721	$499,778,269	$2,948,692	0.59%
Keyport, Borough of	3,548	$183,425,844	$990,499	0.54%
Bradley Beach, Borough of	3,788	$400,929,137	$2,004,646	0.50%
Long Branch, City of	18,701	$1,527,802,728	$6,875,112	0.45%
Deal, Borough of	136	$122,446,063	$453,051	0.37%
Hazlet, Township of	6,736	$369,369,674	$1,292,794	0.35%
Middletown, Township of	17,876	$956,929,375	$3,349,253	0.35%
Red Bank, Borough of	858	$69,189,167	$242,162	0.35%
Little Silver, Borough of	3,090	$449,644,784	$1,393,899	0.31%

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Buildings Exposed to Surge (2018 Values)	Total Annualized Expected Property Losses (2018 Values)	Annualized Percent Loss Ratio
Neptune, Township of	9,413	$636,714,664	$1,846,473	0.29%
Asbury Park, City of	11,274	$583,563,435	$1,575,622	0.27%
Spring Lake Heights, Borough of	1,474	$141,598,370	$382,315	0.27%
Sea Girt, Borough of	1,520	$483,183,139	$1,256,276	0.26%
Atlantic Highlands, Borough of	1,236	$81,800,609	$163,601	0.20%
Neptune City, Borough of	2,649	$140,227,154	$266,432	0.19%
Aberdeen, Township of	2,044	$42,530,763	$63,796	0.15%
Fair Haven, Borough of	1,011	$113,983,854	$136,780	0.12%
Wall, Township of	1,646	$86,795,703	$69,437	0.08%
Shrewsbury, Borough of	891	$102,521,547	$71,765	0.07%
Ocean, Township of	1,686	$99,458,836	$59,675	0.06%
Eatontown, Borough of	1,223	$188,374,201	$18,837	0.01%
Allentown, Borough of	0	$0	$0	0.00%
Colts Neck, Township of	0	$0	$0	0.00%
Englishtown, Borough of	0	$0	$0	0.00%
Farmingdale, Borough of	0	$0	$0	0.00%
Freehold, Borough of	0	$0	$0	0.00%
Freehold, Township of	0	$0	$0	0.00%
Holmdel, Township of	315	$4,930,564	$0	0.00%
Howell, Township of	473	$222,755	$0	0.00%
Manalapan, Township of	0	$0	$0	0.00%
Marlboro, Township of	0	$0	$0	0.00%
Matawan, Borough of	484	$7,128,608	$0	0.00%
Millstone, Township of	0	$0	$0	0.00%
Roosevelt, Borough of	0	$0	$0	0.00%
Shrewsbury, Township of	0	$0	$0	0.00%
Tinton Falls, Borough of	430	$13,953,265	$0	0.00%
Upper Freehold, Township of	0	$0	$0	0.00%
West Long Branch, Borough of	1,513	$151,608,715	$0	0.00%
Monmouth County	142,143	$13,149,612,661	$128,445,562	0.98%

SOURCE: HAZUS-MH
EXPOSURE CALCULATED BY GLS ANALYSTS USING LOCAL ASSESSED VALUES OF BUDDINGS IN CATEGORY 1 THROUGH 4 SLOSH ZONES.

For the number, percentage, and replacement cost value of buildings with risk of storm surge, see the exposure and damage assessment for Hurricanes (above).

4.2.35 STORM SURGE: POTENTIAL FOR FUTURE DEVELOPMENT TO IMPACT HAZARD VULNERABILITY

Infill development and redevelopment would not be likely to substantially increase a jurisdiction's overall exposure to storm surge because existing structures would be replaced with new structures, and the new structures would be built to higher codes and standards offering a certain degree of protection from the hazard. Greenfield development would be more likely, however, to have the potential to substantially increase a jurisdiction's overall vulnerability to the hazard by replacing pervious surface with impervious surface.

Out of the 41 jurisdictions in Monmouth County with mapped storm surge hazard areas, all 41 have potentially developable undeveloped parcels in mapped storm surge hazard areas. The total area of these parcels is approximately 3,804 acres. In other words, nearly 12 percent of the County's potentially developable undeveloped land is in areas potentially susceptible to storm surge. Table 4.2-31 Potential for Future Development to Impact Storm Surge Hazard Vulnerability presents a snapshot of the storm surge hazard, future development trends, the acreage of potentially developable parcels subject to storm surge, and the potential for future development of undeveloped parcels to substantially increase storm surge hazard vulnerability under existing conditions. Jurisdictions with the highest risk of percent of potentially developable undeveloped land in storm surge hazard areas are highlighted in orange (above 75%). Note that only coastal municipalities are included in the table below.

Jurisdictions with a potential for future development to substantially increase storm surge hazard vulnerability under existing conditions should: (a) include storm surge mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development. Please note that not all municipalities are included in the following table. Only municipalities vulnerable to storm surge are listed.

Table 4.2 - 31 Potential for Future Development (PFD) to Impact Storm Surge Hazard Vulnerability

Jurisdiction	Storm Surge Hazard Areas Present	Relative Population Trend (2010-2040)[12]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Storm Surge Hazard Areas	Percent of Potentially Developable Undeveloped Land in Storm Surge Hazard Areas	Local Characterization of Development Trends[13]	PFD on Undeveloped Parcels in Mapped Storm Surge Hazard Areas	PFD of Parcels in Mapped Storm Surge Hazard Areas to Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
Aberdeen, Township of	H	Substantial increase	415	190	45.90%	Mix of greenfield development, infill and redevelopment	•	•
Allenhurst, Borough of	H	Negligible increase	4	4	100.00%	Little if any development expected	•	
Asbury Park, City of	H	Substantial increase	39	32	81.30%	Mix of greenfield development,	•	•

[12] Relative population trend, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.

[13] Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Storm Surge Hazard Areas Present	Relative Population Trend (2010-2040)[12]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Storm Surge Hazard Areas	Percent of Potentially Developable Undeveloped Land in Storm Surge Hazard Areas	Local Characterization of Development Trends[13]	PFD on Undeveloped Parcels in Mapped Storm Surge Hazard Areas	PFD of Parcels in Mapped Storm Surge Hazard Areas to Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
						infill and redevelopment		
Atlantic Highlands, Borough of	H	Moderate increase	60	27	44.60%	Mix of greenfield development, infill and redevelopment	•	•
Avon-By-The-Sea, Borough of	H	Negligible increase	7	7	100.00%	Little if any development expected	•	
Belmar, Borough of	H	Low level increase	13	13	100.00%	Mix of greenfield development, infill and redevelopment	•	•
Bradley Beach, Borough of	H	Moderate increase	14	13	96.60%	Mix of greenfield development, infill and redevelopment	•	•
Brielle, Borough of	H	Low level increase	131	108	82.10%	Mix of greenfield development, infill and redevelopment	•	•
Deal, Borough of	H	Negligible increase	40	26	64.20%	Little if any development expected	•	•
Eatontown, Borough of	H	Substantial increase	347	53	15.40%	Mix of greenfield development, infill and redevelopment	•	•
Fair Haven, Borough of	H	Low level increase	25	14	55.70%	Mix of greenfield development, infill and redevelopment	•	•
Hazlet, Township of	H	Substantial increase	249	156	62.60%	Mix of greenfield development, infill and redevelopment	•	•
Highlands, Borough of	H	Moderate increase	58	35	60.50%	Mix of greenfield development, infill and redevelopment	•	•

Jurisdiction	Storm Surge Hazard Areas Present	Relative Population Trend (2010-2040)[12]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Storm Surge Hazard Areas	Percent of Potentially Developable Undeveloped Land in Storm Surge Hazard Areas	Local Characterization of Development Trends[13]	PFD on Undeveloped Parcels in Mapped Storm Surge Hazard Areas	PFD of Parcels in Mapped Storm Surge Hazard Areas to Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
Holmdel, Township of	M	Substantial increase	593	68	11.40%	Predominantly greenfield development	•	•
Howell, Township of	M	Moderate increase	6,606	181	2.70%	Mix of greenfield development, infill and redevelopment	•	•
Interlaken, Borough of	H	Negligible increase	7	7	100.00%	Little to no development expected	•	
Keansburg, Borough of	H	Substantial increase	85	85	100.00%	Mix of greenfield development, infill and redevelopment	•	•
Keyport, Borough of	H	Substantial increase	68	57	83.70%	Mix of greenfield development, infill and redevelopment	•	•
Lake Como, Borough of	H	Negligible increase	8	8	99.40%	Little to no development expected	•	
Little Silver, Borough of	H	Moderate increase	54	47	87.60%	Mix of greenfield development, infill and redevelopment	•	
Loch Arbour, Village of	H	Low level increase	2	2	100.00%	Little to no development expected	•	
Long Branch, City of	H	Substantial increase	288	211	73.30%	Mix of greenfield development, infill and redevelopment	•	•
Manasquan, Borough of	H	Moderate increase	39	38	95.90%	Mix of greenfield development, infill and redevelopment	•	•
Matawan, Borough of	H	Substantial increase	140	65	46.70%	Mix of greenfield development, infill and redevelopment	•	•

Jurisdiction	Storm Surge Hazard Areas Present	Relative Population Trend (2010-2040)[12]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Storm Surge Hazard Areas	Percent of Potentially Developable Undeveloped Land in Storm Surge Hazard Areas	Local Characterization of Development Trends[13]	PFD on Undeveloped Parcels in Mapped Storm Surge Hazard Areas	PFD of Parcels in Mapped Storm Surge Hazard Areas to Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
Middletown, Township of	H	Moderate increase	2,313	808	35.00%	Mix of greenfield development, infill and redevelopment	•	•
Monmouth Beach, Borough of	H	Negligible increase	57	57	98.60%	Mix of greenfield development, infill and redevelopment	•	•
Neptune City, Borough of	H	Substantial increase	38	22	56.30%	Mix of greenfield development, infill and redevelopment	•	•
Neptune, Township of	H	Substantial increase	833	152	18.20%	Mix of greenfield development, infill and redevelopment	•	•
Ocean, Township of	H	Moderate increase	1,009	72	7.20%	Mix of greenfield development, infill and redevelopment	•	•
Oceanport, Borough of	H	Substantial increase	218	214	98.00%	Mix of greenfield development, infill and redevelopment	•	•
Red Bank, Borough of	M	Substantial increase	79	15	18.70%	Mix of greenfield development, infill and redevelopment	•	•
Rumson, Borough of	H	Low level increase	126	103	82.30%	Mix of greenfield development, infill and redevelopment	•	•
Sea Bright, Borough of	H	Moderate increase	38	38	99.20%	Mix of greenfield development, infill and redevelopment	•	•

Jurisdiction	Storm Surge Hazard Areas Present	Relative Population Trend (2010-2040)[12]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Storm Surge Hazard Areas	Percent of Potentially Developable Undeveloped Land in Storm Surge Hazard Areas	Local Characterization of Development Trends[13]	PFD on Undeveloped Parcels in Mapped Storm Surge Hazard Areas	PFD of Parcels in Mapped Storm Surge Hazard Areas to Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
Sea Girt, Borough of	H	Negligible increase	20	19	96.80%	Little to no development expected	•	
Shrewsbury, Borough of	H	Substantial increase	126	99	78.40%	Mix of greenfield development, infill and redevelopment	•	•
Spring Lake, Borough of	H	Negligible increase	17	16	92.70%	Mix of greenfield development, infill and redevelopment	•	•
Spring Lake Heights, Borough of	H	Low level increase	113	104	92.20%	Little to no development expected	•	•
Tinton Falls, Borough of	M	Substantial increase	1,670	95	5.70%	Predominantly greenfield development	•	•
Union Beach, Borough of	H	Low level increase	278	278	100.00%	Mix of greenfield development, infill and redevelopment	•	•
Wall, Township of	H	Moderate increase	2,446	218	8.90%	Predominantly greenfield development	•	•
West Long Branch, Borough of	H	Substantial increase	84	49	57.90%	Mix of greenfield development, infill and redevelopment	•	•
Monmouth, County of	H	Moderate increase	32,323	3,804	11.80%	Mix of greenfield development, infill and redevelopment	•	•

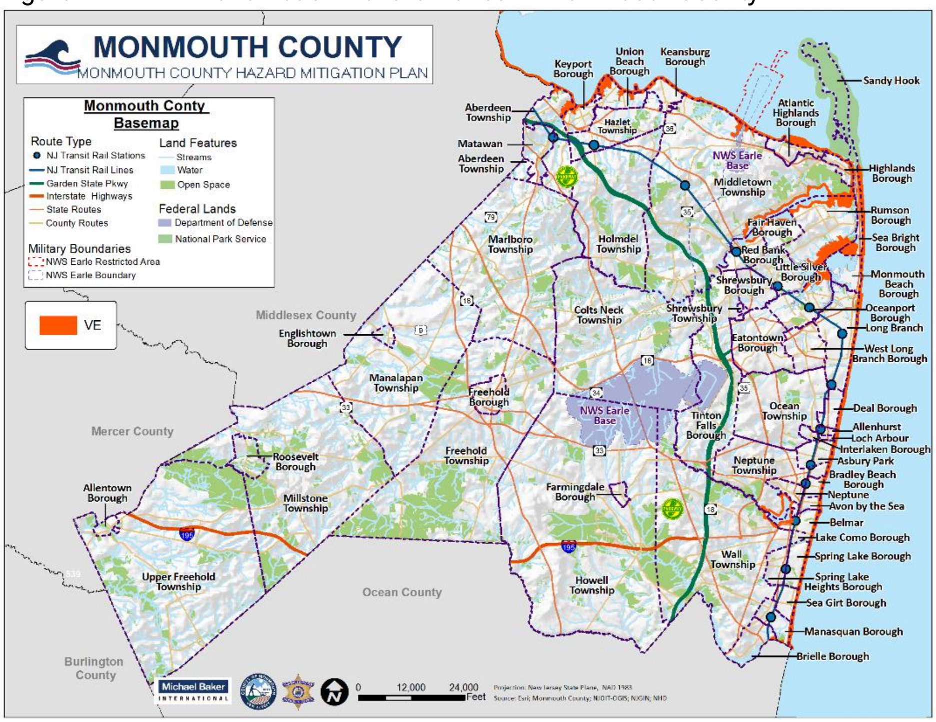
4.2.36 WAVE ACTION: HAZARD DESCRIPTION

Wave action is the characteristics and effects of waves that move inland from an ocean, bay, or other large body of water. Large, fast moving waves can cause extreme erosion and scour and their impact on buildings can cause severe damage. During hurricanes and other high-wind events, storm surge and wind increase the destructiveness of waves and cause them to reach higher elevations and penetrate further inland.

4.2.37 WAVE ACTION: LOCATION

The area most susceptible to wave action in Monmouth County are predominantly located along the immediate coastal and shoreline areas of the Atlantic Ocean and Raritan Bay. Additional areas may occasionally experience wave action during extremely large storm events that cause storm surge (addressed separately within this section). Figure 4.2 – 7 Wave Action Hazard Zones in Monmouth County illustrates the wave action hazard zones for Monmouth County based on FEMA Preliminary and Effective FIRMs. This includes areas mapped as Zone VE according to the most recent FIS completed by FEMA. Zone VE refers to coastal areas with a 1 percent or greater chance of flooding and an additional hazard associated with storm-driven velocity waves of three feet or more.[14]

Figure 4.2 - 7 Wave Action Hazard Zones in Monmouth County



SOURCE: FEMA DFIRM

4.2.38 WAVE ACTION: EXTENT

There is no particular scale that classifies the magnitude or severity of different wave events for different category storms. The extent of flooding associated with a 1% annual probability of occurrence (the base flood or 100-year flood) is used as the regulatory boundary by many agencies and this mapping does

[14] Figure 4.2-3illustrates best available data based on the most recent FEMA Flood Insurance Study (FIS). It should be noted that although wave action hazard areas are not delineated along the Navesink River for the municipalities of Red Bank and Fair Haven it has been determined that these areas in general should be considered susceptible to wave action. It is anticipated that future more detailed flood studies for the area will delineate VE Zones that will support this determination.

include mapping of the V-zone, or the lands that can support breaking waves of three feet or more. This boundary is therefore a convenient tool for assessing the extent of the wave action hazard and risk in flood-prone communities. Higher category storms on the Saffir-Simpson scale would, however, typically have more destructive waves breaking into the built environment at the coastline causing more extensive damages to those susceptible structures.

4.2.39 WAVE ACTION: PREVIOUS OCCURRENCES AND LOSSES

According to NCDC's latest records, 29 recorded wave action events ("high surf") have affected Monmouth County from August 1996 to April 2019 (data excludes wave action associated with other major historical events addressed separately within this section, such as hurricanes and nor'easters). These incidents resulted in a reported total of three deaths and 2 injuries in Monmouth County and caused an estimated $40,000 in property damages. Some recent notable events include the following:

August 14-20, 1995. Swells associated with Hurricane Felix generated rough surf and rip currents for about one week along the New Jersey shore. A 17-year-old surfer drowned off Deal. Two boys were swept off the beach by a large wave at Point Pleasant Beach. A 45-year-old male drowned in Avon-By-The-Sea. Numerous injuries were reported, five alone in Long Beach Township. The rough surf spread to Monmouth County and municipalities along the shore began restricting bathing. By the 16th, waves reached up to eight feet at Sandy Hook and most bathing was prohibited. As Felix weakened offshore, bathing restrictions began to be lifted on the 20th.

August 23-28, 1998. Rip currents and large waves associated with Hurricane Bonnie in the Atlantic Ocean caused hundreds of water rescues and resulted in swimming restrictions up and down the New Jersey shore. In Monmouth County, 10 swimmers were rescued at Bradley Beach and 25 were rescued at Manasquan and Spring Lake. On the 24th, swimming restrictions started as swells increased to six to eight feet. The most reported rescues on the 24th were in Monmouth County (about 25) in Manasquan and Spring Lake. One teenager in Spring Lake was injured. As Bonnie neared the North Carolina Coast on the 26th, beach restrictions became tighter. Numerous beaches were closed, and surfing was banned in several communities. August 30-31, 1999. The combination of swells from Hurricane Bonnie and a stiff northeast flow caused by a strong high-pressure system building over New England produced rough surf, some minor tidal flooding and beach erosion. A major contributing factor to the winds and rip currents was a very strong high-pressure system that built into eastern Canada and New England. Bathing restrictions were in place. The highest recorded tide in Monmouth County was 6.7 feet above average tide heights at Sandy Hook.

August 25-26, 2001. The northeast to east flow around a high and a developing low-pressure system produced rough surf and rip currents along the New Jersey shore. A person nearly drowned while fishing along the shore. A total bathing ban was in effect in Allenhurst, while yellow cautionary flags flew, and partial bathing bans were in effect in other places such as Sea Girt. A 17-foot vessel capsized half a mile off of Shark River Inlet in five to six-foot seas. In Belmar, a 42-foot sport fishing vessel carrying eight persons ran aground between the south jetty and a fishing pier.

November 5, 2008. A nor'easter that developed off the Carolina coast on the night of the 4th caused pounding surf and beach erosion along the New Jersey Coast on the 5th and 6th. It also claimed the life of a man in Monmouth County. At about 11 a.m. EST on the 5th, a man who was fishing on a jetty in

Avon, slipped into the ocean. He was rescued about ten minutes later but could not be saved. The nor'easter formed off the Carolina coast overnight on the 4th and slowly moved northeast.

March 13, 2010. The pounding surf and moderate to locally severe coastal flooding took its toll on the New Jersey coast. The tidal flooding in Monmouth County brought back memories of the December 1992 nor'easter. Wave heights reached 7 to 9 feet. On the Raritan Bay side, a 20-foot-wide cut in a dune occurred at Point Comfort in Keansburg. Shore Boulevard was severely flooded. Smaller dune cuts also occurred in the Bayshore at Port Monmouth and Belford. On the ocean side, 4 to 5-foot vertical cuts were common. Sea Bright lost 50 percent of its dune system. Tidal flooding along the Shrewsbury River spilled into homes and businesses in the central and southern side of the borough. In Manasquan, road damage occurred at the intersection of Third Avenue and Riverside Drive.

September 2-4, 2010. Hurricane Earl, which passed about 165 miles east of Atlantic City during the afternoon of September 3rd, generated large swells, heavy surf, enhanced rip currents and caused minor tidal flooding with the afternoon high tide on the 3rd. The heavy surf also claimed the life of one swimmer on the 2nd.

September 19, 2017. Hurricane Jose meandered offshore for several days. Portions of Monmouth County saw high surf, coastal flooding and tropical storm force winds. Minor damage was reported at a fishing pier.

Note: See the Hurricane and Tropical Storm subsection for discussion of wave impacts during Sandy.

Other notable reports of historical wave action events include the following, as identified by the Planning Committee:

- The Borough of Brielle has indicated that sustained wave action over the years has caused substantial deterioration to a bulkhead along the Manasquan River (at the end of Ocean Avenue). It is believed that during a future coastal storm, severe wave action could cause complete failure of the bulkhead causing great damage to not only the Borough-owned street but could also threaten a large commercial structure and a marine fuel facility located in the immediate proximity of this bulkhead. Saltwater infiltration to the borough's potable water system may also occur.
- The Township of Neptune has indicated that a one-block section of the Shark River Hills area experienced wave action during Sandy. The Ocean Grove area also experienced wave action during Sandy, which damaged the fishing pier, portions of the boardwalk, and dune. During the 1992 nor'easter, sections of the boardwalk were lost, along with some dune erosion.

4.2.40 WAVE ACTION: PROBABILITY OF FUTURE OCCURRENCE

Wave action will continue to have a high probability of occurrence for the coastal flood hazard zones of Monmouth County, and the probability of future occurrences is certain. Less severe wave action events will be more frequent but likely cause less impact (i.e., minor damages, coastal erosion, etc.), while more severe waves associated with less frequent coastal storm events such as hurricanes and nor'easters will cause higher impacts (including property damages) along Monmouth County's shoreline.

4.2.41 WAVE ACTION: POTENTIAL EFFECTS OF CLIMATE CHANGE

The frequency and intensity of coastal storms and severe weather events is expected to increase in the future due to climate change. In the years to come, it is anticipated that Monmouth County will observe drastic changes in storm character, intensity, frequency, and storm tracking. Hurricanes are likely to become more intense with rising sea water temperatures. Coastal erosion rates are likely to increase with rising sea-level, to levels higher than those rates that have been observed over the last century. Storm effects will be more extensive in the future. The following types of impacts can be anticipated in Monmouth County's future as a result of climate change and sea level rise: inundation of low-lying areas; increased frequency and extent of storm-related flooding; wetland loss; saltwater intrusion into estuaries and freshwater aquifers; land loss through submergence and erosion of lands in coastal areas; migration of coastal landforms and habitats; increased salinity in estuaries and coastal fresh; impacts to human populations (property losses, more frequent flood damage, more frequent flooding of roadways and urban centers, risks to people as the population of coastal areas increases); more buildings and infrastructure exposed; currently exposed buildings and infrastructure could be subject to potentially greater losses as water levels increase, and continued rapid coastal development exacerbates the impacts of sea level rise; impacts on gravity flow stormwater systems; impacts on non-coastal areas. Impacts of climate change and sea level rise can affect all parts of a community, including: transportation infrastructure (ports, marinas, airports, roads, bridges, railways); public infrastructure (stormwater and wastewater management systems, drinking water supply and distribution systems, power utility systems, communications systems); public facilities (i.e., police, fire, ambulance, hospitals, schools, daycare centers, adult living facilities, historic landmarks, government buildings, libraries, parks, etc.); economic viability of a community - particularly for communities where tourism tends to drive local economies, as is the case in many of Monmouth County's coastal communities. Climate change and sea level rise could lead to a potential loss of assets that support tourism (i.e., beaches themselves as well beach access points, lodging, restaurants, marinas, fishing habitats, ecotourism, etc.).

4.2.42 WAVE ACTION: VULNERABILITY ASSESSMENT

Impacts

Wave action is a significant hazard to buildings and infrastructure located in coastal areas. Large, fast moving waves can cause extreme erosion and scour and their impact on buildings can cause severe damage. Storm surge and wind increase the destructiveness of waves and cause them to reach higher elevations and penetrate further inland.

Exposure and Damage Estimates

To estimate exposure to wave action, it is assumed that vulnerable areas are located in the VE flood zone, which experiences coastal flood with velocity hazard (wave action). While wave action is not limited to VE zones, wave height and energy is higher in VE zones. To estimate exposure to wave action, the determination of value and population at-risk was calculated through GIS analysis by calculating the proportion of a parcel or census block lying within VE zones and applying that same ratio to the census block population and parcel value to estimate population at risk and value of improvements at risk. Table 4.2 - 32 Exposure to Wave Action by Jurisdiction shows exposure to wave action by jurisdiction, sorted from the highest percent of total building value exposed to wave action to the lowest. A total of 28 jurisdictions have property exposed to wave action.

Table 4.2 - 32 Exposure to Wave Action by Jurisdiction

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located in VE Flood Zone (2018 Values)	Percent of Total Building Value Exposed to Wave Action
Manasquan, Borough of	142	$799,826,975	$50,372,041	6.18%
Union Beach, Borough of	519	$387,844,700	$10,892,606	3.78%
Sea Bright, Borough of	37	$235,586,800	$6,123,371	2.28%
Fair Haven, Borough of	92	$785,619,700	$12,486,679	1.88%
Sea Girt, Borough of	4	$732,097,100	$8,398,641	1.59%
Keyport, Borough of	185	$434,885,600	$6,795,237	1.43%
Red Bank, Borough of	18	$1,194,733,400	$17,494,834	1.31%
Deal, Borough of	12	$822,100,400	$6,976,995	1.21%
Atlantic Highlands, Borough of	55	$364,693,600	$2,456,740	0.87%
Keansburg, Borough of	65	$343,826,000	$3,213,537	0.82%
Belmar, Borough of	59	$553,347,900	$4,309,244	0.75%
Brielle, Borough of	2	$669,338,900	$3,862,182	0.70%
Highlands**, Borough of	96	$342,874,400	$2,201,971	0.69%
Rumson, Borough of	54	$1,600,650,400	$10,712,125	0.67%
Loch Arbour, Village of	0	$69,262,800	$281,258	0.64%
Neptune City, Borough of	16	$305,279,900	$1,016,835	0.38%
Middletown, Township of	234	$5,895,810,731	$20,815,231	0.37%
Asbury Park, City of	0	$1,267,473,400	$2,991,996	0.32%
Aberdeen, Township of	420	$1,074,509,800	$3,205,481	0.27%
Long Branch, City of	119	$2,478,681,000	$7,011,919	0.27%
Avon-By-The-Sea, Borough of	0	$266,879,900	$959,595	0.25%
Neptune, Township of	157	$2,431,214,700	$2,994,974	0.17%
Wall, Township of	40	$3,053,292,400	$3,025,815	0.12%
Allenhurst, Borough of	3	$217,949,000	$156,990	0.09%
Spring Lake, Borough of	0	$1,028,817,800	$1,011,588	0.09%
Monmouth Beach, Borough of	1	$501,592,200	$284,668	0.06%
Allentown, Borough of	0	$127,734,200	$0	0.00%
Bradley Beach, Borough of	0	$462,112,100	$0	0.00%
Colts Neck, Township of	0	$927,454,500	$0	0.00%
Eatontown, Borough of	0	$1,314,725,700	$0	0.00%
Englishtown, Borough of	0	$158,314,100	$0	0.00%
Farmingdale, Borough of	0	$109,883,900	$0	0.00%
Freehold, Borough of	0	$771,202,500	$0	0.00%
Freehold, Township of	0	$4,433,974,800	$0	0.00%
Hazlet, Township of	0	$1,215,098,000	$0	0.00%
Holmdel, Township of	0	$2,104,382,100	$0	0.00%
Howell, Township of	0	$4,204,216,400	$0	0.00%
Interlaken, Borough of	0	$125,000,500	$0	0.00%
Lake Como, Borough of	0	$140,566,300	$0	0.00%
Little Silver, Borough of	0	$873,512,700	$0	0.00%
Manalapan, Township of	0	$4,619,949,900	$0	0.00%
Marlboro, Township of	0	$4,435,729,800	$0	0.00%
Matawan, Borough of	0	$517,395,800	$0	0.00%
Millstone, Township of	0	$1,232,191,160	$0	0.00%

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located in VE Flood Zone (2018 Values)	Percent of Total Building Value Exposed to Wave Action
Ocean, Township of	0	$2,684,842,000	$0	0.00%
Oceanport, Borough of	0	$562,875,800	$0	0.00%
Roosevelt, Borough of	0	$50,136,700	$0	0.00%
Shrewsbury, Borough of	0	$608,635,700	$0	0.00%
Shrewsbury, Township of	0	$30,450,000	$0	0.00%
Spring Lake Heights, Borough of	0	$525,407,200	$0	0.00%
Tinton Falls, Borough of	0	$1,691,986,800	$0	0.00%
Upper Freehold, Township of	0	$851,779,300	$0	0.00%
West Long Branch, Borough of	0	$889,026,200	$0	0.00%
Monmouth County	2,330	$63,526,773,666	$190,052,551	0.31%

*EXPOSURE CALCULATED BY GLS ANALYSTS USING LOCAL ASSESSED VALUES OF BUILDINGS LOCATED IN VE ZONES

Given the lack of readily available historical loss data on significant wave action occurrences in Monmouth County, it is assumed that while one major event (i.e., hurricane or nor'easter) may result in significant losses due to wave action, annualizing structural losses over a long period of time would most likely yield a negligible annualized loss estimate in each jurisdiction exposed to this hazard. However, it should also be noted that over the long term, anticipated sea level rise will increase the risk of damages/losses to future wave action events.

4.2.43 WAVE ACTION: POTENTIAL FOR FUTURE DEVELOPMENT TO IMPACT HAZARD VULNERABILITY

Infill development and redevelopment would not be likely to substantially increase a jurisdiction's overall exposure to wave action because existing structures would be replaced with new structures, and the new structures would be built to higher codes and standards offering a certain degree of protection from the hazard. Greenfield development would be more likely, however, to have the potential to substantially increase a jurisdiction's overall vulnerability to the hazard because a new structure would be placed on previously undeveloped land.

Out of the 28 jurisdictions in Monmouth County with mapped wave action hazard areas, 22 have potentially developable undeveloped parcels in mapped wave action hazard areas. The total area of these parcels is approximately 464 acres. In other words, between one and two percent of the County's potentially developable undeveloped land is in areas potentially susceptible to wave action. **Table 4.2-33 Potential for Future Development to Impact Wave Action Hazard Vulnerability** presents a snapshot of the wave action hazard, future development trends, the acreage of potentially developable parcels subject to wave action, and the potential for future development of undeveloped parcels to substantially increase wave action hazard vulnerability under existing conditions. Not that only coastal municipalities are included in the table below.

Jurisdictions with a potential for future development to substantially increase wave action hazard vulnerability under existing conditions should: (a) include wave action mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development. Please note that not all municipalities are included in the following table. Only municipalities vulnerable to wave action are listed.

Table 4.2 - 33 Potential for Future Development to Impact Wave Action Hazard Vulnerability

Jurisdiction	Wave Action Hazard Areas Present	Relative Population Trend[15] (2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wave Action Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wave Action Hazard Areas	Local Characterization of Development Trends[16]	Potential for Future Development on Undeveloped Parcels in mapped Wave Action Hazard Areas	Potential for Future Development On Undeveloped Parcels In Mapped Wave Action Hazard Areas To Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
Aberdeen Township	M	Substantial increase	415	10	2.5%	Mix of greenfield development, infill and redevelopment	•	•
Allenhurst Borough	M	Negligible increase	4	0	0.0%	Little if any development expected		
Asbury Park City	M	Substantial increase	39	0	0.0%	Mix of greenfield development, infill and redevelopment		
Atlantic Highlands Borough	M	Moderate increase	60	0.4	0.6%	Mix of greenfield development, infill and redevelopment	•	
Avon-By-The-Sea Borough	M	Negligible increase	7	0	0.0%	Little if any development expected		
Belmar Borough	M	Low level increase	13	0	0.0%	Mix of greenfield development, infill and redevelopment		
Bradley Beach Borough	M	Moderate increase	14	0	0.0%	Mix of greenfield development, infill and redevelopment		
Brielle Borough	M	Low level increase	131	1	0.7%	Mix of greenfield development, infill and redevelopment	•	

[15] Relative population trend, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.

[16] Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Wave Action Hazard Areas Present	Relative Population Trend[15] (2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wave Action Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wave Action Hazard Areas	Local Characterization of Development Trends[16]	Potential for Future Development on Undeveloped Parcels in mapped Wave Action Hazard Areas	Potential for Future Development On Undeveloped Parcels In Mapped Wave Action Hazard Areas To Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
Deal Borough	M	Negligible increase	40	8	19.2%	Little if any development expected	•	
Fair Haven Borough	M	Low level increase	25	5	22.1%	Mix of greenfield development, infill and redevelopment	•	
Highlands Borough	M	Moderate increase	58	10	17.2%	Mix of greenfield development, infill and redevelopment	•	•
Keansburg Borough	M	Substantial increase	85	9	10.6%	Mix of greenfield development, infill and redevelopment	•	
Keyport Borough	M	Substantial increase	68	5	7.9%	Mix of greenfield development, infill and redevelopment	•	
Loch Arbour Village	M	Low level increase	2	1	55.0%	Little to no development expected	•	
Long Branch City	M	Substantial increase	288	22	7.6%	Mix of greenfield development, infill and redevelopment	•	•
Manasquan Borough	M	Moderate increase	39	2	4.6%	Mix of greenfield development, infill and redevelopment	•	
Middletown Township	M	Moderate increase	2,313	80	3.4%	Mix of greenfield development, infill and redevelopment	•	•
Monmouth Beach Borough	M	Negligible increase	57	2	2.8%	Mix of greenfield development, infill and redevelopment	•	
Neptune City Borough	M	Substantial increase	38	12	30.5%	Mix of greenfield development, infill	•	•

Jurisdiction	Wave Action Hazard Areas Present	Relative Population Trend[15] (2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wave Action Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wave Action Hazard Areas	Local Characterization of Development Trends[16]	Potential for Future Development on Undeveloped Parcels in mapped Wave Action Hazard Areas	Potential for Future Development On Undeveloped Parcels In Mapped Wave Action Hazard Areas To Substantially Increase Storm Surge Hazard Vulnerability Under Existing Conditions
						and redevelopment		
Neptune Township	M	Substantial increase	833	37	4.4%	Mix of greenfield development, infill and redevelopment	•	•
Oceanport Borough	M	Substantial increase	218	0	0.0%	Mix of greenfield development, infill and redevelopment		
Red Bank Borough	M	Substantial increase	79	1	0.9%	Mix of greenfield development, infill and redevelopment	•	
Rumson Borough	M	Low level increase	126	30	23.5%	Mix of greenfield development, infill and redevelopment	•	•
Sea Bright Borough	M	Moderate increase	38	10	26.1%	Mix of greenfield development, infill and redevelopment	•	•
Sea Girt Borough	M	Negligible increase	20	0.5	2.4%	Little to no development expected	•	
Spring Lake Borough	M	Negligible increase	17	0.4	2.4%	Mix of greenfield development, infill and redevelopment	•	
Union Beach Borough	M	Low level increase	278	216	77.5%	Mix of greenfield development, infill and redevelopment	•	•
Wall Township	M	Moderate increase	2,446	3	0.1%	Predominantly greenfield development	•	
Monmouth County of	H	Moderate increase	32,323	464	4.4%	Mix of greenfield development, infill and redevelopment	•	

4.2.44 COASTAL EROSION: HAZARD DESCRIPTION

Landward displacement of a shoreline caused by the forces of waves and currents. Coastal erosion is measured as the rate of change in the position or horizontal displacement of a shoreline over a period of time. It is generally associated with episodic events such as hurricanes and tropical storms, nor'easters, storm surge and coastal flooding but may also be caused by human activities that alter sediment transport. Construction of shoreline protection structures can mitigate the hazard but may also exacerbate it under some circumstances.

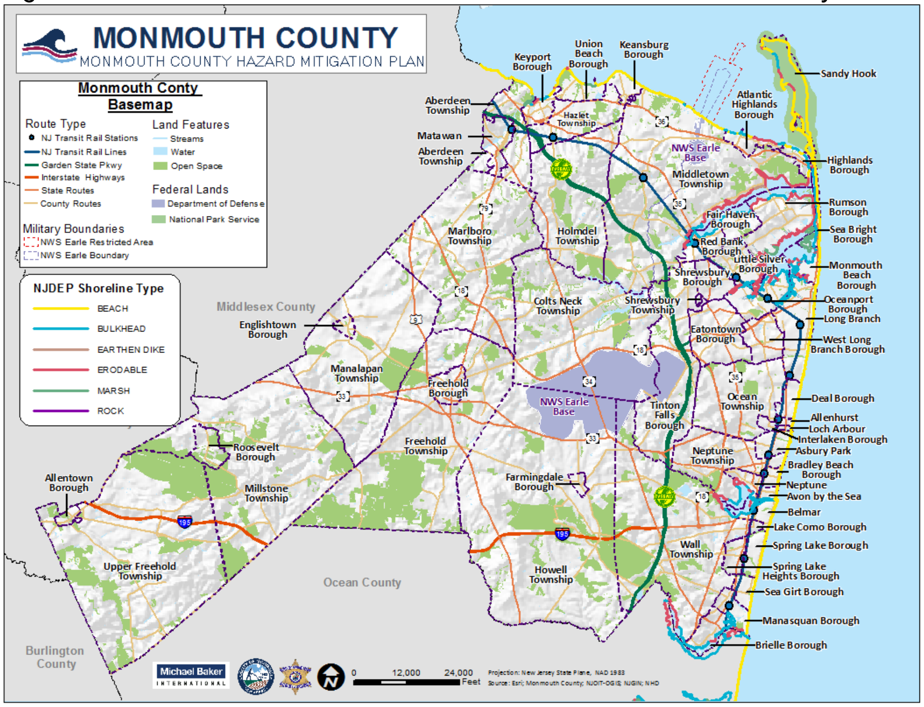
4.2.45 COASTAL EROSION: LOCATION

All of Monmouth County's coastal jurisdictions are susceptible to the coastal erosion hazard. Following a review of historic shoreline data dating back to 1836 provided by the New Jersey Department of Environmental Protection (NJDEP), it is clear that Monmouth County has experienced significantly changing shorelines (moving landward and seaward) due to the effects of erosion, accretion, beach nourishment and structural shoreline protection measures.

Figure 4.2 - 8 NJDEP Shoreline Classifications for Monmouth County illustrates the type of shorelines in Monmouth County as classified by NJDEP. These include the following types: (1) beach, which includes waterfront areas comprised of 100 percent sand; (2) bulkhead, which includes manmade structures at the water's edge, after the rip-rap, which were designed to hold back water and protect the adjacent areas from erosion; (3) marsh, which is classified as areas of natural marsh edge; (4) earthen dike, classified as structures which serve as natural barriers between the land and the water; and (5) erodible, which includes any soft shoreline other than beach, rock, marsh or earthen dike, which are vulnerable at the water's edge. As can be seen in the Figure, most of Monmouth County's shoreline is classified as susceptible to coastal erosion (including "beach" and "erodible" classifications). Coastal erosion in these areas, where coupled with densely developed or significant recreational shorelines, are routinely addressed through beach nourishment programs.

The State HMP summarizes the number and type of NJDEP shoreline structures off the coastline of New Jersey along the Atlantic Ocean and Inland Bays (current as of 1993). Monmouth County is reported to have 0 breakwaters, 172 groins, 9 jetties, 1 revetment, and 11 seawalls. Although not identified in the 1993 State HMP or shown on the countywide map below, there are also many shoreline protection features located along the Monmouth County shore that are designed to reduce coastal storm and erosion hazards. These include hard structures such as jetties, groins, revetments, sea walls and breakwaters. Jetties and groins are protective structures (usually built from rock, wood or concrete) which extend outward from the shoreline. They look alike and provide similar function, but the difference between the two is that jetties are located at inlets, while groins are located along beaches. Sea walls are similar to bulkheads in function, but unlike bulkheads, they are located along the high beach line adjacent to the ocean, protecting property from ocean forces. Revetments are sea walls, which are surrounded on either side by rock or earth fill. A breakwater structure is a protective barrier placed in the water, out in front of a harbor.

Figure 4.2 - 8 NJDEP Shoreline Classifications for Monmouth County



In addition to hard structures, some areas also feature coastal protection systems incorporating engineered dunes and beaches, which are maintained through regular scheduled maintenance and nourishment. Failure to continue these activities would result in an increased risk of damage in many areas during coastal storm events, as the levels of protection are degraded. However, local government entities within Monmouth County and the State of New Jersey have been very active in cooperating with Federal government agencies to ensure that these activities continue to be implemented and adequately maintained. These practices are encouraged and expected to continue.

4.2.46 COASTAL EROSION: EXTENT

Coastal erosion is measured as the rate of change in the position or displacement of a riverbank or shoreline over a period of time. Short-term erosion typically results from periodic natural events, such as flooding, hurricanes, storm surge, and windstorms, but may be intensified by human activities. Long-term erosion is a result of multi-year impacts such as repetitive flooding, wave action, sea level rise, sediment loss, subsidence, and climate change. The severity of coastal erosion is typically measured through a quantitative assessment of annual shoreline change for a given beach cross-section of profile (feet or meters per year) over a long period of time.[17] Erosion rates vary as a function of shoreline type and are influenced primarily by episodic events but can be used in land use and hazard management to define areas of critical concern. Unfortunately, there is no uniform erosion rate database or GIS data layer that defines erosion rates or such areas of critical concern for Monmouth County's shoreline. However, NJOEM indicates that the New Jersey coast is characterized by episodic change resulting from severe but episodic storm events with a recurrence interval of 25 years or greater. Areas of natural

[17] Seasonal fluctuations in beach width is common along the New Jersey shore, but is not considered erosion as the sand removed is typically re-deposited at other times of the year.

erosion and accretion show erratic and almost cyclical patterns in response to storm events. The recovery process, although long, results in a stable beach with a slight recession of approximately one foot per year, half of which can be attributed to relative sea level rise. Monmouth County experiences an average of three feet of erosion per year[18] and occurs on a routine basis during low impact storms.

4.2.47 COASTAL EROSION: PREVIOUS OCCURRENCES AND LOSSES

The NJ State HMP reports 19 instances of coastal erosion affecting Monmouth County from 1936 to 2018 (see **Table 4.2 - 34 Historical Incidents of Coastal Erosion in Monmouth County**). Six of these events have occurred since the last version of the plan was prepared.

Table 4.2 - 34 Historical Incidents of Coastal Erosion in Monmouth County

Date	Associated Hazard Event
March 6-8, 1962	Nor'easter
October 28-November 4, 1991	Nor'easter
September 22-26, 1992	Tropical Storm Danielle
December 10-17, 1992	Coastal Storm
August 8-25, 1994	Hurricane Felix
December 22-26, 1994	Storm
January 7-8, 1996	Blizzard
July 13, 1996	Tropical Storm Bertha
February 4-9, 1998	Nor'easter
April 16, 2007	Nor'easter
August 27-September 5, 2011	Hurricane Irene
October 29, 2011	Nor'easter
October 29, 2012	Superstorm Sandy
March 1-8, 2013	Nor'easter
January 23 - 30, 2015	Winter Storm Juno
Friday, October 02, 2015	Nor'easter
January 22 - 24, 2016	Blizzard
March 14, 2017	Nor'easter
September 5-26, 2017	Hurricane Jose

SOURCE: 2019 NJ STATE HMP

Some of the more recent notable events include:

January 6-8, 1996. The Blizzard of 1996 created erosion damage as a result of high winds and waves. Sand was scoured away by the blizzard, leaving some locations vulnerable to future storms with the worst damage from Manasquan southward. In Manasquan, the storm scoured vertically about four feet of beach for a 500-foot stretch.

July 13, 1996. As a result of Tropical Storm Bertha, Monmouth Beach suffered severe beach erosion. Fifty percent of the beach at the south of the borough was gone. This beach is one of dozens in New Jersey that was being replenished under a USACE project. There was little beach erosion elsewhere.

February 4, 1998. The strongest nor'easter of the winter caused continuous onshore flow resulting in moderate to severe beach erosion in Monmouth County. Two to four feet of beach were lost in most areas. At Sandy Hook, about 80 percent of the new sand placed in a replenishment project was lost as

[18] "Evaluation of Erosion Hazards" prepared by The H. John Heinz III Center for Science, Economics and the Environment, April 2000

several hundred feet of beach disappeared. Both Bradley Beach and Ocean Grove were hard hit by erosion. The waves washed sand onto Ocean Avenue in Bradley Beach.

Hurricane Irene (August 27-28, 2011). Many Monmouth County communities were hard hit by this storm and suffered significant beach erosion as waves washed ashore. Irene produced three to five feet of storm surge and brought torrential rain, which caused significant inland flooding due to the ground already being saturated from previous rainstorms. Several roads and bridges were damaged as a result of Sandy, such as the Hubbard Ave where a water pipe and ripped apart the pavement. Sea Girt's beach was eroded and its boardwalk was severely damaged. Significant beach erosion was reported in Long Branch. Most every coastal community in Monmouth County was impacted to some degree or another by erosion, including those with USACE beach nourishment projects.

Superstorm Sandy (October 29, 2012). Many Monmouth County communities were hard hit by this storm and suffered severe beach erosion as waves washed ashore. Richard Stockton College researchers noted nearly all of their 105 monitored beach sites showed evidence of sand volume losses (Richard Stockton College 2013). NOAA's NCDC reports estimated that the average New Jersey beach became 30 to 40 feet narrower. Despite early USACE estimates that 12 million cubic yards of sand were lost as a result of the storm, later reports indicated that only 6.2 million cubic yards were lost as a result of Sandy (Thompson 2013). Displacement was reported to have occurred primarily in Monmouth and Ocean counties.

Other notable reports of historical coastal erosion events include the following, as identified by the Planning Committee:

- The Township of Aberdeen reported that there has been significant beach erosion in the Cliffwood Beach section of town resulting from hurricanes, tropical storms and nor'easters.
- The Borough of Avon-By-The-Sea indicated that even moderate storms have eaten away at its beachfront leaving portions of the community at risk.
- The Borough of Deal cited that coastal erosion occurs annually, particularly during winter nor'easters.
- The Borough of Keansburg indicated that it is currently experiencing severe coastal erosion.
- The Village of Loch Arbour stated that in 1994 persistent northeasterly winds through the winter to early spring resulted in severe coastal erosion and threatened beach facilities.
- The Township of Ocean has a severe erosion issue along its waterways that lead to the ocean. As storm surge from the ocean pushes back up the waterways, it breaks down the embankments and causes more flooding issues for the ongoing storm and future storms.
- The Borough of Sea Bright has experienced coastal beach erosion since the turn of the 20th century and continues to do so. Also, the Shrewsbury River overtops the western bulkhead every moon tide and in most moderate storms, causing flooding in both the downtown residential and commercial areas of town. The back bay/Shrewsbury River shoreline is mostly bulkhead, but most of it is privately owned and in very poor condition. In some locations the bulkheads require fairly urgent replacement since erosion though the bulkhead line has been observed.
- The Borough of Union Beach, similar to other areas, relies on its coastline as a major line of defense against coastal flooding. Every other year the Borough participates in a sand

replenishment program to maintain its line of defense, but each coastal storm event increases the amount of sand required for replenishment.

- The City of Long Branch reported 10+ feet depth of sand eroded.

4.2.48 COASTAL EROSION: PROBABILITY OF FUTURE OCCURRENCE

Coastal erosion remains a natural, dynamic and continuous process for Monmouth County's coastal jurisdictions and its probability of occurrence is certain. The damaging impacts of coastal erosion are lessened through continuous (and costly) beach nourishment and structural shoreline protection measures; however, it is likely that the impacts of coastal erosion will increase in severity due to future episodic storm events as well as the anticipated slow onset, long-term effects of climate change and sea level rise.

4.2.49 COASTAL EROSION: POTENTIAL EFFECTS OF CLIMATE CHANGE

The frequency and intensity of coastal storms and severe weather events is expected to increase in the future due to climate change. In the years to come, it is anticipated that Monmouth County will observe drastic changes in storm character, intensity, frequency, and storm tracking. Hurricanes are likely to become more intense with rising sea water temperatures. Coastal erosion rates are likely to increase with rising sea-level, to levels higher than those rates that have been observed over the last century. Storm effects will be more extensive in the future.

The following types of impacts can be anticipated in Monmouth County's future as a result of climate change and sea level rise: inundation of low-lying areas; increased frequency and extent of storm-related flooding; wetland loss; saltwater intrusion into estuaries and freshwater aquifers; land loss through submergence and erosion of lands in coastal areas; migration of coastal landforms and habitats; increased salinity in estuaries and coastal fresh; impacts to human populations (property losses, more frequent flood damage, more frequent flooding of roadways and urban centers, risks to people as the population of coastal areas increases); more buildings and infrastructure exposed; currently exposed buildings and infrastructure could be subject to potentially greater losses as water levels increase, and continued rapid coastal development exacerbates the impacts of sea level rise; impacts on gravity flow stormwater systems; impacts on non-coastal areas. Impacts of climate change and sea level rise can affect all parts of a community, including: transportation infrastructure (ports, marinas, airports, roads, bridges, railways); public infrastructure (stormwater and wastewater management systems, drinking water supply and distribution systems, power utility systems, communications systems); public facilities (i.e., police, fire, ambulance, hospitals, schools, daycare centers, adult living facilities, historic landmarks, government buildings, libraries, parks, etc.); economic viability of a community, particularly for communities where tourism tends to drive local economies, as is the case in many of Monmouth County's coastal communities. Climate change and sea level rise could lead to a potential loss of assets that support tourism (i.e., beaches themselves as well beach access points, lodging, restaurants, marinas, fishing habitats, ecotourism, etc.).

4.2.50 COASTAL EROSION: VULNERABILITY ASSESSMENT

Death and injury are not typically associated with coastal erosion, as erosive processes along the coast occur over long durations during which people in the affected areas have sufficient times to evacuate; however, it can destroy buildings and infrastructure. Coastal erosion can also represent a major threat to the local economies of coastal communities that rely on the financial benefits of their recreational beaches.

Exposure and Damage Estimates

Unlike other hazards, the coastal erosion hazard is best described as a relatively slow natural process occurring over the long term, with occasional major impacts wrought by episodic natural events such as hurricanes and nor'easters. Another complicating factor in accurately determining specific coastal erosion hazard areas is the continuous implementation of shoreline reinforcement or nourishment projects completed by federal, state and local government agencies. Typically, areas of high concern with regard to long term coastal erosion are addressed through shoreline hardening or stabilization projects, such as seawalls, breakwaters and beach nourishment. The ability to continue successfully mitigating the effects of coastal erosion hazards throughout Monmouth County will therefore depend on regular shoreline monitoring and the design and implementation of site-specific solutions, as has been done in the past.

The New Jersey Coastal Zone Management Rules (NJAC 7:7E) defines erosion hazard areas as extending inland from the edge of a stabilized upland area to the limit of the area likely to be eroded in 30 years for one to four unit dwelling structures, and 60 years for all other structures, including developed and undeveloped areas[19]. The extent of an erosion hazard area is calculated by multiplying the projected annual erosion rate at a site by 30 for the development of one to four-unit dwelling structures and by 60 for all other developments. According to a study prepared by the Heinz Center[20], much of the coastline of New Jersey, including Monmouth County, experiences an average of three feet of erosion per year.

To estimate exposure to the coastal erosion hazard, data on shoreline type (as classified by the New Jersey Department of Environmental Protection) was used to delineate areas potentially susceptible to the erosion hazard. For purposes of this analysis, these shoreline types were limited to (1) "beach," which includes waterfront areas comprised of 100 percent sand; and (2) "erodible," which includes any soft shoreline other than beach, rock, marsh, sea wall or earthen dike. The determination of value at-risk was calculated through GIS analysis by summing the total improved values for those parcels that were confirmed to have at least one building located within 200 feet of the identified beach or erodible shoreline types. The 200 feet height was determined to be a reasonable yet slightly more conservative estimate for defining erosion hazard areas based on the calculations recommended under NJAC 7:7E as described above (annual erosion rate of three feet per year x 60 years = 180 feet). According to the assessment, 30 jurisdictions have improved property within areas susceptible to coastal erosion.

Monmouth County and its jurisdictions have an active history of pursuing and implementing successful shoreline protection strategies, particularly through the nourishment of critically eroding beaches and for areas in which property is threatened by continued erosion. Due to these aggressively implemented beach nourishment projects and other mitigating factors, it appears likely that buildings in coastal

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[19] This distance is measured from the crest of a bluff for coastal bluff areas, the most seaward established dune crest for unvegetated dune areas, the first vegetation line from the water for established vegetated dune areas, and the landward edge of a beach or the eight-foot North American Datum (NAD), 1983, contour line, whichever is farther inland, for non-dune areas.

[20] "Evaluation of Erosion Hazards" prepared by The H. John Heinz III Center for Science, Economics and the Environment, April 2000. www.heinzctr.org/NEW_WEB/PDF/erosnrpt.pdf#pagemode=bookmarks&view=Fit

erosion hazard areas would be protected from the hazard for at least a foreseeable 30-year planning window (through 2044). Average annual building damages directly attributable to the erosion hazard have been considered to be negligible for the purposes of this risk assessment, assuming that these ongoing beach nourishment and shoreline stabilization practices are expected to be maintained aggressively, implemented on an ongoing basis, and encouraged to continue.

Table 4.2-35 Exposure in Coastal Erosion Areas by Jurisdiction shows exposure to the coastal erosion hazard by jurisdiction. To estimate exposure coastal erosion, the determination of value and population at-risk was calculated through GIS analysis by calculating the proportion of a parcel or census block lying within 200 feet of 'beach' or 'erodible' shoreline types and applying that same ratio to the census block population and parcel value to estimate population at risk and value of improvements at risk.

As mentioned in the Hazard Profiles section, sea level rise will increase the risk of damages/losses due to future coastal erosion and flood events. Rising sea level over time will shorten the return period (increasing the frequency) of episodic coastal erosion. This increased probability clearly will have an effect on the estimation of annualized loss/damage, but one that is typically only analyzed during detailed feasibility studies for projects proposed by the US Army Corps of Engineers.

Table 4.2 - 35 Exposure in Coastal Erosion Areas by Jurisdiction (2018 Values)

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located Within 200 Feet of Beach/ Erodible Shoreline Types (2018 Values)	Percent of Total Building Value Located Within 200 Feet of Beach/ Erodible Shoreline Types	Average Annual Building Damages Directly Attributable to Coastal Erosion Assuming Continued Beach Nourishment and Shoreline Stabilization Practices
Sea Bright, Borough of	300	$235,586,800	$65,305,039	24.36%	Negligible
Monmouth Beach, Borough of	325	$501,592,200	$53,464,884	10.49%	Negligible
Highlands, Borough of	326	$342,874,400	$20,878,514	6.56%	Negligible
Rumson, Borough of	253	$1,600,650,400	$93,323,187	5.87%	Negligible
Oceanport, Borough of	209	$562,875,800	$29,605,147	5.07%	Negligible
Deal, Borough of	29	$822,100,400	$29,171,805	5.06%	Negligible
Little Silver, Borough of	176	$873,512,700	$39,926,563	4.74%	Negligible
Allenhurst, Borough of	10	$217,949,000	$6,781,991	3.68%	Negligible
Sea Girt, Borough of	12	$732,097,100	$16,173,987	3.06%	Negligible
Long Branch, City of	528	$2,478,681,000	$77,733,622	2.94%	Negligible
Atlantic Highlands, Borough of	92	$364,693,600	$8,179,671	2.88%	Negligible
Union Beach, Borough of	129	$387,844,700	$7,605,567	2.64%	Negligible
Neptune City, Borough of	91	$305,279,900	$3,504,491	1.30%	Negligible
Middletown, Township of	316	$5,895,810,731	$67,603,389	1.21%	Negligible
Loch Arbour, Village of	0	$69,262,800	$423,565	0.96%	Negligible
Keyport, Borough of	80	$434,885,600	$3,247,786	0.68%	Negligible
Wall, Township of	146	$3,053,292,400	$16,758,863	0.65%	Negligible

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located Within 200 Feet of Beach/ Erodible Shoreline Types (2018 Values)	Percent of Total Building Value Located Within 200 Feet of Beach/ Erodible Shoreline Types	Average Annual Building Damages Directly Attributable to Coastal Erosion Assuming Continued Beach Nourishment and Shoreline Stabilization Practices
Belmar, Borough of	42	$553,347,900	$3,354,414	0.59%	Negligible
Manasquan, Borough of	32	$799,826,975	$3,879,813	0.48%	Negligible
Avon-By-The-Sea, Borough of	7	$266,879,900	$1,777,553	0.46%	Negligible
Neptune, Township of	229	$2,431,214,700	$7,165,600	0.42%	Negligible
Spring Lake, Borough of	2	$1,028,817,800	$4,194,768	0.36%	Negligible
Fair Haven, Borough of	11	$785,619,700	$2,140,748	0.32%	Negligible
Brielle, Borough of	12	$669,338,900	$1,709,430	0.31%	Negligible
Red Bank, Borough of	57	$1,194,733,400	$4,040,661	0.30%	Negligible
Shrewsbury, Borough of	18	$608,635,700	$1,235,115	0.22%	Negligible
Asbury Park, City of	0	$1,267,473,400	$1,883,331	0.20%	Negligible
Aberdeen, Township of	33	$1,074,509,800	$904,087	0.08%	Negligible
Bradley Beach, Borough of	10	$462,112,100	$153,774	0.03%	Negligible
Keansburg, Borough of	12	$343,826,000	$25,532	0.01%	Negligible
Allentown, Borough of	0	$127,734,200	$0	0.00%	$0
Colts Neck, Township of	0	$927,454,500	$0	0.00%	$0
Eatontown, Borough of	0	$1,314,725,700	$0	0.00%	$0
Englishtown, Borough of	0	$158,314,100	$0	0.00%	$0
Farmingdale, Borough of	0	$109,883,900	$0	0.00%	$0
Freehold, Borough of	0	$771,202,500	$0	0.00%	$0
Freehold, Township of	0	$4,433,974,800	$0	0.00%	$0
Hazlet, Township of	0	$1,215,098,000	$0	0.00%	$0
Holmdel, Township of	0	$2,104,382,100	$0	0.00%	$0
Howell, Township of	0	$4,204,216,400	$0	0.00%	$0
Interlaken, Borough of	0	$125,000,500	$0	0.00%	$0
Lake Como, Borough of	0	$140,566,300	$0	0.00%	$0
Manalapan, Township of	0	$4,619,949,900	$0	0.00%	$0
Marlboro, Township of	0	$4,435,729,800	$0	0.00%	$0
Matawan, Borough of	0	$517,395,800	$0	0.00%	$0
Millstone, Township of	0	$1,232,191,160	$0	0.00%	$0
Ocean, Township of	0	$2,684,842,000	$0	0.00%	$0
Roosevelt, Borough of	0	$50,136,700	$0	0.00%	$0
Shrewsbury, Township of	0	$30,450,000	$0	0.00%	$0
Spring Lake Heights, Borough of	0	$525,407,200	$0	0.00%	$0
Tinton Falls, Borough of	0	$1,691,986,800	$0	0.00%	$0
Upper Freehold, Township of	0	$851,779,300	$0	0.00%	$0
West Long Branch, Borough of	0	$889,026,200	$0	0.00%	$0
Monmouth County	3,487	$63,526,773,666	$572,152,900	0.92%	Negligible

4.2.51 COASTAL EROSION: POTENTIAL FOR FUTURE DEVELOPMENT TO IMPACT HAZARD VULNERABILITY

Infill development and redevelopment would not be likely to substantially increase a jurisdiction's overall exposure to coastal erosion because existing structures would be replaced with new structures, and the new structures would be built to higher codes and standards offering a certain degree of protection from the hazard. Greenfield development would be more likely, however, to have the potential to substantially increase a jurisdiction's overall vulnerability to the hazard because a new structure would be placed on previously undeveloped land.

28 of Monmouth County's communities have mapped coastal erosion hazard areas. Of these, twelve communities have potentially developable undeveloped parcels in mapped coastal erosion hazard areas. The total area of these parcels is approximately 531 acres. In other words, nearly two percent of the County's potentially developable undeveloped land is in areas potentially susceptible to coastal erosion.

Any new construction on parcels in coastal erosion hazard areas would be built at least in accordance with current regulations as related to coastal erosion. New Jersey's Department of Environmental Protection manages coastal development. The regulated coastal zone is an irregularly shaped zone that covers the entire state coastline (although some inland tidal waters are not covered). A permit[21] is required to construct any structure on a beach or dune or within a certain distance of the coast. This distance depends on the structure's size and use. A single-family residential home must be at least 150 feet from the mean high-water line of any tidal waters or the landward limit of a beach or dune, whichever is most landward. The distance for commercial developments depends on the amount of necessary parking spaces (http://www.nj.gov/dep/cmp/). Developers do not need a permit to reconstruct any development that legally existed before July 19, 1994 and subsequently was damaged or destroyed, in whole or in part, by fire, storm, natural hazard or act of God. But any such reconstruction must (1) comply with existing law and (2) not enlarge the development (N.J. Administrative Code § 7:7-2.1).

Furthermore, the USACE has two ongoing projects in the planning area. The USACE Sea Bright to Manasquan, New Jersey, Beach Erosion Control Project; and the USACE Raritan Bay and Sandy Hook Bay, New Jersey, Beach Erosion and Hurricane Protection Project. These provide some level of erosion protection for many of Monmouth County's' communities. Table 4.2-36 Future Development and Coastal Erosion Hazard Area Vulnerability presents a snapshot of the coastal erosion hazard, future development trends, the acreage of potentially developable parcels subject to coastal erosion, and the

[21] There are two linked rules which govern the review of all coastal project proposals. The Coastal Permit Program Rules at N.J.A.C. 7:7E provide the processes for permit reviews. It includes details on what activities need permits; the qualifications for general permits or permits-by- rule; the details for pre-application meetings, contents and fees; review procedures and deadlines; permit appeals; and enforcement of the coastal laws and rules. The second rule is the Coastal Zone Management Rules (CZM Rules) at N.J.A.C. 7:7E. This rule defines Special Areas of environmental interest, details requirements for development projects and sets forth the compliance criteria for permit approval. Certain general permits require compliance of specific sections of the CZM Rule, for example "dunes" or "shellfish habitat." Individual Permit applications must address and demonstrate compliance with each applicable component of the CZM rules for the specific site and regulated activity to be approved. "Coastal Permit" or "permit" means a permit or an authorization, including a Federal Consistency determination and Water Quality Certificate, issued by the Department under this chapter pursuant to any of the following statutes: the Coastal Area Facility Review Act (CAFRA), N.J.S.A. 13:19-1 et seq., the Wetlands Act of 1970, N.J.S.A. 13:9A-1 et seq., the Waterfront Development Law, N.J.S.A. 12:5-3; Section 307 of the Federal Coastal Zone Management Act, 16 U.S.C. §§ 1451 et seq.; or Section 401 of the Federal Water Pollution Control Act, 33 U.S.C. §§ 1251 et seq.

potential for future development of undeveloped parcels to substantially increase coastal erosion hazard vulnerability under existing conditions. Not that only coastal municipalities are included in the table below.

Jurisdictions with a potential for future development to substantially increase coastal erosion hazard vulnerability under existing conditions should: (a) include coastal erosion mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development. Please note that not all municipalities are included in the following table. Only municipalities vulnerable to coastal erosion are listed.

Table 4.2 - 36 Future Development and Coastal Erosion Hazard Area Vulnerability

Jurisdiction	Coastal Erosion Hazard Ranking	Relative Population Trend2 [22](2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Coastal Erosion Hazard Areas	Percent of Potentially Developable Undeveloped Parcels in Coastal Erosion Hazard Areas	Local Characterization of Development Trends29[23]	Potential for Future Development on Undeveloped Parcels in Coastal Erosion Hazard Areas	Is The Jurisdiction Part of a USACE Beach Nourishment Program? If So, This Will Offer Some Degree of Protection	Potential for Future Development on Undeveloped Parcels In Coastal Erosion Hazard Areas to Substantially Increase Coastal Erosion Hazard Vulnerability Under Existing Conditions
Aberdeen, Township of	M	Substantial increase	415	0	0.0%	Mix of greenfield development, infill and redevelopment			
Allenhurst, Borough of	M	Negligible increase	4	0	0.0%	Little if any development expected			
Asbury Park, City of	M	Substantial increase	39	0	0.0%	Mix of greenfield development, infill and redevelopment		•	
Atlantic Highlands, Borough of	M	Moderate increase	60	2	3.0%	Mix of greenfield development, infill and redevelopment	•		
Avon-by-the-Sea, Borough of	M	Negligible increase	7	0	0.0%	Little if any development expected		•	
Belmar, Borough of	M	Low level increase	13	0	0.0%	Mix of greenfield development, infill and redevelopment		•	
Bradley Beach, Borough of	M	Moderate increase	14	0	0.0%	Mix of greenfield development, infill and redevelopment		•	

[22] Relative population trend, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.

23 Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Coastal Erosion Hazard Ranking	Relative Population Trend2 [22](2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Coastal Erosion Hazard Areas	Percent of Potentially Developable Undeveloped Parcels in Coastal Erosion Hazard Areas	Local Characterization of Development Trends29[23]	Potential for Future Development on Undeveloped Parcels in Coastal Erosion Hazard Areas	Is The Jurisdiction Part of a USACE Beach Nourishment Program? If So, This Will Offer Some Degree of Protection	Potential for Future Development on Undeveloped Parcels In Coastal Erosion Hazard Areas to Substantially Increase Coastal Erosion Hazard Vulnerability Under Existing Conditions
Brielle, Borough of	M	Low level increase	131	53	40.3%	Mix of greenfield development, infill and redevelopment	•		•
Deal, Borough of	M	Negligible increase	40	0	0.0%	Little if any development expected			
Fair Haven, Borough of	M	Low level increase	0.2	0	0.6%	Mix of greenfield development, infill and redevelopment	•		
Highlands, Borough of	M	Moderate increase	58	0	0.0%	Mix of greenfield development, infill and redevelopment			
Keansburg, Borough of	M	Substantial increase	85	0	0.0%	Mix of greenfield development, infill and redevelopment		•	
Keyport, Borough of	M	Substantial increase	68	0	0.0%	Mix of greenfield development, infill and redevelopment			
Little Silver, Borough of	M	Moderate increase	54	3	6.2%	Mix of greenfield development, infill and redevelopment	•		
Loch Arbour, Village of	M	Low level increase	2	0	0.0%	Little to no development expected			
Long Branch, City of	M	Substantial increase	288	0	0.0%	Mix of greenfield development, infill and redevelopment		•	
Manasquan, Borough of	M	Moderate increase	39	0	0.0%	Mix of greenfield development, infill and redevelopment		•	
Middletown, Township of	M	Moderate increase	2,313	97	4.2%	Mix of greenfield development, infill and redevelopment	•	•	
Monmouth Beach, Borough of	M	Negligible increase	57	19	32.6%	Mix of greenfield development, infill and redevelopment	•	•	

Jurisdiction	Coastal Erosion Hazard Ranking	Relative Population Trend2 [22](2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Coastal Erosion Hazard Areas	Percent of Potentially Developable Undeveloped Parcels in Coastal Erosion Hazard Areas	Local Characterization of Development Trends29[23]	Potential for Future Development on Undeveloped Parcels in Coastal Erosion Hazard Areas	Is The Jurisdiction Part of a USACE Beach Nourishment Program? If So, This Will Offer Some Degree of Protection	Potential for Future Development on Undeveloped Parcels In Coastal Erosion Hazard Areas to Substantially Increase Coastal Erosion Hazard Vulnerability Under Existing Conditions
Neptune City, Borough of	M	Substantial increase	38	12	30.5%	Mix of greenfield development, infill and redevelopment	•		•
Neptune, Township of	M	Substantial increase	833	40	4.9%	Mix of greenfield development, infill and redevelopment	•	•	
Oceanport, Borough of	M	Substantial increase	218	75	34.5%	Mix of greenfield development, infill and redevelopment	•		•
Red Bank, Borough of	L	Substantial increase	79	3	3.2%	Mix of greenfield development, infill and redevelopment	•		
Rumson, Borough of	M	Low level increase	126	34	27.3%	Mix of greenfield development, infill and redevelopment	•		•
Sea Bright, Borough of	M	Moderate increase	38	0	0.0%	Mix of greenfield development, infill and redevelopment		•	
Sea Girt, Borough of	M	Negligible increase	20	0	0.0%	Little to no development expected		•	
Spring Lake, Borough of	M	Negligible increase	17	0	0.0%	Mix of greenfield development, infill and redevelopment		•	
Union Beach, Borough of	M	Low level increase	278	169	60.8%	Mix of greenfield development, infill and redevelopment	•	•	
Wall, Township of	M	Moderate increase	2,446	24	1.0%	Predominantly greenfield development	•		•
Monmouth, County of	H	Moderate increase	32,323	534	4.6%	Mix of greenfield development, infill and redevelopment	•	•	•

4.3 SEVERE WEATHER

Severe weather events in Monmouth County are very common and can occur at any time. Severe Weather is a new category for the Monmouth County HMP that emerged from the Steering Committee meeting. The United States Natural Hazards Statistics provides statistical information on fatalities, injuries, and damages caused by weather-related hazards. These statistics were compiled by the Office of Services and the National Climatic Data Center (NCDC) from information contained in in the publication Storm Data. The severe weather profile includes extreme temperatures, tornadoes, extreme wind, and lightning.

4.3.1 EXTREME TEMPERATURES: HAZARD DESCRIPTION

According to FEMA, extreme heat and extreme cold constitute different conditions in different parts of the country. Extreme cold can range from near freezing temperatures in the southern United States to temperatures well below zero in the northern states. Similarly, extreme heat is typically recognized as the condition where temperatures consistently stay ten degrees or more above a region's average high temperature for an extended period. Fatalities can result from extreme temperatures, as they can push the human body beyond its limits (hyperthermia and hypothermia).

4.3.2 EXTREME TEMPERATURES: LOCATION

Monmouth County is located in a region of the country that is susceptible to both extreme heat and extreme cold. During periods of extreme temperature conditions, the effects are felt over a widespread geographic area and it is generally assumed that the entire planning area is uniformly exposed to extreme heat and extreme cold. Areas along the immediate coast might experience minor differences in apparent temperatures due to the combined effects of air temperature, relative humidity, and wind speed.

4.3.3 EXTREME TEMPERATURES: EXTENT

The speed of onset of extreme temperature events typically offers 24 hours of warning time. The duration of historic events in Monmouth County is typically less than one week. The extent of extremely cold temperatures is typically measured through the Wind Chill Temperature (WCT) Index. The WCT Index provides a formula for calculating the dangers from winter winds and freezing temperatures. It is, essentially, a calculation of the temperature that is felt when the effects of wind speed are added to the base air temperature. Figure 4.3-1 NWS Wind Chill Index shows the NOAA NWS Wind Chill Chart.

Figure 4.3 - 1 NWS Wind Chill Index

Wind Chill Chart

Temperature (°F)

Wind (mph) \ Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

Wind Chill (°F) = 35.74 + 0.6215T - 35.75($V^{0.16}$) + 0.4275T($V^{0.16}$)

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

The extent of the extremely hot temperatures is typically measured through the Heat Index, which calculates the dangers from high relative humidity and extremely hot temperatures. It is, essentially, a calculation of the temperature that is felt when the effects of relative humidity are added to the base air temperature. Figure 4.3-2 NWS Heat Index displays extreme temperatures as four different risk categories: caution, extreme caution, danger, and extreme danger.

Figure 4.3 - 2 NWS Heat Index

NOAA national weather service: heat index

temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Caution
Extreme Caution
Danger
Extreme Danger

The following reports of historical extreme temperature events were expressed by the Planning Committee:

- The Borough of Farmingdale and the Township of Howell have experienced several heat emergencies coupled with power outages that have required evacuation and shelter of senior facilities.

- The Township of Holmdel indicated that many of the power distribution transformers are located "in ground" and on days when temperatures reach or exceed 100 degrees it is not uncommon to have two or three concurrent power outages in developments. Coupled with the potential for a wind event at the same time, power outages could cause many heavily treed areas/developments to be without power for extended periods. More and more "age restricted" developments also mean the potential for high impact on the area's growing senior population.
- The Borough of Matawan has experienced rolling blackouts that have caused brief power outages during the extreme heat, specifically causing an issue with signalized traffic control at main intersections throughout the Borough.
- The Borough of Oceanport has experienced recent power loss situations coupled with extreme heat events. Although no major damage or financial loss has occurred, power loss has impacted the local population, and particularly seniors.
- The Borough of Shrewsbury indicated that extreme temperature related events have recently been on the rise. The Borough experiences power outages during extreme heat and drought conditions forcing water usage restrictions. Cold temperatures create similar power outages and property damage due to freezing water pipes in private homes and businesses alike.
- The Township of Wall experienced extreme temperature conditions in the late 1990s and early 2000s including a couple of extreme heat and extreme cold events that caused damages. The extreme heat significantly strained the power infrastructure resulting in many outages. During extreme cold, water main breaks have often occurred.
- Past extreme heat events in the Borough of West Long Branch have led to various power outages.
- The Township of Marlboro has had issues with power outages, localized flooding, and significant snowstorms causing lengthy disruptions of service to the community as well as limiting the public's ability to travel and commute. (Nor'easter)
- The Borough of Brielle indicated that the most severe winter storms affecting Brielle are usually coastal/nor'easter events, during which the Borough experiences minor to moderate coastal flooding. The other major concern is power outages due to snow laden trees\/branches falling on power lines.

4.3.4 EXTREME TEMPERATURES: PREVIOUS OCCURRENCES AND LOSSES

According to the National Climatic Data Center (NCDC), over 90 days of recorded extreme heat events have affected Monmouth County since May 1996 and have resulted in 301 injuries in Monmouth County.

June 25, 1998. A two-day hot spell brought some of the highest temperatures of the summer to New Jersey. Injuries occurred when 15 people fainted at an outdoor ceremony in Fort Monmouth.

July 4-11, 1999. A brutal heat wave spanned the entire Independence Day weekend and ran through the 11th. The combination of the temperature and humidity produced heat indices of around 110 degrees during the afternoon of each day. Four heat-related deaths occurred in Monmouth County, mostly impacting elderly persons in poor health with no air-conditioning and inadequate ventilation. Utility companies issued power alerts and requested that customers reduce consumption, and some implemented rolling blackouts. High temperatures were recorded at 100 degrees in Freehold and 99 degrees in Belmar.

August 1-3, 2006. A strong area of high pressure anchored over the East Coast pushed heat indices into the 105 to 110-degree range across the state. Local utility companies broke records for demand. Sporadic blackouts occurred throughout the county. Several people were treated on the boardwalk for heat exhaustion. A total of 35 people suffered from minor heat-related injuries in Belmar on August 2nd.

June 7-10, 2008. Heat indices as high as around 100 were observed in northern New Jersey. The NCDC reported heat related injuries across Monmouth County. Many cooling centers were opened to assist senior citizens. In Monmouth and Ocean Counties about 10,000 homes and businesses lost power.

July 5-7, 2010. The hottest weather of the summer season occurred on July 5th through the 7th throughout the state of New Jersey. Many high temperatures exceeded 100 degrees for 2 to 3 consecutive days - with even higher heat index values. There were cases of heat exhaustion along Monmouth County boardwalks. A notable temperature of 104 degrees was recorded in Marlboro. Six people in Monmouth County suffered heat related injuries during this event.

July 21-24, 2011. High temperatures during this heat wave reached into the 100's. Afternoon heat indices were in the range of 110 to 120 degrees in some locations. The largest concentration of heat related injuries occurred at the Vans Warped Tour stop at Monmouth Park in Oceanport on the 24th. Three hundred and one people were treated for heat exhaustion, twenty-seven were taken to hospitals, three were admitted.

July 17-18, 2012. An unseasonably hot and humid air mass affected New Jersey on the 17th and 18th. High temperatures on the 17th reached into the mid to upper 90s in most places with afternoon heat indices near 100F. On July 18th, the combination of scorching high temperatures (around 100 degrees) and higher dew points produced hourly afternoon heat indices that reached between 105F and 110F.

July 18-19, 2013. Widespread high temperatures reached into the mid to upper 90s and the most oppressive days (combination of heat and humidity) occurred on the 18th and 19th. Morning lows those days were near 80 degrees in highly urbanized areas and afternoon heat indices reached 105 to 110 degrees. To combat the heat, many cooling centers were opened.

According to the NCDC, 22 recorded extreme cold events have affected Monmouth County since 1994 No deaths or property damage was reported but 7 people did suffer injuries. Notable events include the following:

January 13-28, 2003. A cold frontal passage initiated two weeks of unseasonably cold weather. The coldest mornings were on the 18th and 28th as low temperatures dipped into the single digits or below zero. The extreme cold caused homeless shelters to fill to capacity. Several water mains broke because of the extreme cold. In Monmouth County, ferry service between the county and New York City was suspended from January 23rd through the 26th because of ice in Raritan Bay and around the piers in New York City. About 70 percent of Raritan Bay was frozen. About 4,000 commuters who took the ferries in Highlands, Atlantic Highlands and the Belford section of Middletown Township had to scramble to find alternate ways to get to and from Manhattan. In Freehold, a 12-inch water main burst on U.S. Route 9 on the 30th that flooded and closed the southbound lanes of the roadway. A low temperature of 4 degrees was recorded in Freehold.

January 2004. An arctic air mass brought some of the coldest weather in years to New Jersey from the evening of the 9th through the morning of the 11th, posing a dangerous situation for the homeless and the elderly who could not afford to heat their homes. Many pipes froze and burst both inside and outside of structures. Firefighters had difficulty battling blazes as the water quickly turned to ice. There was a higher incidence of chimney fires and a general shortage of firewood. Another arctic air mass on the 15th brought similar impacts. While temperatures were slightly higher than the previous outbreak, winds were stronger and wind chill factors were lower as well. Ferry service between Monmouth County and New York City was cancelled because of excessive ice in Raritan Bay and the Hudson River. The low temperature at Freehold was recorded at 1 degree, and the lowest hourly wind chill factor in Belmar was 23 degrees below zero.

January 16-18, 2009. A large arctic high-pressure system moved toward the area during the 16th and 17th. Maximum temperatures were only in the teens and minimums dropped into the single digits. Gusty winds produced wind chill values to zero and below zero, especially during the nighttime hours.

January 23, 2013. In Monmouth County, a 53-year-old man was in critical condition after he was found outdoors near the intersection of Willow and Locust Streets in Highlands Borough without a coat and in bare feet. Low temperatures on the morning of the 23rd included 5 degrees in Howell, and 8 degrees in both Wall and Holmdel.

January 2014. A series of three arctic blasts occurred on January 4th, 7th, and 22nd. Temperatures were recorded at 1 degree below zero in Howell on the 4th. On the 7th, strong northwest winds produced wind chill factors as low as 15 to 25 degrees below zero in most areas that morning. Low temperatures were near zero. High temperatures struggled to reach double digits. The excessive cold caused some schools to either cancel classes or have delayed openings. AAA Mid-Atlantic reported an 81 percent increase in service calls, mainly for dead batteries. Amtrak reported extensive delays in its rail service. The cold weather also affected power supplies. Electricity suppliers struggled to keep up with surging demand as the cold forced some power plants to shut Utilities asked their customers where possible to switch to diesel or fuel oil. While some low temperatures were higher than what occurred on January 4th, the wind made it feel much colder than the air temperatures. Lowest hourly wind chill factors during the morning of the 7th included 19 degrees below zero in Belmar. Lowest temperatures on the morning of the 22nd included 7 degrees in Belmar - or 13 degrees below zero with the wind chill.

Table 4.3 - 1 Extreme Temperature Events from 2001-April 2019 in Monmouth County

Date	Event	Duration (in days)	Max or Min Temperature (degrees F)	Deaths	Injuries	Property Damage
5/2/2001	Excessive Heat	2	92	0	0	0
6/26/2007	Excessive Heat	2	95	0	0	0
7/9/2007	Excessive Heat	1	97	0	0	0
8/7/2007	Excessive Heat	1	95	0	0	0
8/25/2007	Excessive Heat	1	92	0	0	0
2/5/2007	Extreme Cold/Wind Chill	2	6	0	7	0
6/7/2008	Excessive Heat	3	97	0	6	0

Date	Event	Duration (in days)	Max or Min Temperature (degrees F)	Deaths	Injuries	Property Damage
8/10/2009	Excessive Heat	1	94	0	0	0
6/23/2010	Excessive Heat	1	97	0	0	0
6/27/2010	Excessive Heat	1	96	0	0	0
7/5/2010	Excessive Heat	2	104	0	0	0
7/23/2010	Excessive Heat	2	97	0	0	0
7/21/2011	Excessive Heat	3	102	0	301	0
7/18/2012	Excessive Heat	1	100	0	0	0
7/18/2013	Excessive Heat	1	99	0	0	0

SOURCE: NCDC, 2019

4.3.5 EXTREME TEMPERATURES: PROBABILITY OF FUTURE OCCURRENCE

Extreme temperature events will continue to have a high probability of occurrence in Monmouth County, and the probability of future occurrences in Monmouth County is certain (higher for extreme heat than extreme cold). While the impact of such occurrences on people and property is typically minimal, it is anticipated that the threat to human lives and safety is increasing due to growing elderly populations in many of Monmouth County's municipal jurisdictions.

4.3.6 EXTREME TEMPERATURES: POTENTIAL EFFECTS OF CLIMATE CHANGE

In August 2019, NOAA announced the average global temperature in July 2019 was 1.71°F above the 20th-century average of 60.4°F. It is predicted that by the 2020s, the average annual temperature in New Jersey will increase by 1.5°F to 3°F above the statewide baseline of 52.7°F. By 2050, the temperature is projected to increase 3°F to 5°F (Sustainable Jersey Climate Change Adaptation Task Force 2013).

4.3.7 EXTREME TEMPERATURES: VULNERABILITY ASSESSMENT

Impacts

Extreme temperatures are primarily a threat to human life and health, though they are also hazardous to livestock and agricultural crops and occasionally might threaten property and infrastructure and disrupt transportation systems. They can also exacerbate the impact of other hazards such as severe weather events that cause widespread power outages. Emergency responders are often called upon to work with public officials/non-profit agencies for heating/cooling venues, and to transport vulnerable sectors of the population to such venues.

Extreme temperatures are likely to result in relatively minor impacts in Monmouth County, with very few injuries (if any), minor and sporadic property damage, and minimal disruption on quality of life. Temporary shutdown of critical facilities to reduce energy usage or due to the fact that employees may not be able to get to the facility is possible. Common impacts associated with extreme heat in Monmouth County include injuries associated with swimming to escape extreme heat, and individuals seeking medical treatment for heat related illness (i.e., for heat stress, exhaustion, heat stroke, etc.), and power outages from an associated strain on electrical networks. Cooling centers are typically opened, and schools altering class schedules and/or activities to ensure student safety. Extreme heat events most heavily typically impact the elderly and disadvantaged. Primary impacts of concern for extreme cold temperatures include the life-threatening effects of overexposure hypothermia on people, particularly the elderly and disadvantaged. Other significant impacts include strains on livestock and agriculture. Monmouth County has Code Blue Warming Center system in place with transportation and notifications for residents during extreme cold temperatures.

Exposure and Damage Estimates

While all of Monmouth County is exposed to extreme temperatures, existing buildings, infrastructure, and critical facilities are not considered vulnerable to significant damage caused by extreme heat or cold events. Damages can occur when thermal tolerances of various systems are exceeded. Extreme cold can cause thermal cracking of paved surfaces and freezing of pipes. Extreme heat can cause softening and traffic- related rutting of paved surfaces; and buckling of railway tracks. Extreme temperatures can place greater demand on utility systems, with possible associated power outages. While losses could be high for particular events and could result in increased maintenance costs over time with frequent occurrences, average annual property losses associated with extreme temperatures are anticipated to be minimal across the planning area. Extreme temperatures do however present a significant life and safety threat to Monmouth County's population.

Heat casualties are usually caused by lack of adequate air conditioning or heat exhaustion. The most vulnerable population to heat casualties are the elderly or infirmed, who frequently live on low fixed incomes and cannot afford to run air-conditioning on a regular basis. This population is sometimes isolated, with no immediate family or friends to look out for their well-being. Casualties resulting from extreme cold may result from a lack of adequate heat, carbon monoxide poisoning from unsafe heat sources and frostbite. The most vulnerable populations to cold casualties are the elderly or infirmed and low-income households, as they may not be able to afford to operate a heat source on a regular basis and may not have immediate family or friends to look out for their well-being.

Given the lack of historical data and limited likelihood for structural losses resulting from extreme heat or cold occurrences in Monmouth County, annualizing potential structural losses over a long period of time would most likely yield a negligible annualized loss estimate for the entire county.

4.3.8 TORNADO: HAZARD DESCRIPTION

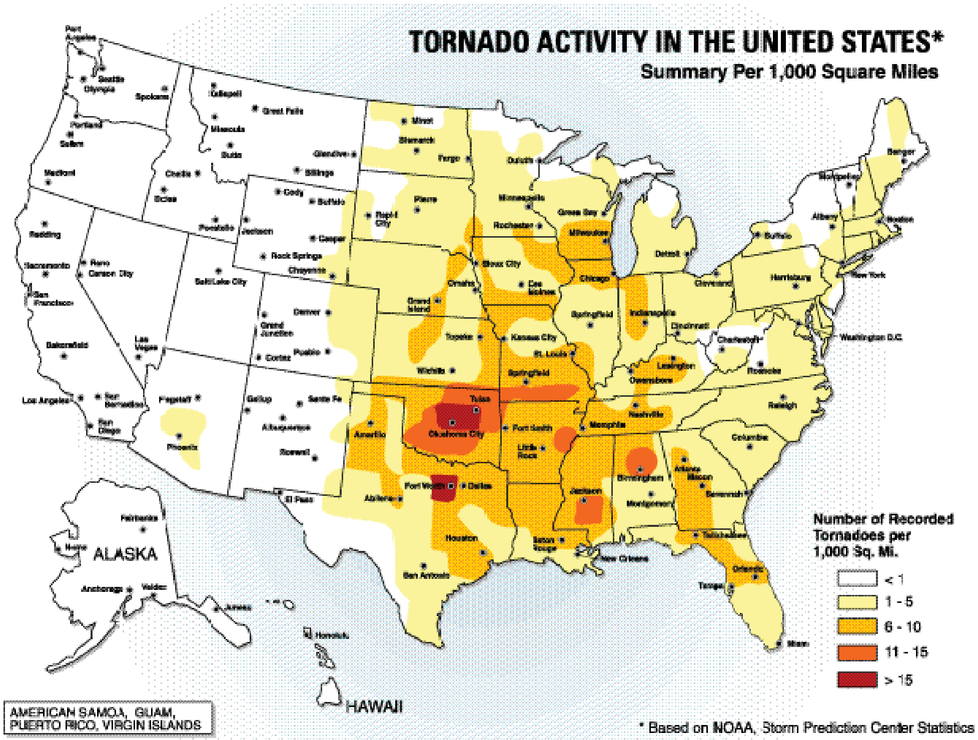
A tornado is a violently rotating column of air that has contact with the ground and is often visible as a funnel cloud. Its vortex rotates cyclonically with wind speeds ranging from as low as 40 mph to as high as 300 mph. Tornadoes are most often generated by thunderstorm activity when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The destruction caused by tornadoes ranges from light to catastrophic depending on the intensity, size and duration of the storm.

4.3.9 TORNADO: LOCATION

Monmouth County is located in an area that is susceptible to tornados, though their occurrence is not nearly as frequent or intense as it is in other regions of the country. Of the roughly five tornadoes that touch down in New Jersey each year, most tend to be of low magnitude (from EF0 to EF2) and typically impact only relatively small areas. Figure 4.3-3 Tornado Activity in the United States shows tornado activity in the United States based on the number of recorded tornadoes per 1,000 square miles. Tornadoes are completely random, and it is not possible to predict specific tornado hazard areas.

Tornadoes can occur anywhere, and no one location is more susceptible than another. All of Monmouth County is uniformly exposed.

Figure 4.3 - 3 Tornado Activity in the United States



4.3.10 TORNADO: EXTENT

Table 4.3 - 2 Enhanced Fujita Scale for Tornados shows the Enhanced Fujita Scale for Tornadoes which was developed to measure tornado strength and associated damages.

Table 4.3 - 2 Enhanced Fujita Scale for Tornados

Storm Category	Damage Level	3 Second Gust (mph)	Description of Damages	Photo Example
EF0	LIGHT	65-85	Some damage to chimneys; branches broken off trees; shallow- rooted trees pushed over; sign boards damaged.	
EF1	MODERATE	86-110	Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.	
EF2	SIGNIFICANT	111-135	Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; high-rise windows broken and blown in; light-object missiles generated.	

Storm Category	Damage Level	3 Second Gust (mph)	Description of Damages	Photo Example
EF3	SEVERE	136-165	Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.	
EF4	DEVASTATING	166-200	Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown, and large missiles generated.	
EF5	INCREDIBLE	200+	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 m (109 yd); trees debarked; steel reinforced concrete structures badly damaged.	

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION; FEDERAL EMERGENCY MANAGEMENT AGENCY

The tornadoes associated with tropical cyclones are most frequent in September and October when the incidence of tropical storm systems is greatest. This type of tornado usually occurs around the perimeter of the storm, and most often to the right and ahead of the storm path or the storm center as it comes ashore. These tornadoes commonly occur as part of large outbreaks and generally move in an easterly direction.

4.3.11 TORNADO: PREVIOUS OCCURRENCES AND LOSSES

According to NCDC, there have been 11 recorded tornado events in Monmouth County between 1950 and April 2019. Two tornadoes have occurred since the last version of the plan was prepared. Most of these events were determined to be of minimal tornado intensity, as shown in Table 4.3-3 Historical Tornadoes in Monmouth County. Since 1950 No recorded tornadoes in Monmouth County have resulted in deaths or injuries, but did cause an estimated $1.525 million in property damages, with the most severe event being an F2 tornado that touched down in northern Manalapan Township and extreme southwest Marlboro Township in May 2001 that caused an estimated $1M in damages.

Table 4.3 - 3 Historical Tornadoes in Monmouth County Since 1950

Date	Location	Magnitude	Deaths	Injuries
8/10/1952	Millstone Township	F1	0	0
10/16/1955	Tinton Falls Borough	F2	0	0
4/18/1960	Upper Freehold Township	F1	0	0
3/10/1964	Howell Township	F1	0	0
3/26/1964	Neptune Township	F0	0	0
11/1/1994	Loch Arbour Village	F0	0	0
8/13/1997	Middletown Township and Highland Borough	F0	0	0
5/27/2001	Manalapan and Marlboro Township	F2	0	0
8/9/2011	Millstone Township	EF0	0	0
6/24/2017	Howell Township	EF0	0	0
		Total	0	0

SOURCE: NCDC

Notable events include the following:

November 1, 1994. A tornado briefly touched down in the Village of Loch Arbour around 6 p.m. at the intersection of Euclid and Edgemont Avenues. The tornado lifted between Spier and Corlies Avenue about 100 yards from the Atlantic Ocean. About five homes on Euclid Avenue suffered substantial roof damage. Most of the eight other homes which sustained minor damage were on Buena Vista Court. About two dozen trees were uprooted. Most of them were decaying within. Tops were sheared off a number of other trees. Damage was estimated by the NCDC at $75,000; however, the Village indicated that damages were closer to $200,000 for this event.

August 13, 1997. A F0 tornado touched down briefly in Middletown Township and Highlands Borough before it went into Sandy Hook Bay and dissipated. The path length was about 1.2 miles and the path width about 75 yards. The tornado damaged several cars and homes, and uprooted and/or snapped numerous trees, but no injuries were reported. The tornado touched down in northeastern Middletown Township near Pape Drive and Navesink Avenue, moving northeast where it uprooted a tree on Williams Street that crushed three parked cars. Another car was burned when it came in contact with downed wires on Buttermilk Valley Road. A tree also crushed an awning in the Shadow Lane Mobile Home Park. In Highlands Borough, a shed was blown off its foundation and carried by the tornado between two houses. Other structural damage was mainly confined to broken windows, torn shingles and gutters. Maximum wind speeds were estimated at the high end of the F0 scale at about 70 mph.

May 27, 2001. An F2 tornado struck extreme northern Manalapan and extreme southwest Marlboro Townships. The tornado's path length was estimated at 1.5 miles and its path width was around 200 feet. It was initially a relatively weak tornado (F0) but intensified into an F1 before it reached Kentucky Court in Manalapan Township. One property on Kentucky Court lost dozens of trees. The tornado also downed trees on Ivanhoe and Rowena Roads. The tornado reached its maximum strength (F2) as it passed through Debracy Court, where the worst damage occurred. Four houses were severely damaged, and about 12 others suffered minor damage. The tornado weakened to an F1 after it left Debracy Court. As the tornado crossed into Marlboro Township, it knocked down dozens of trees in Hawkins Road Park. As the tornado exited the park, it weakened to an F0. It still knocked a tree onto a house on MacLeisch Drive and ripped shingles and gutters from homes on Guest and MacLeisch Drives. The tornado lifted as it approached Barclay Brook.

August 9, 2011. An EF0 tornado touched down in Millstone Township in Monmouth County. The tornado initially touched down north of Buono Farm and tracked northeast where it crossed New Jersey State Route 33 and damaged a flagpole and business fencing. A barn was damaged on Prodelin Way. Numerous trees and some wires were knocked down along its path, especially on Prodelin and Arrowhead Ways and Bergen Mills Road. The tornado moved along Arrowhead Way before it lifted. The tornado's approximate path length was 1.7 miles, maximum path width of 50 yards and estimated maximum wind speed of 70 mph. No deaths or injuries were reported, though property damages were estimated at $100,000.

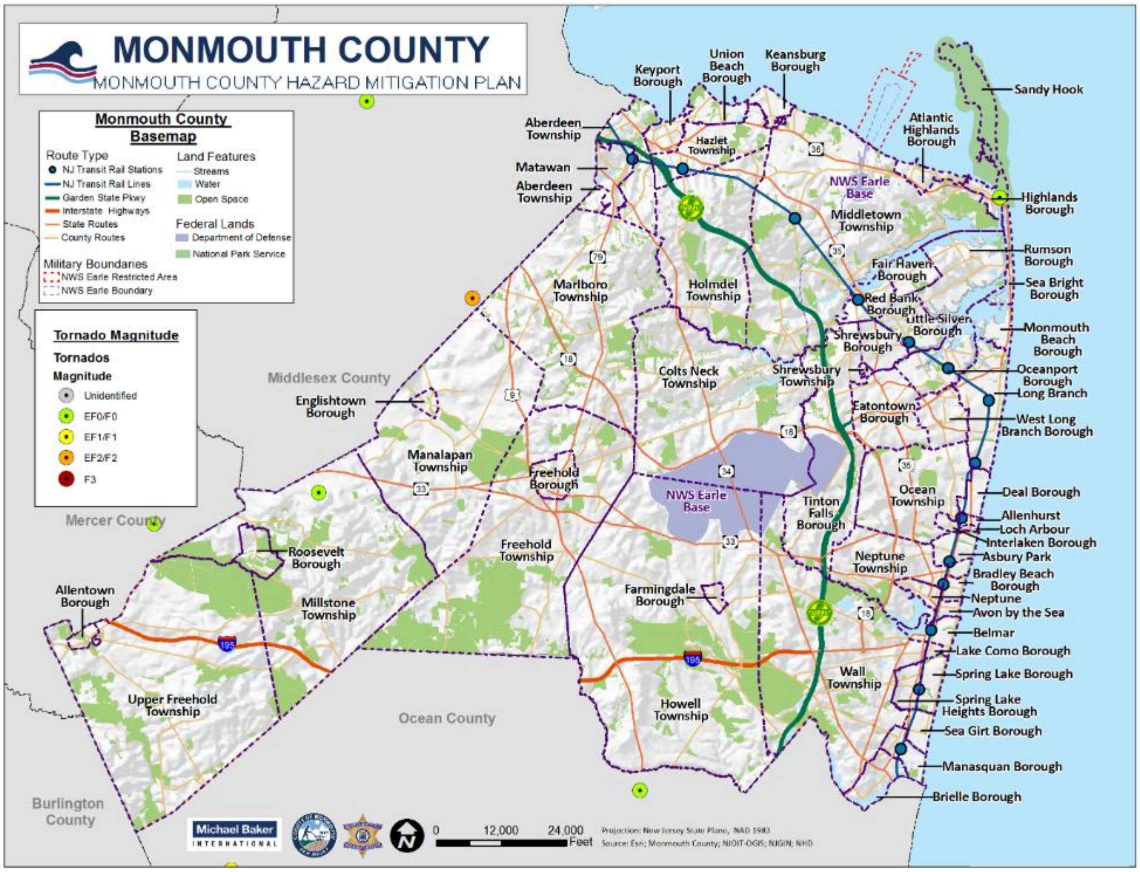
June 24, 2017. A band of gusty convective showers moved through during the morning hours in association with the remnants of tropical storm Cindy. Several reports of damage were reported from the winds. Thousands lost power. The tornado touched down near Ft. Plains Rd. in Howell for approximately two minutes, then briefly touched down again near Lower Squankum (Howell) a few minutes later.

Table 4.3 - 4 Historical Tornadoes in Monmouth County (1950-April 2019) by Jurisdiction lists the number of tornado events in Monmouth County only for jurisdictions that experienced tornadic activity. Estimated magnitude for each tornado is also listed. As tornado events might impact multiple jurisdictions, the total number of events in this table is greater than the number of records provided by NCDC based on detailed information regarding impacted areas. The specific location of reported touchdown occurrences for each of these events in Monmouth County (where known) is shown in Figure 4.3-4 Historical Tornado Touchdown Locations. Please note that all municipalities are not listed in the following table. Only municipalities that have experienced historical occurrences of tornadoes are listed.

Table 4.3 - 4 Historical Tornadoes in Monmouth County (1950-April 2019) by Jurisdiction

Jurisdiction	Number of Events	Magnitude (Enhanced Fujita Scale)						Maximum F Scale
		EF0	EF1	EF2	EF3	EF4	EF5	
Highlands, Borough of	1	1	0	0	0	0	0	EF0
Howell, Township of	3	2	1	0	0	0	0	EF1
Loch Arbour, Village of	1	1	0	0	0	0	0	EF0
Manalapan, Township of	1	0	0	1	0	0	0	EF2
Marlboro, Township of	1	0	0	1	0	0	0	EF2
Middletown, Township of	1	1	0	0	0	0	0	EF0
Millstone, Township of	2	1	1	0	0	0	0	EF1
Neptune, Township of	1	1	0	0	0	0	0	EF0
Tinton Falls, Borough of	1	0	0	1	0	0	0	EF2
Upper Freehold, Township of	1	0	1	0	0	0	0	EF1
Total	13	7	3	3	0	0	0	-

Figure 4.3 - 4 Historical Tornado Touchdown Locations



Other notable reports of historical tornado events include the following, as identified by the Planning Committee:

- The Village of Loch Arbour indicated that the F0 tornado reported in 1994 resulted in property damages totaling $200,000.
- The Township of Upper Freehold reported that property damages associated with its one historic event included damage to communications antennas, schools, and horse and agricultural farms.

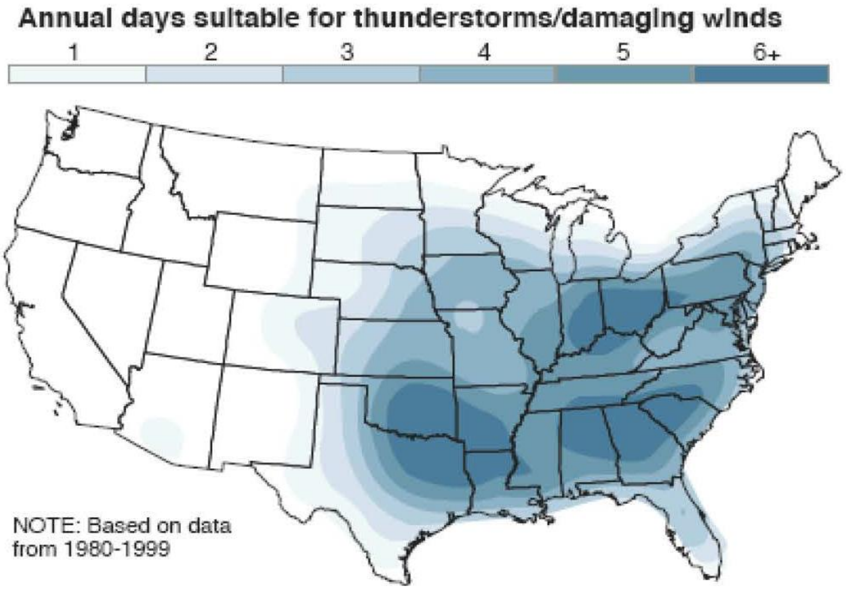
4.3.12 TORNADO: PROBABILITY OF FUTURE OCCURRENCE

It is likely that Monmouth County will continue to experience weak to moderate tornado events, though their frequency of occurrence will be fairly low. Probability data made available through NOAA's National Severe Storms Laboratory (NSSL) indicate that Monmouth County is in an area that experiences less than one tornado event per year. Historical storm data made available through NCDC confirm this data (nine confirmed events in 59 years, resulting in an estimated annual probability of a tornado event of 15 percent). In New Jersey, tornadoes are more likely to occur during the months of March through August and tend to form in the late afternoon and early evening.

4.3.13 TORNADO: POTENTIAL EFFECTS OF CLIMATE CHANGE

National Aeronautics and Space Administration (NASA) scientists suggest that the United States will face more severe thunderstorms in the future, with deadly lightning, damaging hail, and the potential for tornadoes in the event of climate change. A recent study conducted by NASA predicts that smaller storm events like thunderstorms will also be more dangerous due to climate change (NASA 2007). Figure 4.3 – 5 Annual Days Suitable for Thunderstorms/Damaging Winds identifies those areas, particularly within the eastern United States, that are more prone to thunderstorms, including New Jersey (NWS 2010).

Figure 4.3 - 5 Annual Days Suitable for Thunderstorms/Damaging Winds



SOURCE: BORENSTEIN, 2007

4.3.14 TORNADO: VULNERABILITY ASSESSMENT

Impacts

Tornados are nature's most violent storms. The most intense tornados can cause fatalities and catastrophic damage to both trees and the built environment in a matter of seconds. The number deaths, injuries, and dollar amount of damages can fluctuate drastically depending on the severity of the tornado and the degree and type of development in the damage path.

Emergency responders are called upon for search and rescue, to tend to the injured, assist in evacuations, and to close roads and direct traffic. Transportation, communications, and the general operation of government could be affected by an incident. Property damage can be significant within the tornado's path. Trees can be damaged or destroyed. Power outages can occur. These impacts tend to be felt in rather limited areas, due to the nature of the tornado hazard itself (tornados with limited widths and path lengths after touchdown).

The destruction caused by tornadoes ranges from light to catastrophic depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction, including residential dwellings and particularly manufactured homes.

Exposure and Damage Estimates

Historical evidence shows that Monmouth County is vulnerable to tornadic activity. Rather than estimating the potential annual loss average, the amount of property damage per storm event, adjusted for inflation, was calculated in this damage estimate. Please note that all municipalities are not listed in the following table. Only municipalities that have experienced historical occurrences of tornadoes are listed.

Table 4.3 - 5 Damage Estimates by Tornado

Date	Location	Average Amount of Property Damage (2020 Value)
8/10/1952	Millstone Township	$96,106.26
10/16/1955	Tinton Falls Borough	N/A
4/18/1960	Upper Freehold Township	$820.26
3/10/1964	Howell Township	$757,791.32
3/26/1964	Neptune Township	$75,779.13
11/1/1994	Loch Arbour Village	$125,506.36
8/13/1997	Middletown Township and Highland Borough	$78,844.96
5/27/2001	Manalapan and Marlboro Township	$1,456,811.17
8/9/2011	Millstone Township	$119,509.26
6/24/2017	Howell Township	N/A

SOURCE: NOAA STORM EVENTS DATABASE

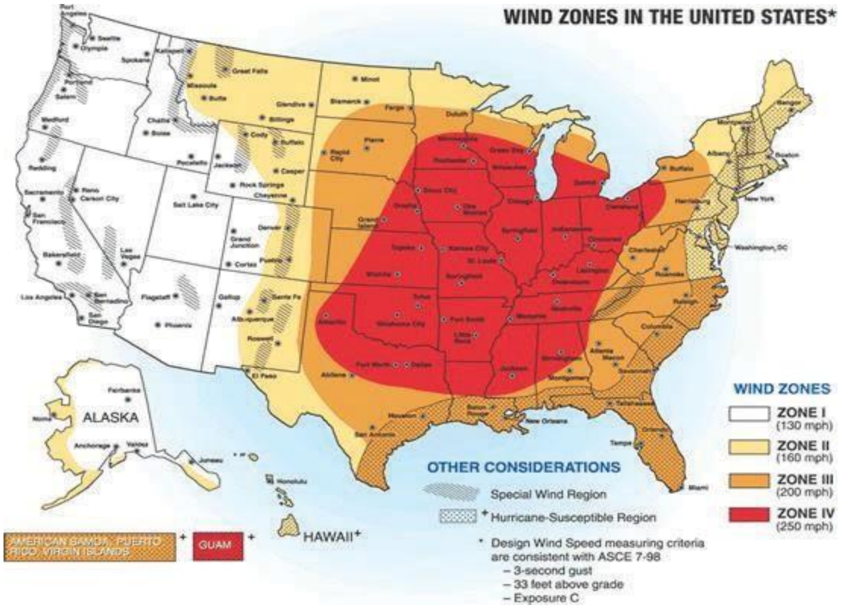
4.3.15 EXTREME WIND: HAZARD DESCRIPTION

Wind is air that is in constant motion relative to the surface of the earth. Extreme wind events can occur suddenly without warning. They can occur at any time of the day or night, in any part of the country. Extreme winds pose a threat to lives, property, and vital utilities primarily due to the effects of flying debris and can down trees and power lines. Extreme winds are most commonly the result of hurricanes, tropical storms, nor'easters, severe thunderstorms and tornadoes, but can also occur in their absence as mere "windstorms." One type of windstorm, the downburst, can cause damage equivalent to a strong tornado.

4.3.16 EXTREME WIND: LOCATION

Extreme wind events are experienced in every region of the United States. The extreme wind hazard area covers the whole of Monmouth County and the entire planning area is uniformly susceptible to the extreme wind hazard. The County is also at risk to straight-line wind which comes out of a thunderstorm. Figure 4.4-2 Wind Zones in the United States illustrates various wind zones throughout the country based on design wind speeds established by the American Society of Civil Engineers. It divides the country into four wind zones, geographically representing the frequency and magnitude of potential extreme wind events including severe thunderstorms, tornadoes and hurricanes. The figure shows that all areas of Monmouth County are located within Zone II and are susceptible to hurricanes, with a design wind speed for shelters of 160 mph (3- second gust).

Figure 4.3 - 6 Wind Zones in the United States



4.3.17 EXTREME WIND: EXTENT

Extreme winds can occur alone, such as during straight-line wind events and derechos, or it can accompany other natural hazards, including hurricanes and severe thunderstorms. Severe wind poses a threat to lives, property, and vital utilities primarily due to the effects of flying debris or downed trees and power lines. Severe wind will typically cause the greatest damage to structures of light construction, particularly manufactured homes. Table 4.3-6 Severity and Typical Effects of Various Sustained Wind Speeds illustrates the severity and typical effects of various sustained wind speeds. These would be reflective of high winds associated with thunderstorms, hurricanes, tropical storms and nor'easters. Typical effects of wind are very different for tornados; Table 4.3 - 7 Severity and Typical Effects of Various Tornado Wind Speeds 3-Second Gust illustrates the severity and typical effects of wind during tornados, as measured by various 3 second gusts. Note that tornados are addressed separately later in this plan section.

Table 4.3 - 6 Severity and Typical Effects of Various Sustained Wind Speeds

Sustained Wind Speed* (mph)	Equivalent Saffir-Simpson Scale** (Hurricanes)	Severity of Damage	Typical Effects
0-73 (V3S=0 to 88)	N/A	Isolated	Isolated damage for winds below 50 mph. Above 50 mph, expect some minor damage to buildings of light material. Small branches blown from trees.
74-95 (V_{3S} =89 to 115)	1	Minor	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap, and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.

Sustained Wind Speed* (mph)	Equivalent Saffir-Simpson Scale** (Hurricanes)	Severity of Damage	Typical Effects
96-110 (V3S=116 to 130)	2	Extensive	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near total power loss is expected with outages that could last from several days to weeks.
111-129 (V3S=131 to 149)	3	Devastating	Devastating damage will occur: Well-built framed homes 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.
130-156 (V3S=150 to 176)	4	Catastrophic	Catastrophic damage will occur: Well-built framed homes 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.
157 or higher (V3S>177)	5	Catastrophic	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.

Table 4.3 - 7 Severity and Typical Effects of Various Tornado Wind Speeds 3-Second Gust

Maximum Wind Speeds 3 Second Gust (mph)	Equivalent Enhanced Fujita Scale* (Tornadoes)	Severity	Typical Effects
65-85	EF0	Light	Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
86-110	EF1	Moderate	Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
111-135	EF2	Significant	Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; high-rise windows broken and blown in; light-object missiles generated.
136-165	EF3	Severe	Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
166-200	EF4	Devastating	Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown, and large missiles generated.
Over 200	EF5	Incredible	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly in excess of 100 m

Maximum Wind Speeds 3 Second Gust (mph)	Equivalent Enhanced Fujita Scale* (Tornadoes)	Severity	Typical Effects
			(109 yd); trees debarked; steel reinforced concrete structures badly damaged.

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION[24]

4.3.18 EXTREME WIND: PREVIOUS OCCURRENCES AND LOSSES

According to NCDC, 104 recorded high wind events have affected Monmouth County since 1950. Twelve of these have occurred since the last plan was prepared. As mentioned earlier, extreme wind events are often associated with other notable events such as hurricanes and tropical storms, nor'easters and winter storms - each of which are addressed separately within this section. According to NCDC, several notable extreme wind events in Monmouth County were directly associated with these event types. Events from the previous plan as well as those that have occurred since the last plan are in the table below.

Table 4.3 - 8 High Wind Events in Monmouth County to April 2019

Date	Associated Hazard Event	Deaths	Injuries	Property Damage
11/14/1995	Nor'easter	0	0	Not known
10/8/1996	Tropical Storm Josephine	0	0	Not known
3/31/1997	Winter Storm	0	0	Not known
11/7/1997	Nor'easter	0	0	Not known
2/4/1998	Nor'easter	0	0	Not known
2/23/1998- 02/25/1998	Nor'easter	0	0	Not known
9/9/1998	Severe Thunderstorms	1	30	Not known
9/16/1999	Hurricane Floyd	0	0	Not known
1/25/2000	Winter Storm	0	0	Not known
4/9/2000	Winter Storm	0	0	Not known
8/7/2000	Severe Thunderstorms	0	0	$1 million
8/2/2002	Severe Thunderstorms	0	0	$10.2 million
9/11/2002	Tropical Storm Gustav	0	0	Not known
10/16/2002	Nor'easter	0	0	Not known
11/16/2002	Nor'easter	0	0	Not known
2/17/2003	Winter Storm	0	0	Not known
7/22/2003	Severe Thunderstorms	0	0	$500,000
9/18/2003	Tropical Storm Isabel	0	0	Not known
3/8/2005	Winter Storm	0	0	Not known
1/18/2006	Severe Thunderstorms	0	0	$250,000
2/11/2006	Winter Storm	0	0	Not known

[24] THE 2003 INTERNATIONAL BUILDING CODE TABLE L609.3.L WAS USED TO CONVERT SAFFIR-SIMPSON SUSTAINED WIND SPEEDS TO 3-SECOND GUSTS (V3S) FOR THE PURPOSES OF COMPARISON BETWEEN HURRICANE AND TORNADO WINDS. THE SAFFIR-SIMPSON SCALE IS DESCRIBED FURTHER IN THIS SECTION UNDER HURRICANE AND TROPICAL STORM

Date	Associated Hazard Event	Deaths	Injuries	Property Damage
9/1/2006	Remnants of Tropical Storm Ernesto	0	0	Not known
8/17/2007	Severe Thunderstorms	0	0	$5,000
11/3/2007	Remnants of Hurricane Noel	0	0	Not known
3/5/2008	Severe Thunderstorms	0	0	$100,000
9/7/2008	Tropical Storm Hannah	0	0	Not known
12/21/2008-12/22/2008	Winter Storm	0	0	Not known
3/1/2009	Nor'easter	0	0	Not known
10/5/2009	Nor'easter	0	0	Not known
11/13/2009	Nor'easter	0	0	Not known
3/13/2010		0	0	$500,000
12/26/2010	Blizzard	0	0	Not known
8/27/2011-08/28/2011	Hurricane Irene	0	0	Not known
10/29/2012	Superstorm Sandy	0	0	$1,750,000,000
11/7/2012	Nor'Easter	0	0	$13,000
12/21/2012		0	0	$50,000
12/26/2012		0	0	$25,000
1/31/2013	Severe Thunderstorms	0	0	$20,000
2/27/2013		0	0	$10,000
3/6/2013	Nor'Easter	0	0	$10,000
4/3/2016	Thunderstorms	0	0	$0
1/23/2017		0	0	$10
3/2/2017	Thunderstorms	0	0	$0
3/2/2018		0	0	$0
10/27/2018		0	0	$0
07/22/19	Thunderstorm	0	1	Not Known
10/16/19	Nor’easter	0	0	Not Known

SOURCE: NCDC, 2019

A longer description of some of these events is included below:

September 9, 1998. A squall line of severe thunderstorms capsized boats and downed trees and power lines throughout Monmouth County. The USCG rescued about 60 people from overturned boats - mostly in Sandy Hook Bay. About 30 people were injured and one man drowned. In Sea Bright, lifeguards rescued people from a capsized catamaran. A wind gust to 75 mph was reported in Freehold.

August 7, 2000. A strong downburst produced by a severe thunderstorm produced wind gusts between 75 and 90 mph which caused significant tree damage in Marlboro and Colts Neck. Property damages were estimated at $1 million. The most significant damage occurred in an area bounded by State Route 18 to the west, County Route 537 to the south, Dutch Land Road to the north and Montrose Road to the east.

August 2, 2002. A line of severe thunderstorms brought hurricane-force wind gusts and downed thousands of trees and power lines, damaging homes, vehicles and hundreds of poles. Most municipalities county reported damage and a state of emergency was declared in the county. Damages were estimated at $10.2 million. A wind gust of 83 mph was measured at the North Shrewsbury Ice Boat Clubhouse before the instrument broke. In West Long Branch Borough, Monmouth University suffered extensive damage.

July 22, 2003. A severe thunderstorm caused about $500,000 in property damage. About 4,000 homes and businesses lost power. Numerous tree limbs and one large tree were downed in Wall. In Belmar, about 25 homes and six cars were damaged, one home was shifted off its foundation, and another home's roof was ripped off.

January 18, 2006. Peak wind gusts nearly reached between 45 and 70 mph. In Middletown, a school bus struck a downed tree, but no injuries occurred. Vehicles were damaged by downed trees in Colts Neck and Englishtown.

August 17, 2007. High winds from strong to severe thunderstorms during the afternoon and evening of August 17th caused damages in several areas of the county. Trees and wires were downed in Monmouth Beach, Keansburg, from Holmdel through Deal, and from Freehold southeast to Manasquan. In Keansburg, a downed limb and wires resulted in a fire which spread along electrical lines into a house.

February 13, 2008. Strong winds collapsed two large window walls at the Ocean Township Elementary School gymnasium, which caused about $5,000 in damage. About 30 to 40 students from two gym classes were in the room at the time; however, none were injured.

March 5, 2008. A line of severe thunderstorms produced nearly $100,000 in wind related damage in Monmouth County. In Eatontown, a large uprooted tree crushed one trailer and ripped a hole in the roof of the trailer next door. The same storm ripped siding from some other homes in the area. Downed trees and closed roadways were reported in Farmingdale, Wall and Neptune. Power outages because of downed wires occurred in Bradley Beach, Eatontown, Farmingdale, Howell and Neptune. Wind gusts of 61 mph and 60 mph were measured in Sandy Hook and Tinton Falls respectively. Two women were injured when a tree fell on their vehicle in Manalapan. In Middletown, the Navesink section was hit the hardest. Outages because of downed trees and limbs occurred in Colts Neck, Englishtown, Freehold, Hazlet, Middletown, Neptune, Oceanport and Union Beach. A wind gust to 68 mph was measured at Sandy Hook.

March 13, 2010. Strong to high winds downed thousands of trees and tree limbs, damaged telephone poles and caused record breaking utility outages. Damages of $500,000 were reported by the NCDC for Monmouth County, though damages were incurred across the state. Fallen trees damaged homes. Numerous roadways were closed because of downed trees and debris. Rail services were also suspended because of downed wires and poles. A state of emergency was declared state-wide on the 14th.

August 27-28, 2011. Hurricane Irene made landfall as tropical storm at Brigantine (Atlantic County). Monmouth County was impacted by tropical storm force sustained winds, with higher gusts including

63 mph recorded at Sandy Hook and 52 mph in Belmar. High winds downed trees and power lines across the county, with power outages reported for 121,000 homes.

October 29, 2012. Superstorm Sandy made landfall in Atlantic County as a post tropical storm in Brigantine. Monmouth and Ocean Counties were the two hardest-hit counties in the state. Wind damage was estimated at $1.5 billion in eastern Monmouth County, and at $250 million in western Monmouth County. Monmouth County had the greatest number of sustained outages of any county in the state. Upwards of 45,000 fallen trees had to be cut through to restore power, and power was unable to be restored to thousands of shore and barrier island customers because of massive structure and infrastructure damages. Peak wind gusts ranged from 61 mph in Wall to 87 mph at Sandy Hook. Maximum sustained winds included 68 mph at Sandy Hook and 61 mph in Long Branch.

Other notable reports of historical extreme wind events include the following, as identified by the Planning Committee:

- The Borough of Atlantic Highlands is located on Raritan and Sandy Hook Bays, and high winds routinely cause large problems with boats, docks and buildings.
- The Borough of Deal experienced extreme winds including microbursts during the reported August 2002 event that resulted in approximately $250,000 in damages to Borough facilities.
- The Borough of Fair Haven reports that wind damage has caused many problems to older large trees in town over the last few years.
- The Borough of Freehold reported that many wind events have caused damages to street trees.
- The Township of Marlboro had a straight-line wind occurrence in the early 1990s that caused moderate damage to a wooded area on School Road East.
- The Borough of Matawan recently experienced an extreme wind event for one portion of town resulting in the loss of power for the Freneau section and the closing of State Highway 79 for several hours due to downed trees and power lines.
- The Borough of Neptune City had numerous trees blown down with power lines taken down during a storm event in 1993, causing many outages.
- The Township of Neptune had several instances of wind damage due to Sandy: the top sections of two radio towers were sheared off; the Ocean Grove auditorium lost a portion of its roof; and the Unexcelled Fire Company on Highway 33 suffered roof damage and partial structural collapse.
- The Township of Ocean has experienced several severe windstorms between 2002 and 2007 which caused damage to both residential and commercial structures.
- The Borough of Oceanport was devastated by the August 2002 storm event. For three days they had no power, and the cleanup was extensive and costly.
- The Borough of Rumson has seen damage in recent years due to wind, mainly on trees, telephone poles and power lines.

- The Borough of Shrewsbury has sustained heavy tree damage during periods of heavy winds. Damage to private property such as homes and automobiles have been documented on numerous occasions.
- The Township of Upper Freehold experienced damaging wind events in August 2002 and August 2003, which resulted in downed trees and utilities, and impassable roads.

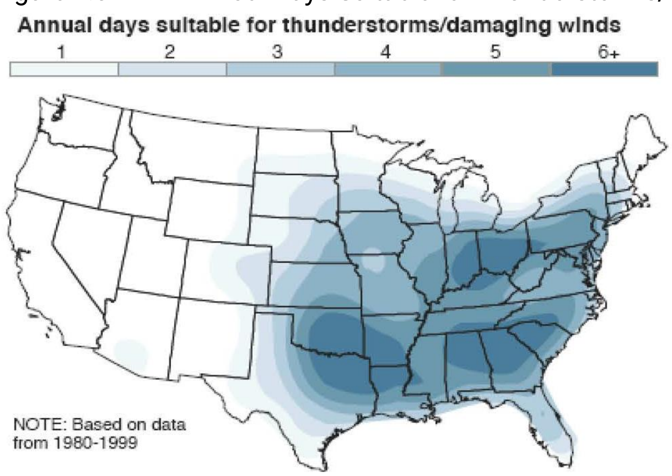
4.3.19 EXTREME WIND: PROBABILITY OF FUTURE OCCURRENCE

Extreme wind events will continue to have a high probability of occurrence in Monmouth County, and the probability of future occurrences in Monmouth County is certain. The entire planning area is susceptible to a wide variety of recurring events that cause extreme wind conditions including severe thunderstorms (most frequent), tornadoes, hurricanes, tropical storms and nor'easters. Based on historic occurrence data, Monmouth County can expect approximately 5 to 10 extreme wind events per year.

4.3.20 EXTREME WIND: POTENTIAL EFFECTS OF CLIMATE CHANGE

National Aeronautics and Space Administration (NASA) scientists suggest that the United States will face more severe thunderstorms in the future, with deadly lightning, damaging hail, and the potential for tornadoes in the event of climate change. A recent study conducted by NASA predicts that smaller storm events like thunderstorms will also be more dangerous due to climate change (NASA 2007). Figure 4.3 – 7 Annual Days Suitable for Thunderstorms/Damaging Winds identifies those areas, particularly within the eastern United States, that are more prone to thunderstorms, including New Jersey (NWS 2010).

Figure 4.3 - 7 Annual Days Suitable for Thunderstorms/Damaging Winds



SOURCE: BORENSTEIN, 2007

4.3.21 EXTREME WIND: VULNERABILITY ASSESSMENT

Impacts

Impacts associated with extreme wind in Monmouth County can be critical. Multiple deaths/injuries are possible, large portions of property in the affected area can be damaged or destroyed (depending on the nature of the event), and a complete shutdown of critical facilities for more than one week could all be possible, depending on the type of wind event and the nature of the event.

Some extreme wind events can be forecasted; others are completely unpredictable. Emergency responders are called up for evacuations, road closures, and attending to the injured. Flying debris, in extreme wind events, can cause secondary impacts while trees can be downed and buildings can be damaged. High winds can directly damage private property as well as roads and bridges, schools, hospitals, and other types of critical facilities and utilities and communications facilities. In addition, impaired access to these facilities during extreme wind events can cause secondary, indirect damages.

Extreme winds may stem from other hazards, including hurricanes and tropical storms, nor'easter, and tornadoes; however, only reported extreme wind events not related to other hazards are considered in this analysis. Vulnerability to winds from hurricanes and tropical storms, nor'easter, and tornadoes are addressed individually in other sections.

Exposure and Damage Estimates

Because it cannot be predicted where extreme winds may occur, all existing and future buildings, facilities and populations are considered to be exposed to this hazard and could potentially be impacted. It is important to note that only reported extreme wind occurrences have been factored into this vulnerability assessment[4]. For the 2014 plan update, NCDC historical extreme wind loss data current as of September 2014 includes a total of 238 days with high wind, thunderstorm wind, and strong wind events between October 1968 and May 2014 (not including Superstorm Sandy). Of these, there are 51 event records in the database through and including the year 1999, and 333 event records from 2000 to 2014; and all event records prior to the year 2000 include $0 in damages - presumably due to database limitations as opposed to decades of non- damaging wind events. Therefore, to estimate jurisdictional losses due to extreme wind, expected annualized losses were calculated for the 14.5-year period of record between January 2000 and May 2014:

- NCDC losses were obtained for the entire county ($19,168,995 total; using a 14.5-year period of record, yielding an expected annualized loss of $1,322,000).
- NCDC event records included specific loss histories in 11 jurisdictions totaling $3,001,000; and $16,167,995 for all other events countywide.
- Expected annualized losses of $1,322,000 were divided by 53 jurisdictions to get an average per community number of $24,943.

Jurisdiction specific loss histories were greater than this average number for three jurisdictions, and less than this average number for eight jurisdictions. Annual losses were reported as is for the three jurisdictions with actual loss histories greater than the average; the annual losses for these three jurisdictions combined ($172,414) was deducted from the total annual losses ($1,322,000) to get an average annual loss for distribution across the remaining 50 communities ($1,322,000-

$172,414=$1,149,586/50=$22,922 average annual losses for the 50 communities for which specific jurisdictional data was either not available or was found to be less than the overall $24,943 average).

Table 4.4-9 Potential Annualized Losses from Extreme Wind by Jurisdiction shows potential annualized property losses and percent loss ratio resulting from extreme wind for each jurisdiction in Monmouth County based on historic occurrences as reported by NCDC. For the plan update, population estimates were refined using Census 2010 block level data, and annualized expected property losses were based on updated (2018) improvement values.

Table 4.3 - 9 Potential Annualized Losses from Extreme Wind by Jurisdiction

Jurisdiction	Estimated Population At Risk	Total Assessed Value of Improvements (2018 Values)	Annualized Expected Property Losses	Annualized Percent Loss Ratio
Shrewsbury, Township of	1,117	$30,450,000	$25,893	0.09%
Loch Arbour, Village of	195	$69,262,800	$25,893	0.06%
Roosevelt, Borough of	808	$50,136,700	$25,893	0.06%
Interlaken, Borough of	825	$125,000,500	$25,893	0.03%
Allentown, Borough of	1,890	$127,734,200	$25,893	0.02%
Englishtown, Borough of	2,131	$158,314,100	$25,893	0.02%
Farmingdale, Borough of	1,470	$109,883,900	$25,893	0.02%
Allenhurst, Borough of	506	$217,949,000	$25,893	0.01%
Atlantic Highlands, Borough of	4,322	$364,693,600	$25,893	0.01%
Avon-by-the-Sea, Borough of	1,814	$266,879,900	$25,893	0.01%
Belmar, Borough of	5,719	$553,347,900	$38,833	0.01%
Bradley Beach, Borough of	4,262	$462,112,100	$25,893	0.01%
Freehold, Borough of	11,938	$771,202,500	$77,667	0.01%
Highlands, Borough of	4,880	$342,874,400	$25,893	0.01%
Keansburg, Borough of	9,868	$343,826,000	$25,893	0.01%
Keyport, Borough of	7,138	$434,885,600	$25,893	0.01%
Lake Como, Borough of	1,518	$140,566,300	$25,893	0.01%
Monmouth Beach, Borough of	3,247	$501,592,200	$25,893	0.01%
Neptune City, Borough of	27,728	$305,279,900	$25,893	0.01%
Sea Bright, Borough of	1,304	$235,586,800	$25,893	0.01%
Spring Lake Heights, Borough of	4,645	$525,407,200	$25,893	0.01%
Union Beach, Borough of	5,634	$387,844,700	$25,893	0.01%
Asbury Park, City of	15,830	$1,267,473,400	$25,893	0.00%
Brielle, Borough of	4,738	$669,338,900	$25,893	0.00%
Colts Neck, Township of	10,018	$927,454,500	$25,893	0.00%
Deal, Borough of	579	$822,100,400	$25,893	0.00%
Eatontown, Borough of	12,258	$1,314,725,700	$25,893	0.00%
Fair Haven, Borough of	6,015	$785,619,700	$25,893	0.00%
Freehold, Township of	35,429	$4,433,974,800	$25,893	0.00%
Hazlet, Township of	20,082	$1,215,098,000	$25,893	0.00%
Holmdel, Township of	16,648	$2,104,382,100	$25,893	0.00%

Jurisdiction	Estimated Population At Risk	Total Assessed Value of Improvements (2018 Values)	Annualized Expected Property Losses	Annualized Percent Loss Ratio
Howell, Township of	52,076	$4,204,216,400	$25,893	0.00%
Little Silver, Borough of	5,917	$873,512,700	$25,893	0.00%
Long Branch, City of	30,751	$2,478,681,000	$25,893	0.00%
Manalapan, Township of	40,096	$4,619,949,900	$25,893	0.00%
Manasquan, Borough of	5,824	$799,826,975	$25,893	0.00%
Marlboro, Township of	40,466	$4,435,729,800	$77,667	0.00%
Matawan, Borough of	8,898	$517,395,800	$25,893	0.00%
Middletown, Township of	65,952	$5,895,810,731	$25,893	0.00%
Millstone, Township of	10,522	$1,232,191,160	$25,893	0.00%
Neptune, Township of	4,749	$2,431,214,700	$25,893	0.00%
Ocean, Township of	27,006	$2,684,842,000	$25,893	0.00%
Oceanport, Borough of	5,762	$562,875,800	$25,893	0.00%
Red Bank, Borough of	12,220	$1,194,733,400	$25,893	0.00%
Rumson, Borough of	6,874	$1,600,650,400	$25,893	0.00%
Sea Girt, Borough of	1,714	$732,097,100	$25,893	0.00%
Shrewsbury, Borough of	4,051	$608,635,700	$25,893	0.00%
Spring Lake, Borough of	2,980	$1,028,817,800	$25,893	0.00%
Tinton Falls, Borough of	17,902	$1,691,986,800	$25,893	0.00%
Upper Freehold, Township of	6,899	$851,779,300	$25,893	0.00%
Wall, Township of	26,020	$3,053,292,400	$25,893	0.00%
West Long Branch, Borough of	7,944	$889,026,200	$25,893	0.00%
Aberdeen, Township of	18,372	$1,074,509,800	$25,893	0.00%
Monmouth County	627,551	$63,526,773,666	$1,488,787	0.002%

*EXPOSURE CALCULATED BY GLS ANALYSTS USING LOCAL ASSESSED VALUES

4.3.22 LIGHTNING: HAZARD DESCRIPTION

Lightning is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a "bolt" when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning rapidly heats the sky as it flashes, but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes thunder. On average, 80 people are killed each year by lightning strikes in the United States.

4.3.23 LIGHTNING: LOCATION AND EXTENT

Monmouth County is located in a region of the country that is susceptible to lightning strikes, though not as susceptible as southeastern states. Figure 4.3-8 Lightning Flash Density in the United States shows a lightning flash density map for the years 1996-2000 based upon data provided by Vaisala's U.S. National Lightning Detection Network (NLDN®).

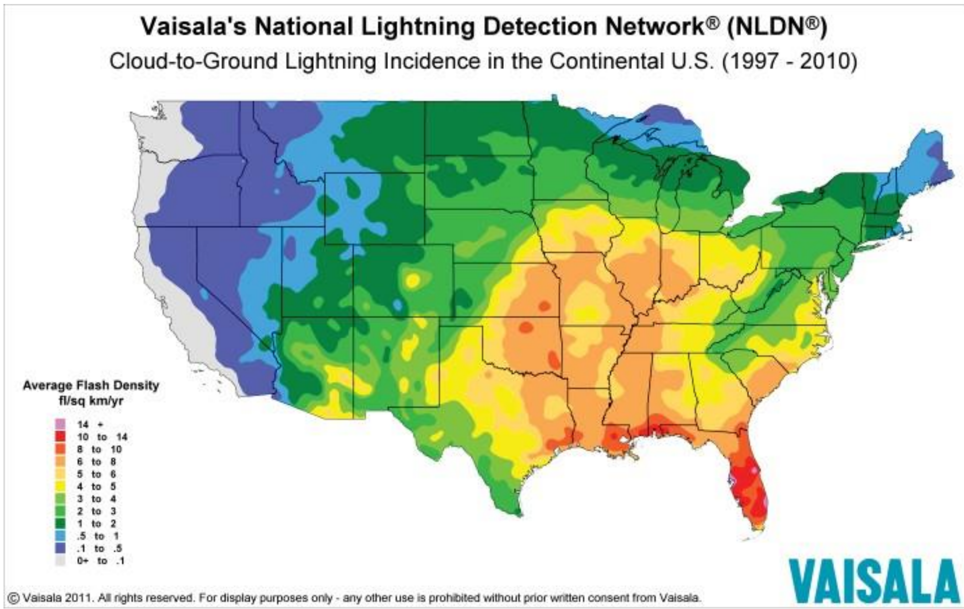


Figure 4.3 - 8 Lightning Flash Density in the United States

SOURCE: HTTP://WWW.VAISALA.COM/VAISALA%20DOCUMENTS/SCIENTIFIC%20PAPERS/20L4%20ILDC%20ILMC/ILMC-THURSDAY/ROEDER%20ET%20AL-MAPPING%20LIGHTNING%20FATALITY%20RISK-20L4-ILDC-ILMC.PDF

All areas of Monmouth County are equally susceptible to lightning strike. While lightning occurs randomly anywhere and anytime, the most common location for lightning fatalities and injuries to people is in open areas such as parks, beaches, golf courses and other recreational areas. Monmouth County remains susceptible to lightning deaths and injuries due to the large number of people who engage in outdoor activities, particularly more so along the shoreline of its coastal jurisdictions.

4.3.24 LIGHTNING: PREVIOUS OCCURRENCES AND LOSSES

According to NCDC, 51 recorded lightning strike incidents have affected Monmouth County from May 1997 to April 2019. A total of 1 event has occurred since the last version of this plan was prepared. All incidents have resulted in a reported total of seven direct deaths and 13 direct injuries and caused an estimated $2.424 million in property damages. Some more notable events include the following:

September 15, 2000. Lightning struck the communications tower of the Neptune Township Police Department, damaging the police radios, repeaters and dispatch consoles. All 911 calls were forwarded to the county center. The police operated from a backup communications center until normal operations resumed later in the evening. Damages were estimated at $40,000.

August 27, 2001. Lightning struck a three-story home in Upper Freehold Township. The four-alarm fire totally destroyed the home and damages were estimated at $500,000.

July 11, 2002. A woman was fatally struck by lightning in Bradley Beach. She was found in distress on the beach with burn marks on the mid-section of her body before she died.

August 17, 2007. A severe thunderstorm caused two fatalities and an estimated $200,000 in damages across Monmouth County. A woman was struck by lightning as she was about to enter a restaurant on U.S. Route 9 North in Howell. She was pronounced dead about one hour later. A two-story home's roof was struck by a bolt of lightning in Middletown Township. A fire in the attic area caused moderate damage.

June 1, 2010. A 12-story condominium was evacuated for three days after a lightning strike struck one of the towers and knocked out the sprinkler system pump, which is needed to get water up to the twelfth floor in the event of a fire. Estimated damages were $10,000.

July 13, 2010. Two lightning strikes caused about 8,200 homes and businesses to lose power in Ocean Township. The lightning struck a power substation and a transformer around East Mall Drive and State Route. Damages were estimated at $5,000.

July 19, 2010. A line of strong to locally severe thunderstorms occurred. A man was struck and killed by lightning in Middletown while in contact with a tree and observing a house fire that was started by a previous lightning strike. Another man and a police officer were also injured by the same lightning strike. A lightning strike set the attic of a house on fire in Middletown Township. One firefighter was injured. Damages were estimated at $25,000.

September 16, 2010. Lightning struck the roof of an apartment building in Eatontown. About three apartments sustained fire damage and all units below them suffered water and smoke damage. Tenants from all twenty-four units were evacuated for at least one night. No injuries were reported. Damages were estimated at $100,000.

July 7, 2011. For the third time in 2011, the water treatment plant in Allentown Borough was struck by lightning. This lightning strike fried computerized controls and caused about an estimated $40,000 in damages.

August 14, 2011. A lightning strike and ensuing fire badly damaged a Maxim Road home in Howell. The fire started toward the rear of the home's attic and third floor and spread to the second floor before it was declared under control at 9 a.m. EDT. No serious injuries were reported but the fire was estimated to have caused $225,000 in damages.

August 21, 2011. An estimated $22,000 in damages was reported due to lightning strikes during this event. A lightning strike started an insulation fire at a home in Atlantic Highlands. Lightning struck a cable wire and traveled along it and ignited the home's insulation. No injuries were reported. Lightning struck the Monmouth County 911 radio tower in Freehold. A lightning strike to one of its water towers on Union Lane caused Brielle to declare an emergency on the 21^{st} The lightning strike damaged electrical panels and also short circuited the entrance gate and a computer on the premises.

August 13, 2013. A complex of showers and thunderstorms produced wind damage and flash flooding. Cloud-to-ground lightning strikes peaked at 6,000 per hour as this complex moved through New Jersey. The thunderstorms caused about 14,500 homes and businesses to lose power on the 13th. A lightning strike at the Borough Hall in Manasquan caused damage and disrupted the communication systems in the borough. They were transferred to other facilities.

July 16, 2016. A cold frontal boundary along with several shortwaves and a sea breeze produced numerous showers and thunderstorms across the southern and central portions of New Jersey during the afternoon and evening hours of the 16th. A few strong wind gusts not associated with damage were measured or estimated at 53 mph in Toms River, 57 mph in Berkeley Township, and 50 mph in northern Howell Township. A lightning strike caused a house fire in Manalapan.

Other notable reports of historical lightning events include the following, as identified by the Planning Committee:

- The Borough of Bradley Beach has dealt with at least two significant lightning situations in recent years, one in which lightning struck the ocean in the vicinity of a swimmer who was killed, and the other was a lightning storm in which two houses were struck causing extensive damage.
- The Borough of Farmingdale's Police Department radio tower was struck once and lost power (a portable field communications unit was mobilized to handle dispatch duties).
- The Borough of Highlands has experienced lighting storms, which have resulted in buildings being struck and damaged, trees being struck and knocked down thus blocking roadways and critical facilities (Borough Hall and Police Department) being struck and having computer and electrical equipment damaged/destroyed.
- The Borough of Keansburg's Police Department radio tower has been struck by lightning twice.
- The Borough of Matawan Police Department Headquarters suffered a direct lightning strike in 2005 which resulted in the loss of power and all communication, including radio, telephone and computer equipment.
- The Township of Ocean has experienced numerous lightning events which caused several large trees to come down onto private property and cause extensive damage.
- The Borough of Oceanport had a police officer on traffic post during the summer struck during a lightning event. The lightning knocked him to the ground, but he suffered no serious injury.
- The Borough of Sea Bright has experienced lightning strikes in the past knocking out power stations and pumping (sewer) stations.
- The Township of Upper Freehold reports that from February 2000 to August 2007 records from the fire company show that lightning struck 15 houses (one of which burnt to the ground), plus numerous power poles and transformers and trees that endangered structures.

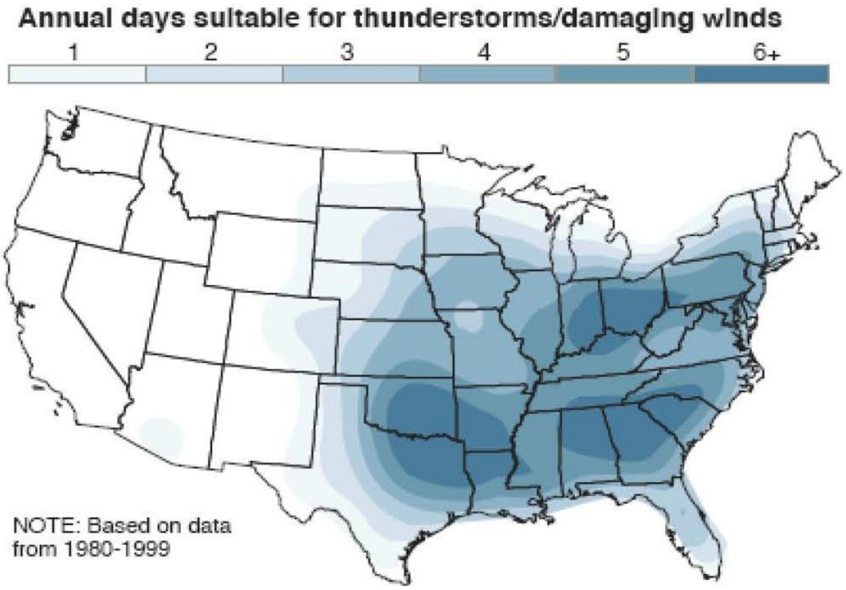
4.3.25 LIGHTNING: PROBABILITY OF FUTURE OCCURRENCE

The probability of occurrence for future lightning events in Monmouth County is certain. According to NOAA, Monmouth County is located in an area of the country that experiences three lightning flashes per square kilometer per year (approximately 2,300 flashes countywide per year). Given this regular frequency of occurrence, it can be expected that future lightning events will continue to threaten life and cause minor property damages throughout Monmouth County.

4.3.26 LIGHTNING: POTENTIAL EFFECTS OF CLIMATE CHANGE

National Aeronautics and Space Administration (NASA) scientists suggest that the United States will face more severe thunderstorms in the future, with deadly lightning, damaging hail, and the potential for tornadoes in the event of climate change. A recent study conducted by NASA predicts that smaller storm events like thunderstorms will also be more dangerous due to climate change (NASA 2007). Figure 4.3 – 9 Annual Days Suitable for Thunderstorms/Damaging Winds identifies those areas, particularly within the eastern United States, that are more prone to thunderstorms, including New Jersey (NWS 2010).

Figure 4.3 - 9 Annual Days Suitable for Thunderstorms/Damaging Winds



SOURCE: BORENSTEIN, 2007

4.3.27 LIGHTNING: VULNERABILITY ASSESSMENT

Impacts

On average, 80 people are killed, and hundreds are injured each year by lightning strikes in the United States. Lightning can strike communications equipment (i.e., radio or cell towers, antennae, satellite dishes, electrical transformers, etc.) and hamper communication and emergency response. Lightning strikes can also cause significant damage to buildings, critical facilities, and infrastructure, largely by igniting a fire. In addition, lightning can ignite vegetation to cause a wildfire.

Lightning's impacts can typically be characterized as minor in Monmouth County. Events are typically associated with very few injuries (if any), only minor property damage, and minimal disruption on quality of life. The shutdown of critical facilities, if at all, is typically only temporary in nature.

Historical impacts in Monmouth County have included direct health impacts to individuals struck by lightning, structure damages from fires caused by lightning, and impacts to emergency communications facilities when towers have been struck by lightning. Lightning occurs frequently in Monmouth County, but damaging events are relatively few in number and limited in scope when they do occur. Building codes requiring buildings to be grounded work to decrease damages. Members of the general public who are outdoors are particularly vulnerable during an event. Lightning most typically occurs within 10 miles of a thunderstorm.

Exposure and Damage Estimates

Because it cannot be predicted where lightning may strike, all existing and future buildings, facilities and populations are considered to be exposed to this hazard and could potentially be impacted. For the plan update, NCDC historical lightning data current as of September 2014 was queried. The data includes a total of 60 lightning events between May 1997 and August 2013, resulting in $2.42 million in damages, 7 deaths, and 13 injuries. The lack of event records prior to the year 1997 is due to database limitations as opposed to decades without lightning events. To estimate jurisdictional losses due to lightning, expected annualized losses were calculated as follows for the 16.25-year period of record between May 1997 and August 2013:

- NCDC losses were obtained for the entire county ($2,424,300 total; using a 16.25-year period of record, this yields expected annualized losses of $149,188).
- NCDC event records included specific loss histories in 19 jurisdictions totaling $2,189,300; and
- $235,000 for all other events countywide.
- Expected annualized losses of $149,188 were divided by 53 jurisdictions to get an average per community number of $2,815.
- Jurisdiction specific loss histories were greater than this average number for 6 jurisdictions, and less than this average number for 13 jurisdictions. Annual losses were reported as-is for the 6 jurisdictions with actual loss histories greater than the average; the annual losses for these 6 jurisdictions combined ($124,923) was deducted from the total annual losses ($149,188) to get an average annual loss for distribution across the remaining communities ($149,188-$124,923=$24,265/47=$516 average annual losses for each of the 47 communities for which specific jurisdictional data was either not available or was less than the overall $2,815 average).

Table 4.3 - 10 Potential Annualized Losses from Lightning by Jurisdiction shows potential annualized property losses and percent loss ratios resulting from the lightning hazard for each jurisdiction in Monmouth County based on historic occurrences as reported by NCDC. For the plan update, population estimates were refined using Census 2010 block level data; and annualized expected property losses reflect updated (2012) improvement values.

Table 4.3 - 10 Potential Annualized Losses from Lightning by Jurisdiction

Jurisdiction	Estimated Population At Risk	Total Assessed Value of Improvements 2018 Values	Annualized Expected Property Losses	Annualized Percent Loss Ratio
Aberdeen, Township of	18,372	$1,074,509,800	$581	0.00%
Allenhurst, Borough of	506	$217,949,000	$581	0.00%
Allentown, Borough of	1,890	$127,734,200	$581	0.00%
Asbury Park, City of	15,830	$1,267,473,400	$581	0.00%
Atlantic Highlands, Borough of	4,322	$364,693,600	$581	0.00%
Avon-by-the-Sea, Borough of	1,814	$266,879,900	$581	0.00%
Belmar, Borough of	5,719	$553,347,900	$581	0.00%
Bradley Beach, Borough of	4,262	$462,112,100	$581	0.00%
Brielle, Borough of	4,738	$669,338,900	$581	0.00%
Colts Neck, Township of	10,018	$927,454,500	$581	0.00%
Deal, Borough of	579	$822,100,400	$581	0.00%
Eatontown, Borough of	12,258	$1,314,725,700	$581	0.00%
Englishtown, Borough of	2,131	$158,314,100	$581	0.00%
Fair Haven, Borough of	6,015	$785,619,700	$581	0.00%
Farmingdale, Borough of	1,470	$109,883,900	$581	0.00%

Jurisdiction	Estimated Population At Risk	Total Assessed Value of Improvements 2018 Values	Annualized Expected Property Losses	Annualized Percent Loss Ratio
Freehold, Borough of	11,938	$771,202,500	$581	0.00%
Freehold, Township of	35,429	$4,433,974,800	$581	0.00%
Hazlet, Township of	20,082	$1,215,098,000	$581	0.00%
Highlands, Borough of	4,880	$342,874,400	$581	0.00%
Holmdel, Township of	16,648	$2,104,382,100	$581	0.00%
Howell, Township of	52,076	$4,204,216,400	$581	0.00%
Interlaken, Borough of	825	$125,000,500	$581	0.00%
Keansburg, Borough of	9,868	$343,826,000	$581	0.00%
Keyport, Borough of	7,138	$434,885,600	$581	0.00%
Lake Como, Borough of	1,518	$140,566,300	$581	0.00%
Little Silver, Borough of	5,917	$873,512,700	$581	0.00%
Loch Arbour, Village of	195	$69,262,800	$581	0.00%
Long Branch, City of	30,751	$2,478,681,000	$581	0.00%
Manalapan, Township of	40,096	$4,619,949,900	$6,930	0.00%
Manasquan, Borough of	5,824	$799,826,975	$581	0.00%
Marlboro, Township of	40,466	$4,435,729,800	$581	0.00%
Matawan, Borough of	8,898	$517,395,800	$581	0.00%
Middletown, Township of	65,952	$5,895,810,731	$15,940	0.00%
Millstone, Township of	10,522	$1,232,191,160	$581	0.00%
Monmouth Beach, Borough of	3,247	$501,592,200	$581	0.00%
Neptune City, Borough of	27,728	$305,279,900	$581	0.00%
Neptune, Township of	4,749	$2,431,214,700	$581	0.00%
Ocean, Township of	27,006	$2,684,842,000	$581	0.00%
Oceanport, Borough of	5,762	$562,875,800	$6,930	0.00%
Red Bank, Borough of	12,220	$1,194,733,400	$581	0.00%
Roosevelt, Borough of	808	$50,136,700	$581	0.00%
Rumson, Borough of	6,874	$1,600,650,400	$581	0.00%
Sea Bright, Borough of	1,304	$235,586,800	$581	0.00%
Sea Girt, Borough of	1,714	$732,097,100	$581	0.00%
Shrewsbury, Borough of	4,051	$608,635,700	$581	0.00%
Shrewsbury, Township of	1,117	$30,450,000	$581	0.00%
Spring Lake, Borough of	2,980	$1,028,817,800	$581	0.00%
Spring Lake Heights, Borough of	4,645	$525,407,200	$581	0.00%
Tinton Falls, Borough of	17,902	$1,691,986,800	$581	0.00%
Union Beach, Borough of	5,634	$387,844,700	$581	0.00%
Upper Freehold, Township of	6,899	$851,779,300	$34,651	0.00%
Wall, Township of	26,020	$3,053,292,400	$581	0.00%
West Long Branch, Borough of	7,944	$889,026,200	$581	0.00%
Monmouth County	627,551	$63,526,773,666	$168,010	0.0003%

4.4 WINTER STORM

4.4.1 HAZARD DESCRIPTION

Winter storms may include snow, sleet, freezing rain, or a mix of these wintry forms of precipitation. Blizzards, the most dangerous of all winter storm, combine low temperatures, heavy snowfall, and winds of at least 35 miles per hour, reducing visibility to only a few yards. Ice storms occur when moisture falls and freezes immediately upon impact on trees, powerlines, communication towers, structures, roads and other hard surfaces. Winter storms and ice storms can down trees, cause widespread power outages, damage property, and cause fatalities and injuries to human life.

4.4.2 LOCATION

Nearly the entire continental United States is susceptible to winter storms, but the degree of exposure typically depends on the normal expected severity of local winter weather. Monmouth County is accustomed to severe winter weather conditions and is prepared for the potential disruptions they might cause, though intense winter storms might still overwhelm local capabilities. While Monmouth County is located south of the typical boundary between freezing and non-freezing precipitation during wintertime, annual snowfall on a countywide basis averages 25 to 26 inches and the maximum recorded seasonal snowfall is 70 inches (1957-1958). All areas throughout the County are susceptible to the hazard effects of winter storms including snow and ice, and Monmouth County's coastal jurisdictions are also extremely susceptible to the added effects of storm surge, wave action, coastal erosion and tidal flooding that might be wrought by nor'easters, whose effects are discussed separately in this section.

4.4.3 EXTENT

The magnitude or severity of a severe winter storm depends on several factors including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and time of occurrence during the day (i.e., weekday versus weekend), and time of season.

The extent of a severe winter storm can be classified by meteorological measurements and by evaluating its societal impacts. NOAA's National Climatic Data Center (NCDC) is currently producing the Regional Snowfall Index (RSI) for significant snowstorms that impact the eastern two-thirds of the United States. The RSI ranks snowstorm impacts on a scale from one to five. It is based on the spatial extent of the storm, the amount of snowfall, and the interaction of the extent and snowfall totals with population (based on the 2000 Census). The NCDC has analyzed and assigned RSI values to over 500 storms since 1900 (NOAA- NCDC 2011). Table 4.4 - 1 Regional Snowfall Index Ranking Categories presents the five RSI ranking categories.

Table 4.4 - 1 Regional Snowfall Index Ranking Categories

Category	Description	RSI Value
1	Notable	1-3
2	Significant	3-6
3	Major	6-10
4	Crippling	10-18
5	Extreme	18.0+

4.4.4 PREVIOUS OCCURRENCES AND LOSSES

According to NCDC, 172 recorded winter storm events (classified as: blizzard, heavy snow, ice storm, sleet, winter storm, winter weather) have affected Monmouth County between January 1996 and April 2019. Thirty-six events have occurred since the last plan update. All incidents resulted in no reported deaths or injuries in Monmouth County, but are associated with approximately $5 million in property damages. Note that this statement only includes injuries reported by NCDC. Table 4.4-2 Winter Storms in Monmouth County lists all of the winter storm events that have occurred from September 2014 (last plan update)-April 2019. None of these events resulted in injury or fatality.

Table 4.4 - 2 Winter Storms in Monmouth County, September 2014-April 2019

Date	Event
1/4/2018	Blizzard
1/26/2015	Heavy Snow
3/5/2015	Heavy Snow
2/21/2015	Winter Storm
3/1/2015	Winter Storm
1/22/2016	Winter Storm
1/7/2017	Winter Storm
2/9/2017	Winter Storm
1/4/2018	Winter Storm
3/21/2018	Winter Storm
1/23/2015	Winter Weather
2/1/2015	Winter Weather
2/9/2015	Winter Weather
2/14/2015	Winter Weather
2/16/2015	Winter Weather
3/1/2015	Winter Weather
3/3/2015	Winter Weather
3/20/2015	Winter Weather
1/12/2016	Winter Weather
1/17/2016	Winter Weather
2/5/2016	Winter Weather
2/15/2016	Winter Weather
3/4/2016	Winter Weather
12/17/2016	Winter Weather
1/5/2017	Winter Weather
2/9/2017	Winter Weather
3/10/2017	Winter Weather
12/9/2017	Winter Weather
3/7/2018	Winter Weather
3/12/2018	Winter Weather

Date	Event
4/2/2018	Winter Weather
11/15/2018	Winter Weather
2/11/2019	Winter Weather
2/20/2019	Winter Weather
3/1/2019	Winter Weather
3/3/2019	Winter Weather

SOURCE: NCDC, 2019

Notable events include the following:

January 6-8, 1996. The Blizzard of 1996 brought record breaking snow to most of New Jersey and paralyzed the region for several days, caused most municipalities to exceed their annual snow budgets during this one storm. A state of emergency was declared by Governor Whitman, which lasted a week. The state was also declared a federal disaster area. Snowfall accumulations averaged 20 to 30 inches in Monmouth County, with 30 inches in Howell and 28 inches in Freehold. In addition to the heavy snow, wind gusts reached hurricane force along the coast. Eight housing additions in Manasquan collapsed. Navigation Tower aides at Manasquan were toppled. Many areas lost power. Evacuations of some coastal residents occurred in Belmar, Port Monmouth, Sea Bright and Manasquan. Street flooding was reported in these areas and also in Avon. In Sea Bright, flooding from the Shrewsbury River exacerbated the flooding. State Route 36 was closed from the Highlands/Sea Bright Bridge through Monmouth Beach. The worst damage along the coast was the erosion.

February 16-17, 2003 (President's Day Storm). The most powerful storm to affect New Jersey since the Blizzard of 1996 struck during the President's Day Weekend. Governor McGreevey declared a state of emergency, and many municipalities declared their own snow emergencies. In Monmouth County, drifts reached six feet. In Wall, a high school roof collapsed on the 18th because of four-foot drifts at one corner of the roof. A country store was badly damaged in Freehold. The National Guard was deployed to assist with evacuations. The strong winds caused about 11,000 homes and businesses to lose power. Monmouth Beach was hit the hardest by power outages, waiting two days for power to be restored. Peak wind gusts included 49 mph in Keansburg and snow accumulations included 22.8 inches in Cream Ridge, 22 inches in Hazlet, 21 inches in Manalapan, and 20.5 inches in Wall.

January 22, 2005. A very potent Alberta low pressure system dropped heavy snow across northern and southwestern New Jersey and a wintry mix across southeastern New Jersey. Governor Codey declared a state of emergency, requiring vehicles to stay off of public roads and thoroughfares. Gusty northwest winds, which followed in the wake of the storm caused considerable drifting snow and hampered road crews' efforts as drifts continued to form on roads. The unseasonably cold weather also rendered the salt less effective. Snow emergencies were declared by many municipalities. Specific snowfall accumulations included 17 inches in Howell and 16.5 inches in Cream Ridge.

February 14, 2007 (Valentine's Day Storm). A severe winter storm impacted the Ohio Valley before moving northeast over New England. Monmouth County experienced a severe icing, with 0.5 inches of ice accumulation reported at Tinton Falls. Peak wind speeds ranged from 36 to 48 mph. Cream Ridge recorded 3.2 inches of total precipitation, which was all sleet. Numerous trees were downed, and extensive power outages plagued the area.

December 26, 2010. A major and for parts of eastern New Jersey record breaking winter storm and blizzard affected the state on Sunday the 26^{th} and Monday the 27^{th}. A state of emergency was declared in New Jersey. The heavy snow bands and blizzard conditions resulted in snowfall rates of two to three inches per hour at times. Strong to high winds continued to hamper snowplow operations through the 27th. Bus service was suspended throughout the state as of 830 p.m. on the 26th and did not resume until the 28th. While the overall number of accidents was low, about 2,300 motorists were stranded on average for 10 to 12 hours. The Red Cross opened shelters in the eastern part of the state. In addition, stranded motorists used town halls, rest stops and movie theaters as shelters. Blood supplies ran low. Trash schedules were delayed about a day and recycling schedules were delayed up to one week. Monmouth County was one of the counties that were most affected by the blizzard as many roadways were closed and remained closed through the 27th because of drifting. An eleven mile stretch of State Route 18 remained closed for a couple of days. The weight of the snow caused a roof collapse at the Naval Weapons Station Earle in Colts Neck. An overturned vehicle in Tinton Falls resulted in an injury. A train struck an abandoned vehicle in Red Bank, but no injuries were caused. Closed malls in Monmouth County did not open until the 28th at the earliest. The Sea Streak Manhattan Ferry service from Monmouth County ran on a modified schedule on the 27th. Athletic competitions were either postponed or cancelled. Major roadways such as Interstate 195 (8-foot drifts) and New Jersey State Routes 18, 35, 36, 66 and 138 were closed into the 27th. Long Branch emergency personnel alone responded to about 700 calls. This was a new single snowstorm record surpassing the previous record of 20.0 inches during the President's Day snowstorm of February 2003. Representative snowfall included 25.0 inches in Colts Neck, 24.0 inches in Neptune, 22.0 inches in Red Bank and 20.0 inches in Holmdel. At Sandy Hook, the high tide reached 7.13 feet above mean lower low water. Minor tidal flooding starts at 6.7 feet above mean lower low water.

November 7-8, 2012. A strong nor'easter caused high winds, heavy snow, and damaging waves and minor tidal flooding days after Superstorm Sandy, causing setbacks in the start of many local restoration efforts and forced evacuations of some coastal areas yet again. Unfortunately, the heaviest snow fell in the counties that were affected the hardest by Sandy and upwards of an additional 150,000 customers lost power. The combination of heavy snow and wind brought down additional trees, poles and wires. Representative snowfall included 13.0 inches in Freehold, 12.0 inches in Allaire, 11.0 inches in Howell, and 6.0 inches in Oakhurst.

March 5, 2015. Waves of low pressure that formed along a sinking cold front brought New Jersey heavy snow and the southern half of the state its heaviest snow of the season. Snowfall averaged 4 to 9 inches with the highest amounts in central New Jersey. Less snow fell in Sussex County. The heavy snow prompted Governor Chris Christie to declare a state of emergency and close state offices to non-emergency personnel. Nearly all schools and universities in the state were closed on the 5th. Many were also closed the next day. The snow also caused hazardous travel and hundreds of accidents, including a fatal one in Somerset County.

January 12, 2016. A strong southerly flow preceding a cold front produced wind gusts in the 30 to 40 mph range during the afternoon hours on January 12th. Higher gusts...in the 40 to 50 mph range, then occurred during the evening and early overnight hours as the cold front, then its associated upper level trough axis, moved through. Snow showers associated with this frontal passage produced the first coating of snow so far this winter season in some areas. Some specific wind gusts include 42 MPH near Huguenot. Strong winds toppled a tree onto a house in Howell Township, NJ, but no one was home at the time.

January 4, 2018. An area of low pressure tracked up the east coast interacting with a cold front which lead to rapid development of a winter storm across the state. This storm quickly moved out by the 5th. However, snowfall accumulations and gusty winds occurred with the storm. Blizzard conditions occurred along many coastal locations. Top wind gusts were generally around 40 mph across the state but were highest in Ocean county, closer to 60 mph. Snow amounts were highest in southern and coastal New Jersey with over 6 inches, totals were only a few inches further northwest. A state of Emergency was declared during the height of the storm. Several hundred vehicles were stranded, and hundreds of thousands were without power at some point. Severe cold continued for the next week leading to many locations going to code blue operations and closing of the Cape May Lewes Ferry. ASOS/AWOS sites indicated blizzard criteria was met. Snowfall was over a foot in many locations.

October 16, 2019: Now labeled a "bomb cyclone," this nor'easter brought 30- to 50-mph winds and heavy rains to the County. According to the NWS, a bomb cyclone is a low-pressure system that is a strong nor'easter, one that can even resemble a small tropical storm and can build strength very quickly. Middletown Township experienced the third highest power outages in the state with more than 330 residents without power.

Other notable reports of historical winter storm events include the following, as identified by the Planning Committee:

- The Township of Aberdeen was affected by the Blizzard of 1996, as well as severe snowstorms in 2003, 2005 and 2006. The Township incurred substantial costs related to emergency protective measures, snow removal, etc.
- The Borough of Avon-By-The-Sea reported that winter storms have been the most common occurrence resulting in disaster declarations for their jurisdiction in the past few years.
- The Borough of Brielle indicated that the most severe winter storms affecting Brielle are usually coastal/nor'easter events, during which the Borough experiences minor to moderate coastal flooding. The other major concern is power outages due to snow laden trees/branches falling on power lines.
- The Borough of Fair Haven reported that the Valentine's Day Storm of 2007 caused power outages that lasted for several days.
- The Township of Ocean was heavily impacted by the Valentine's Day Storm of 2007 which paralyzed a section of town by fallen trees across roadways and downed power/phone lines, which caused the evacuation of several hundred residents.
- The Borough of Oceanport indicated that the Valentine's Day Storm of 2007 had a big impact on all areas. Major cleanup lasted over a month and some areas went without power for 12 to 18 hours.

- The Borough of Shrewsbury was heavily affected by the ice storm of February 2007, which caused three days of power outage for 90 percent of the area's homes and businesses, and up to seven days for several dozen homes. It also caused damage to three private homes.

4.4.5 PROBABILITY OF FUTURE OCCURRENCE

Winter storm events will continue to have a high probability of occurrence in Monmouth County, and the probability of future occurrences in Monmouth County is certain. While the impact of snow and ice storms will cause major disruptions to transportation, commerce and electrical power as well as significant overtime work for government employees, large scale property damages and/or threats to human life and safety are not expected. Nor'easters occur less frequently but represent a much greater hazard of concern as it relates to the impacts of winter storm events (addressed separately within this section). Winter storms typically occur in New Jersey from late November through mid-April, with peak months being December through March. Nor'easters are one type of severe winter storm that typically bring high winds, coastal surge and tidal flooding along with heavy precipitation, which are addressed separately within this section.

4.4.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

In terms of snowfall and ice storms, there is a lack of quantitative data to predict how future climate change will affect this hazard. It is likely that the number of winter weather events may decrease, and the winter weather season may shorten; however, it is also possible that the intensity of winter storms may increase. The exact effect on winter weather is still highly uncertain (Sustainable Jersey Climate Change Adaptation Task Force 2013).

4.4.7 VULNERABILITY ASSESSMENT

Impacts

Winter storms can have tremendous impacts on Monmouth County. Though typically short in duration, winter storms can result in significant snow accumulations, with tremendous impacts on local transportation via road, rail, and air. Impacts are exacerbated with storms having an ice component, as snow loads are increased and driving conditions substantially worsen. Significant snow loads on roofs of buildings has the potential to compromise the structural integrity with possible collapse. On vegetation, snow and ice loads can result in downed trees and limbs - particularly during periods of high winds - which can result in outages when limbs fall on power lines and communication lines. Secondary impacts from power outages can include frozen pipes, business losses, negative impacts on people associated with trying to heat their homes using portable heat sources (i.e., kerosene) or stoves including carbon monoxide poisoning and fire risks. Secondary impacts from downed communication lines can hamper the response and recovery efforts due to lack of communication. The human impact of winter storms tends to be exacerbated in areas of social vulnerability (for example, low income, and a high proportion of the very young and/or very old).

Exposure and Damage Estimates

Because winter storms often impact large areas and cross jurisdictional boundaries, all existing and future buildings, facilities and populations are considered to be exposed to this hazard and could potentially be impacted. For the plan update, NCDC historical winter storm data current as of September 2014 was queried for events categorized as: blizzards, heavy snow, ice storms, sleet, winter storms, and winter weather. The data includes a total of 136 winter weather days between January 1996[8] and September 2014, resulting in approximately $5 million in property damages. No event records are included prior to 1996. To estimate jurisdictional losses due to winter storms, expected annualized losses were calculated as follows for the 18-year period of record:

- NCDC losses were obtained for the entire county ($5,000,000 total; using an 18-year period of record, yields expected annualized losses of $277,778).
- NCDC event records were all zone-based, without specific loss histories for any of the County's 53 jurisdictions.
- Expected annualized losses of $277,778 were divided by 53 jurisdictions to get an average per community number of $5,241.

It should be noted that the estimation of losses to winter storms was limited to documented structural damages and do not include other types of damages or economic impacts such as power outages, infrastructure repair and restoration, loss of business income and snow removal costs. In the absence of detailed historical data, it is difficult to model and quantify these other types of non-structural losses for winter storm at a jurisdictional level in Monmouth County. However, as described in the *Hazard Profiles* section, it should be recognized that such losses are indeed significant, and their associated costs are most often borne by local government and the private sector.

Table 4.4 - 3 Potential Annualized Losses from Winter Storms by Jurisdiction shows potential annualized property losses and percent loss ratios resulting from the winter storm hazard for each jurisdiction in Monmouth County based on historic occurrences. For the plan update, population estimates were refined using Census 2010 block level data; and annualized expected property losses are based on updated (2012) improvement values.

Table 4.4 - 3 Potential Annualized Losses from Winter Storms by Jurisdiction

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Annualized Expected Property Losses	Annualized Percent Loss Ratio
Aberdeen, Township of	18,372	$1,074,509,800	$5,902	0.00%
Allenhurst, Borough of	506	$217,949,000	$5,902	0.00%
Allentown, Borough of	1,890	$127,734,200	$5,902	0.00%
Asbury Park, City of	15,830	$1,267,473,400	$5,902	0.00%
Atlantic Highlands, Borough of	4,322	$364,693,600	$5,902	0.00%
Avon-By-The-Sea, Borough of	1,814	$266,879,900	$5,902	0.00%
Belmar, Borough of	5,719	$553,347,900	$5,902	0.00%
Bradley Beach, Borough of	4,262	$462,112,100	$5,902	0.00%
Brielle, Borough of	4,738	$669,338,900	$5,902	0.00%
Colts Neck, Township of	10,018	$927,454,500	$5,902	0.00%
Deal, Borough of	579	$822,100,400	$5,902	0.00%
Eatontown, Borough of	12,258	$1,314,725,700	$5,902	0.00%
Englishtown, Borough of	2,131	$158,314,100	$5,902	0.00%
Fair Haven, Borough of	6,015	$785,619,700	$5,902	0.00%
Farmingdale, Borough of	1,470	$109,883,900	$5,902	0.00%

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Annualized Expected Property Losses	Annualized Percent Loss Ratio
Freehold, Borough of	11,938	$771,202,500	$5,902	0.00%
Freehold, Township of	35,429	$4,433,974,800	$5,902	0.00%
Hazlet, Township of	20,082	$1,215,098,000	$5,902	0.00%
Highlands, Borough of	4,880	$342,874,400	$5,902	0.00%
Holmdel, Township of	16,648	$2,104,382,100	$5,902	0.00%
Howell, Township of	52,076	$4,204,216,400	$5,902	0.00%
Interlaken, Borough of	825	$125,000,500	$5,902	0.01%
Keansburg, Borough of	9,868	$343,826,000	$5,902	0.00%
Keyport, Borough of	7,138	$434,885,600	$5,902	0.00%
Lake Como, Borough of	1,518	$140,566,300	$5,902	0.00%
Little Silver, Borough of	5,917	$873,512,700	$5,902	0.00%
Loch Arbour, Village of	195	$69,262,800	$5,902	0.01%
Long Branch, City of	30,751	$2,478,681,000	$5,902	0.00%
Manalapan, Township of	40,096	$4,619,949,900	$5,902	0.00%
Manasquan, Borough of	5,824	$799,826,975	$5,902	0.00%
Marlboro, Township of	40,466	$4,435,729,800	$5,902	0.00%
Matawan, Borough of	8,898	$517,395,800	$5,902	0.00%
Middletown, Township of	65,952	$5,895,810,731	$5,902	0.00%
Millstone, Township of	10,522	$1,232,191,160	$5,902	0.00%
Monmouth Beach, Borough of	3,247	$501,592,200	$5,902	0.00%
Neptune City, Borough of	27,728	$305,279,900	$5,902	0.00%
Neptune, Township of	4,749	$2,431,214,700	$5,902	0.00%
Ocean, Township of	27,006	$2,684,842,000	$5,902	0.00%
Oceanport, Borough of	5,762	$562,875,800	$5,902	0.00%
Red Bank, Borough of	12,220	$1,194,733,400	$5,902	0.00%
Roosevelt, Borough of	808	$50,136,700	$5,902	0.01%
Rumson, Borough of	6,874	$1,600,650,400	$5,902	0.00%
Sea Bright, Borough of	1,304	$235,586,800	$5,902	0.00%
Sea Girt, Borough of	1,714	$732,097,100	$5,902	0.00%
Shrewsbury, Borough of	4,051	$608,635,700	$5,902	0.00%
Shrewsbury, Township of	1,117	$30,450,000	$5,902	0.02%
Spring Lake, Borough of	2,980	$1,028,817,800	$5,902	0.00%
Spring Lake Heights, Borough of	4,645	$525,407,200	$5,902	0.00%
Tinton Falls, Borough of	17,902	$1,691,986,800	$5,902	0.00%
Union Beach, Borough of	5,634	$387,844,700	$5,902	0.00%
Upper Freehold, Township of	6,899	$851,779,300	$5,902	0.00%
Wall, Township of	26,020	$3,053,292,400	$5,902	0.00%
West Long Branch, Borough of	7,944	$889,026,200	$5,902	0.00%
Monmouth County	627,551	$63,526,773,666	$312,823	0.001%

4.5 DAM FAILURE

4.5.1 HAZARD DESCRIPTION

Dam failure is the collapse, breach, or other failure of a darn structure resulting in downstream flooding. In the event of a dam failure, the energy of the water stored behind even a small darn is capable of causing loss of life and severe property damage if development exists downstream of the darn. Dam failure can result from natural events, human-induced events, or a combination of the two. The most common cause of darn failure is prolonged rainfall that produces flooding. Failures due to other natural events such as hurricanes, earthquakes or landslides are significant because there is generally little or no advance warning.

4.5.2 LOCATION

The NJDEP Dams Database has identified and classified 112 state-regulated dams and 16 other structures located within Monmouth County. NJDEP classifies "other structures" as dams that are less than five feet, have been removed, never built, or failed. Of the 112 dams, 11 dams have been classified as having "High Hazard Potential," meaning their failure may cause the probable loss of life or extensive property damage. This list includes the highest risk dams. Of the 112 dams, 16 dams have been classified as having "Significant Hazard Potential," meaning their failure may cause significant damage to property and project operation, but loss of human life is not envisioned. This classification applies to predominantly rural, agricultural areas, where dam failure may damage isolated homes, major highways or railroads or cause interruption of service of relatively important public utilities. The remaining 85 dams are classified as "low hazard potential" meaning their failure would cause loss of the dam itself but little or no additional damage to other property. It is important to note that dam hazard classification is based on the consequences of dam failure-not the condition, probability or risk of failure itself. NJDEP's list is available in Table 4.5-1 State-Regulated Dams and Other Structures in Monmouth County. Specific locations for all state-regulated dams that have been geo-referenced for mapping purposes are illustrated in Figure 4.5-1 State-Regulated Dams and Other Structures in Monmouth County. Please note that all municipalities are not listed in the following table. Only municipalities that that contain state-regulated dams are listed.

Figure 4.5 - 1 State-Regulated Dams and Other Structures in Monmouth County

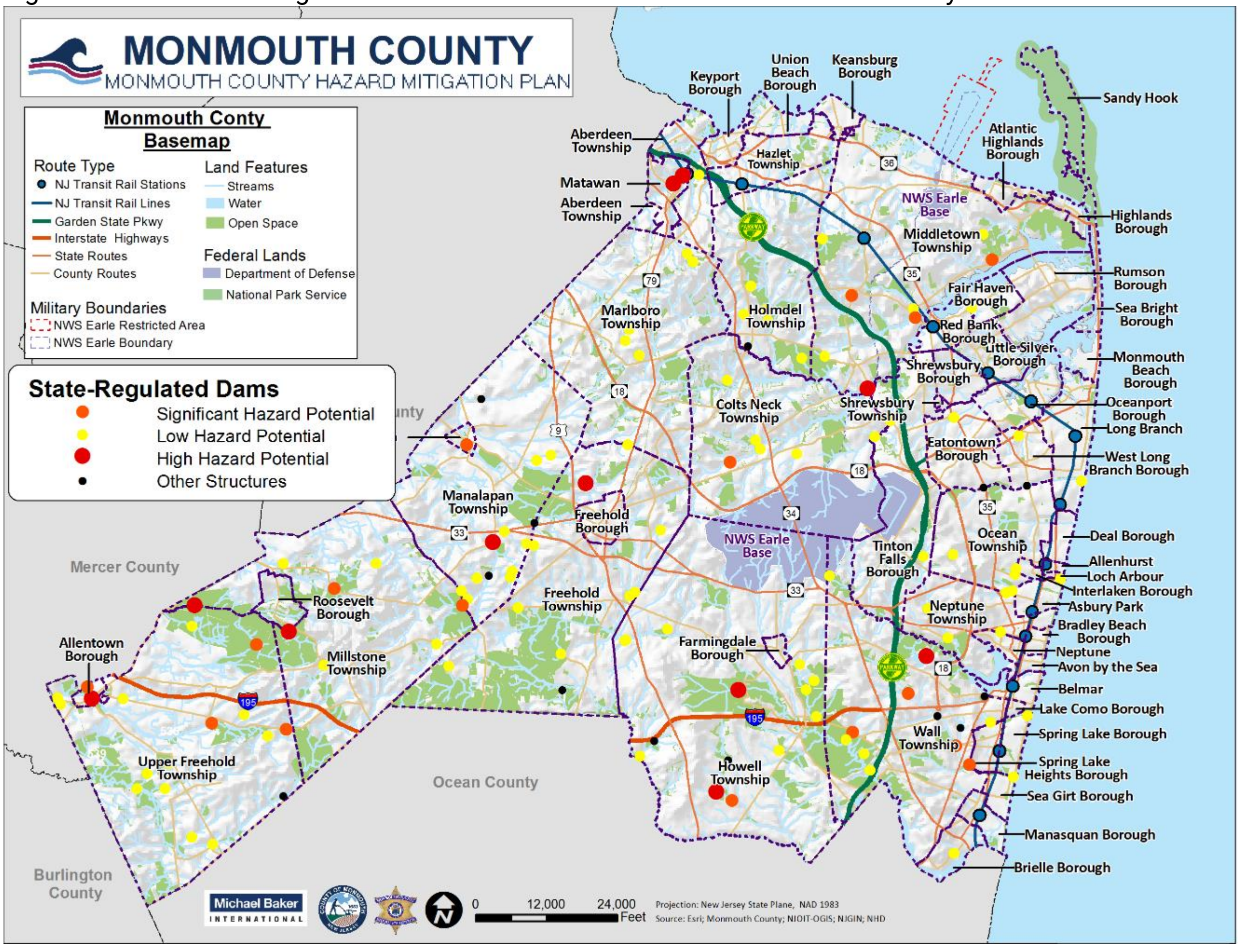


Table 4.5 - 1 State-Regulated Dams and Other Structures in Monmouth County

Jurisdiction	Total High Hazard Dams	Total Significant Hazard Dams	Total Low Hazard Dams	Total Number of Dams	Other Structures
Aberdeen Township	0	0	1	1	0
Allentown Borough	1	1	0	2	0
Asbury Park City	0	0	1	1	0
Brielle Borough	0	0	1	1	0
Colts Neck Township	1	1	5	7	0
Eatontown Borough	0	0	1	1	0
Englishtown Borough	0	1	0	1	0
Fair Haven Borough	0	0	1	1	0
Freehold Township	1	0	8	9	1
Holmdel Township	0	0	5	5	1
Howell Township	2	1	9	12	2
Long Branch City	0	0	1	1	0
Manalapan Township	1	1	9	11	3
Marlboro Township	0	0	5	5	0
Matawan Borough	2	0	0	2	0
Middletown Township	0	3	4	7	0

Jurisdiction	Total High Hazard Dams	Total Significant Hazard Dams	Total Low Hazard Dams	Total Number of Dams	Other Structures
Millstone Township	1	1	4	6	0
Neptune Township	0	0	4	4	1
Ocean Township	0	0	4	4	2
Sea Girt Borough	0	0	1	1	0
Spring Lake Borough	0	0	1	1	0
Tinton Falls Borough	0	0	2	2	0
Upper Freehold Township	1	3	12	15	1
Wall Township	1	4	5	10	4
West Long Branch Borough	0	0	1	1	1
Monmouth County Total	11	16	85	112	16

SOURCE: NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF DAM SAFETY AND FLOOD CONTROL

According to NJDEP, the three dams within Monmouth County that are in "poor" condition; these include the Matawan Lake Dam and Lake Lefferts Dam, both located in Matawan Borough, and Lake Louise Dam located in Howell Township. Both municipalities address these dams in their mitigation strategy and note FEMA's National Dam Safety Program for High-Hazard Potential Dam Grant Program as a potential funding source.

4.5.3 EXTENT

The extent or magnitude of a dam failure event can be measured in terms of the classification of the dam. The NJDEP assigns one of four hazard classifications to state-regulated dams in New Jersey. The classifications relate to the potential for property damage and/or loss of life in the event of a dam failure:

- Class I (High-Hazard Potential) - Failure of the dam may result in probable loss of life and/or extensive property damage.
- Class II (Significant-Hazard Potential) - Failure of the dam may result in significant property damage; however, loss of life is not envisioned.
- Class III (Low-Hazard Potential) - Failure of the dam is not expected to result in loss of life and/or significant property damage.
- Class IV (Small-Dam Low-Hazard Potential) - Failure of the dam is not expected to result in loss of life or significant property damage.

Table 4.5-2 State Regulated Dams with High or Significant Hazard Potential lists information for all state-regulated dams in Monmouth County reported as having High (H) Hazard Potential or Significant (S) Hazard Potential. There are a total of 27 dams in the County classified as either high or significant hazard potential (12 dams are high hazard potential and 15 are classified as significant hazard potential)[25]. Of the 27 high and significant hazard potential dams in the County, 26 dams have completed an Emergency Action Plan (EAP), which according to the Association of State Fam Safety of

[25] In addition to the dams listed in Table 4.6-2, representatives of Wall Township have also expressed concern about the Brick Reservoir. While this dam is not currently considered a major dam by the Federal NID, or a high/significant hazard dam in the State's Inventory, local authorities have reported concerns regarding the impact any failure of this dam would have on the Herbertsville Road area of the Township.

Officials is a written document that identifies incidents that can lead to potential emergency conditions at a dam, identifies the areas that can be affected by the less of reservoir and specifies pre-planned actions to be followed to minimize property damage, potential loss of infrastructure and water resource, and potential loss of life because of failure or mis-operation of a dam. Additionally, 24 high hazard dams have submitted an Operations and Maintenance Plan (O&M), which according to DEP is a formal document that provides guidance and instruction to project personnel for the proper operation and maintenance of the reservoir and dam.. All the high-hazard dams have been inspected within the last two years. For the complete table of dams in Monmouth County, including information on the condition of each dam, refer to Appendix Volume I Jurisdictional Information Vol. 56 Monmouth County Dams (confidential version). Each of the nine municipalities that have high hazard potential dams created mitigation actions to mitigate against dam failure (see Appendix Vol. I – Jurisdictional Information).

Table 4.5 - 2 State-Regulated Dams with High or Significant Hazard Potential

Jurisdiction	Dam Name	Hazard Potential	River/Stream	Owner(s)
Allentown Borough	Allentown Dam	H	Doctors Creek	Monmouth County and Allentown
Colts Neck Township	Swimming River Reservoir Dam	H	Robins Swamp Brook	New Jersey-American Water Company
Freehold Township	Lake Topanemus Dam	H	McGellaird's Brook	Monmouth County, Freehold Borough, Freehold Township
Howell Township	Echo Lake Dam	H	Haystack Brook-TR	Monmouth County, Howell Township
Howell Township	Manasquan Reservoir Dam	H	Timber Swamp Brook	New Jersey Water Supply Authority
Howell Township	Lake Louise Dam	H	Branch of Haystack Brook	Monmouth County, Howell Township
Manalapan Township	Millhurst Lake Dam	H	Manalapan Brook	Monmouth County, Manalapan Township
Matawan Borough	Matawan Lake Dam	H	Gravelly Brook	Monmouth County, Matawan Borough
Matawan Borough	Lake Lefferts Dam	H	Matawan Creek	Monmouth County, Matawan Borough
Millstone Township	Assunpink #18 Dam	H	Assunpink Creek	Division of Fish & Wildlife
Upper Freehold Township	Assunpink #4 Dam	H	Assunpink Creek	Division of Fish & Wildlife
Wall Township	Glendola Reservoir Dam	H	Robins Swamp Brook	New Jersey-American Water Company
Allentown Borough	Indian Dam	S	Indian Run	Monmouth County, Allentown Water Department, Mercer County
Colts Neck Township	Bucks Mill Dam	S	Yellow Brook	Monmouth County, Colts Neck Township
Englishtown Borough	Englishtown Lake Dam	S	Matchaponix Brook	Monmouth County, Englishtown Borough
Manalapan Township	Manalapan Brook Pond Dam	S	Manalapan Brook	Monmouth County Park System
Middletown Township	Upper Pond Dam	S	Nut Swamp Brook-TR	Craig A. Fine, Esq.
Middletown Township	Navesink River Road Dam	S	Navesink River-TR	Monmouth County
Middletown Township	Shadow Lake Dam	S	Quioley Creek	Monmouth County, Middletown Township
Millstone Township	Perrineville Dam	S	Rocky Brook	Monmouth County
Upper Freehold Township	Red Valley Dam	S	Doctors Creek	Monmouth County, Fin Fur & Feather Club
Upper Freehold Township	Imlaystown Lake Dam	S	Doctors Creek	Division of Fish & Wildlife, Upper Freehold Township
Upper Freehold Township	Assunpink #19 Dam	S	Assunpink Creek	Division of Fish & Wildlife
Wall Township	Old Mill Pond Dam	S	Wreck Pond Brook	Township of Wall, JDE Spring Lake, LLC

Jurisdiction	Dam Name	Hazard Potential	River/Stream	Owner(s)
Wall Township	Hurley Pond Dam	S	Wreck Pond Brook	Monmouth County, Pleviers, Wall Township
Wall Township	Brisbane Lake Dam	S	Mill Run	Division of Parks and Forestry, Monmouth County
Wall Township	Osborns Mills Dam	S	Wreck Pond Brook	Monmouth County, Wall Township

SOURCE: NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF DAM SAFETY AND FLOOD CONTROL[26]

4.5.4 PREVIOUS OCCURRENCES AND LOSSES

According to NJDEP's Bureau of Dam Safety and Flood Control, New Jersey has not experienced any historic major dam failures but there have been an increasing number of small dam failures. This is largely attributed to the lack of maintenance and inspection, as well as the fact that many of the dams in the state are nearing the end of their design life. Although not catastrophic events, Monmouth County has experienced a number of small dam failure events that have caused reported property damages. Notable events include the following:

July 1989. According to the National Performance of Dams Program (NPDP) at Stanford University, the Holmdel Park Dam located in Holmdel reportedly failed following heavy rains at the spillway culvert, but no associated property damages were reported. Records indicate that seepage piping (soil erosion) was involved in the failure, and the dam was subsequently reconstructed.

October 13-14, 2005. Monmouth County experienced a heavy rain event which brought several inches to the area in a short amount of time. According to NCDC, this led to flooding on area creeks and rivers, which also caused minor dam failures at several locations. Dams failed on both Spring Lake and Mill Pond, and Deal Lake overflowed, forcing the evacuation of nearly 1,200 residents and a declared state of emergency. The failure of a dam on Wreck Pond caused the flooding of Spring Lake, Spring Lake Heights, Sea Girt and Wall. A mandatory evacuation of Spring Lake was implemented during the morning of the 14th. In Wall, the cost of repairing the Wreck Pond Dam was estimated at $4.2 million. On the other side of the township, a dam breach on Mill Pond within Allaire State Park caused significant water damage and a roadway collapse in the Historic Village within the park, flooding the general purposes building.

Hurricane Irene 2011. Earthen dams at Shadow Lake and Lake Lefferts failed, flooding roads and forcing the closure of Hubbard Avenue in Middletown and Ravine Drive in Matawan.

4.5.5 PROBABILITY OF FUTURE OCCURRENCE

Dam failures are rare and hard to forecast future occurrence, however they normally coincide with events that cause them such as earthquakes, landslides, and excessive rainfall and snowmelt. Dam failures in New Jersey are often caused by heavy rains or other precipitation. The probability of dam failure in Bergen County is low (State HMP). The probability of a dam failure occurrence in Monmouth County is relatively low due to routine inspection, repair and maintenance programs, though the possibility of a future failure event is likely increasing due to aging dam structures that may need repair or

26 *DAM ALSO LISTED AS A "MAJOR" DAM IN THE USGS NATIONAL INVENTORY OF DAMS (NID). MAJOR DAMS ARE DESCRIBED AS 50 FEET OR MORE IN HEIGHT, OR WITH A NORMAL STORAGE CAPACITY OF 5,000 ACRE-FEET OR MORE, OR WITH A MAXIMUM STORAGE CAPACITY OF 25,000 ACRE-FEET OR MORE.

reconstruction. The NJDEP's Dam Safety program serves to ensure the safety and integrity of dams in New Jersey and, thereby, protect people and property from the consequences of dam failures. A

4.5.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or its entire designed margin of safety, also known as freeboard. Loss of designed margin of safety may cause floodwaters more readily to overtop the dam or create unintended loads. Such situations could lead to a dam failure.

4.5.7 VULNERABILITY ASSESSMENT

Impacts

Dam failure presents a significant potential for disaster, in that significant loss of life and property would be expected in addition to the possible loss of power and water resources. The most common cause of dam failure is prolonged rainfall that produces flooding. Failures due to other natural events such as hurricanes, earthquakes or landslides are significant because there is generally little or no advance warning. The best way to mitigate dam failure is through the proper construction, inspection, maintenance and operation of dams, as well as maintaining and updating Emergency Action Plans for use in the event of a dam failure.

Exposure and Damage Estimates

Of the nine "high hazard" dams in Monmouth County, three have been classified by USGS as "major" dams and represent the most significant hazard risk based on the potential consequences of a dam failure. Major dams are described as 50 feet or more in height, or with a normal storage capacity of 5,000 acre-feet or more, or with a maximum storage capacity of 25,000 acre-feet or more. In Monmouth County, these include the Glendola Reservoir Dam in Wall Township, the Manasquan Reservoir Dam in Howell Township, and the Swimming River Reservoir Dam in Colts Neck Township.

The most accurate method to estimate exposure and potential losses to the dam failure hazard relies on data produced through detailed dam failure inundation studies, often prepared by the owners of dam facilities as part of their own emergency action plans. Inundation studies and/or associated maps for dams in Monmouth County were requested from the NJDEP for this assessment but were not made available because they either did not exist or were restricted from public release, due to security purposes. Vulnerability has been assessed by other methods for this plan but should be refined during future plan updates if dam failure inundation data should become available.

For the 2009 Plan, it was assumed that the most immediate area of impact would likely be within one mile downstream of the location of a dam. Potentially susceptible areas were assumed to be parcels within one mile of the downstream side of the dam, on both banks. The determination of value at-risk was calculated through GIS analysis by summing the total improved values for those parcels that were confirmed to have at least one building located within one mile on the downstream side of the dam location. The 2009 Plan methodology did not consider topographic constraints to water flow; assumed that 100% of improved property on affected parcels was at risk; and used Census 2000 data at the tract level. Thus, it represented an overestimation of both population and improved property at risk.

This methodology was refined for the 2014 Plan Update, where each dam's characteristics as well as the nature of local topography were used to generate rough delineations of potentially susceptible areas. The value of improvements at risk was estimated based on the proportion of parcel area within estimated inundation areas (for example, if 10% of the parcel area was assumed to be at risk of inundation during a breach of the dam, 10% of the assessed value of improvements on that parcel were also assumed to be at risk). This new approach was deemed acceptable for planning purposes, in the absence of more detailed dam inundation flooding limits (based on detailed hydrologic/hydraulic modeling).

Table 4.5 - 3 Exposure in Dam Failure Hazard Areas for Major High Hazard Dams shows population and assessed building value exposure to dam failure by jurisdiction. Population estimates have been refined using more recent Census 2010 data, at the block level, and assessed values reflect more recent 2012 assessment data.

Table 4.5 - 3 Exposure in Dam Failure Hazard Areas for Major High Hazard Dams

Jurisdiction	Population At-Risk	Assessed Value of Buildings At-Risk
Glendola Reservoir Dam (height = 65 feet / normal storage capacity = 3,155-acre feet)		
Neptune, Township of	288	$11,360,000
Wall, Township of	102	$3,460,300
Total	390	$14,821,000
Manasquan Reservoir Dam (height = 53 feet / normal storage capacity = 14,470-acre feet)		
Howell, Township of	104	$13,949,200
Total	104	$13,949,200
Swimming River Reservoir Dam (height = 45 feet / normal storage capacity = 8,000-acre feet)		
Colts Neck, Township of	1	$0
Middletown, Township of	214	$5,677,700
Tinton Falls, Borough of	464	$5,369,300
Total	679	$11,047,000

*EXPOSURE CALCULATED BY GLS ANALYSTS USING LOCAL ASSESSED VALUES

The Glendola Reservoir Dam is located in Wall Township and is southwest of Neptune Township. In Wall, the area downstream of this dam location includes residential buildings within close proximity (within 0.25 miles of the dam), as well as a large county-owned park comprised of approximately 100 acres of undeveloped land. North of the park, there is residential development in Neptune that is within a one-mile radius of the dam and could potentially be impacted should the dam fail. The Manasquan Reservoir Dam is located in Howell Township. Within a one-mile radius from the dam on the downstream side, there is a county-owned golf course, two schools located north of the golf course, residential development east of the golf course, and new residential development south of the golf course. Most property in the immediate area surrounding the dam is owned by either the State of New Jersey or Monmouth County. The Swimming River Reservoir Dam is located in Colts Neck Township but is situated so that the outfall is in close proximity to Middletown Township and Tinton Falls Township. There are no buildings located on the downstream side of the dam in Colts Neck. Middletown has residential development within 0.3 miles of the dam (downstream), and Tinton Falls has residential development within 0.5 miles of the dam (downstream). Middletown would likely experience greater impacts from a failure of this dam than Tinton Falls, as Middletown has more area located within a one-mile radius of the dam on the downstream side. Along the stream that outfalls from the dam, there is undeveloped land along the stream, which would likely experience the most water inundation in the event of a dam failure.

The general at-risk population in the event of a dam failure would be located downstream of the dam within close proximity of the outfall (most likely within one mile). Protection of human life through administration of proper emergency notification and evacuation planning is crucial to minimizing social losses due to dam failure. Given the lack of historical data on significant dam failure occurrences or the availability of inundation maps for Monmouth County, it is assumed that while one major event may result in significant losses, annualizing structural losses over a long period of time would most likely yield a negligible annualized loss estimate for jurisdictions exposed to this hazard.

Table 4.5 - 4 Total Number and Percent of Critical Facilities, Critical Infrastructure, and Historic & Cultural Resources with Risk of Dam Failure shows the number and percentage of critical facilities with risk of dam failure, as well as the estimated replacement cost value (RCV) of the critical facilities with risk of dam failure. Because estimated inundation areas of Monmouth County's dams were unavailable, we estimated the inundation areas by creating a 1.5-mile radius buffer around each dam in ArcMap. Since upstream and downstream flows were not considered in the analysis, it is possible we have overestimated the number and percentage of critical facilities as some may be upstream of the dam. The Table also shows the estimated replacement cost value (RCV) of critical facilities with risk of dam failure. First, we approximated the market value of improvements on each of the parcels in the state using MOD-IV and taxation rates from 2017 (NJ Office of Information Technology (OIT), 2017; NJ Division of Taxation, 2017). Georeferenced critical facility data points were then intersected with the parcel layer to attribute the parcel's market value of improvements to each critical facility. Some critical facilities had been geolocated to the nearest road centerline and thus were not captured when intersected with parcels. As a proxy, we calculated the median market value for improvements from the critical facilities geolocated on their proper parcels and attributed this median value to all other critical facilities.

Table 4.5 - 4 Total Number and Percent of Critical Facilities, Critical Infrastructure, and Historic & Cultural Resources with Risk of Dam Failure

Jurisdiction	Number of Critical Facilities with Risk of Dam Failure	Percentage of Critical Facilities with Risk of Dam Failure	RCV of Critical Facilities with Risk of Dam Failure
Aberdeen, Township of	22	88%	$68,853,431.68
Allenhurst, Borough of	3	100%	$2,111,700.86
Allentown, Borough of	6	100%	$50,976,659.61
Asbury Park, City of	24	100%	$84,311,380.78
Atlantic Highlands, Borough of	6	86%	$12,143,925.79
Avon-By-The-Sea, Borough of	5	83%	$4,830,642.53
Belmar, Borough of	12	100%	$24,764,071.74
Bradley Beach, Borough of	8	100%	$10,026,250.84
Brielle, Borough of	11	100%	$13,312,340.36
Colts Neck, Township of	17	94%	$58,175,417.70
Deal, Borough of	6	100%	$10,873,640.21
Eatontown, Borough of	21	100%	$52,370,935.72
Englishtown, Borough of	6	100%	$4,019,590.58
Fair Haven, Borough of	10	100%	$16,632,157.32

Jurisdiction	Number of Critical Facilities with Risk of Dam Failure	Percentage of Critical Facilities with Risk of Dam Failure	RCV of Critical Facilities with Risk of Dam Failure
Farmingdale, Borough of	12	100%	$10,783,376.34
Freehold, Borough of	45	94%	$344,940,186.39
Freehold, Township of	78	93%	$699,137,738.53
Hazlet, Township of	9	24%	$18,206,417.14
Highlands, Borough of	0	0%	$0.00
Holmdel, Township of	18	69%	$75,694,712.24
Howell, Township of	39	56%	$156,472,826.77
Interlaken, Borough of	2	100%	$508,634.31
Keansburg, Borough of	0	0%	$0.00
Keyport, Borough of	15	79%	$61,501,153.41
Lake Como, Borough of	5	100%	$4,114,147.21
Little Silver, Borough of	5	50%	$33,710,397.03
Loch Arbour, Village of	0	0%	$0.00
Long Branch, City of	26	59%	$322,789,727.88
Manalapan, Township of	42	89%	$172,209,246.04
Manasquan, Borough of	11	100%	$42,864,901.17
Marlboro, Township of	40	77%	$181,418,951.60
Matawan, Borough of	15	100%	$13,489,167.77
Middletown, Township of	49	46%	$322,370,504.88
Millstone, Township of	10	91%	$30,426,387.96
Monmouth Beach, Borough of	0	0%	$0.00
Neptune City, Borough of	10	100%	$16,658,579.73
Neptune, Township of	50	100%	$571,059,060.87
Ocean, Township of	36	100%	$225,649,333.55
Oceanport, Borough of	5	0%	$7,009,724.39
Red Bank, Borough of	28	100%	$118,946,759.54
Roosevelt, Borough of	4	100%	$1,572,616.05
Rumson, Borough of	4	29%	$4,289,908.69
Sea Bright, Borough of	0	0%	$0.00
Sea Girt, Borough of	7	100%	$4,721,701.59
Shrewsbury, Borough of	9	64%	$28,648,587.12
Shrewsbury, Township of	1	100%	$0.00
Spring Lake, Borough of	8	100%	$23,213,644.02
Spring Lake Heights, Borough of	7	100%	$9,433,355.10
Tinton Falls, Borough of	36	78%	$166,661,394.88
Union Beach, Borough of	0	0%	$0.00
Upper Freehold, Township of	12	100%	$18,741,656.03
Wall, Township of	52	96%	$271,980,023.82
West Long Branch, Borough of	14	100%	$50,850,734.71

Jurisdiction	Number of Critical Infrastructure with Risk of Dam Failure	Percentage of Critical Infrastructure with Risk of Dam Failure	RCV of Critical Infrastructure with Risk of Dam Failure
Aberdeen, Township of	0	0%	$0.00
Allenhurst, Borough of	1	100%	$0.00
Allentown, Borough of	0	0%	$0.00

Jurisdiction	Number of Critical Infrastructure with Risk of Dam Failure	Percentage of Critical Infrastructure with Risk of Dam Failure	RCV of Critical Infrastructure with Risk of Dam Failure
Asbury Park, City of	1	100%	$0.00
Atlantic Highlands, Borough of	4	80%	$165,213.23
Avon-By-The-Sea, Borough of	0	0%	$0.00
Belmar, Borough of	0	0%	$0.00
Bradley Beach, Borough of	1	100%	$0.00
Brielle, Borough of	0	0%	$0.00
Colts Neck, Township of	0	0%	$0.00
Deal, Borough of	0	0%	$0.00
Eatontown, Borough of	1	100%	$0.00
Englishtown, Borough of	0	0%	$0.00
Fair Haven, Borough of	0	0%	$0.00
Farmingdale, Borough of	0	0%	$0.00
Freehold, Borough of	0	0%	$0.00
Freehold, Township of	0	0%	$0.00
Hazlet, Township of	1	100%	$0.00
Highlands, Borough of	0	0%	$0.00
Holmdel, Township of	0	0%	$0.00
Howell, Township of	0	0%	$0.00
Interlaken, Borough of	0	0%	$0.00
Keansburg, Borough of	0	0%	$0.00
Keyport, Borough of	1	100%	$228,094.08
Lake Como, Borough of	0	0%	$0.00
Little Silver, Borough of	0	0%	$0.00
Loch Arbour, Village of	0	0%	$0.00
Long Branch, City of	2	100%	$0.00
Manalapan, Township of	0	0%	$0.00
Manasquan, Borough of	1	100%	$0.00
Marlboro, Township of	0	0%	$0.00
Matawan, Borough of	1	100%	$81,906.17
Middletown, Township of	1	100%	$0.00
Millstone, Township of	0	0%	$0.00
Monmouth Beach, Borough of	0	0%	$0.00
Neptune City, Borough of	1	0%	$0.00
Neptune, Township of	0	0%	$0.00
Ocean, Township of	0	0%	$0.00
Oceanport, Borough of	1	100%	$0.00
Red Bank, Borough of	10	100%	$8,241,945.35
Roosevelt, Borough of	0	0%	$0.00
Rumson, Borough of	0	0%	$0.00
Sea Bright, Borough of	0	0%	$0.00
Sea Girt, Borough of	0	0%	$0.00
Shrewsbury, Borough of	1	100%	$0.00
Shrewsbury, Township of	0	0%	$0.00
Spring Lake, Borough of	1	100%	$0.00
Spring Lake Heights, Borough of	0	0%	$0.00
Tinton Falls, Borough of	13	93%	$32,093,859.24
Union Beach, Borough of	0	0%	$0.00

Jurisdiction	Number of Critical Infrastructure with Risk of Dam Failure	Percentage of Critical Infrastructure with Risk of Dam Failure	RCV of Critical Infrastructure with Risk of Dam Failure
Upper Freehold, Township of	0	0%	$0.00
Wall, Township of	12	100%	$1,217,235.24
West Long Branch, Borough of	0	0%	$0.00

Jurisdiction	Number of Historic & Cultural Resources with Risk of Dam Failure	Percentage of Historic & Cultural Resources with Risk of Dam Failure	RCV of Historic & Cultural Resources with Risk of Dam Failure
Aberdeen, Township of	22	96%	$2,022,961.79
Allenhurst, Borough of	304	100%	$189,150,109.30
Allentown, Borough of	228	100%	$67,719,674.48
Asbury Park, City of	45	100%	$69,270,756.34
Atlantic Highlands, Borough of	5	25%	$2,742,966.49
Avon-By-The-Sea, Borough of	25	83%	$5,895,144.67
Belmar, Borough of	15	100%	$5,204,072.67
Bradley Beach, Borough of	23	96%	$13,964,636.26
Brielle, Borough of	23	100%	$14,708,876.66
Colts Neck, Township of	116	81%	$137,008,663.93
Deal, Borough of	24	100%	$29,134,683.55
Eatontown, Borough of	49	100%	$509,487,987.06
Englishtown, Borough of	28	100%	$6,287,316.37
Fair Haven, Borough of	29	100%	$7,196,082.85
Farmingdale, Borough of	31	100%	$3,974,302.94
Freehold, Borough of	124	91%	$148,979,789.15
Freehold, Township of	85	93%	$61,842,761.49
Hazlet, Township of	4	33%	$681,348.69
Highlands, Borough of	0	0%	$0.00
Holmdel, Township of	98	88%	$81,371,671.76
Howell, Township of	89	89%	$8,239,685.88
Interlaken, Borough of	16	100%	$3,153,493.73
Keansburg, Borough of	0	0%	$0.00
Keyport, Borough of	113	48%	$32,606,655.38
Lake Como, Borough of	2	100%	$0.00
Little Silver, Borough of	21	50%	$9,711,069.07
Loch Arbour, Village of	8	100%	$2,488,337.03
Long Branch, City of	59	60%	$23,689,519.68
Manalapan, Township of	75	82%	$9,425,817.27
Manasquan, Borough of	42	79%	$45,880,761.57
Marlboro, Township of	160	90%	$62,637,119.99
Matawan, Borough of	69	100%	$9,985,886.56
Middletown, Township of	34	59%	$151,052,838.77
Millstone, Township of	184	87%	$18,529,774.68
Monmouth Beach, Borough of	0	0%	$0.00
Neptune City, Borough of	1	100%	$122,319.02
Neptune, Township of	1818	99%	$390,077,970.18

Jurisdiction	Number of Historic & Cultural Resources with Risk of Dam Failure	Percentage of Historic & Cultural Resources with Risk of Dam Failure	RCV of Historic & Cultural Resources with Risk of Dam Failure
Ocean, Township of	35	100%	$34,560,741.67
Oceanport, Borough of	47	89%	$216,051,174.02
Red Bank, Borough of	99	100%	$109,501,485.48
Roosevelt, Borough of	259	100%	$37,890,274.44
Rumson, Borough of	8	44%	$455,261.78
Sea Bright, Borough of	0	0%	$0.00
Sea Girt, Borough of	23	100%	$75,963,601.69
Shrewsbury, Borough of	86	93%	$166,796,659.71
Shrewsbury, Township of	1	100%	$0.00
Spring Lake, Borough of	77	100%	$47,545,209.62
Spring Lake Heights, Borough of	16	100%	$13,234,751.15
Tinton Falls, Borough of	68	92%	$97,854,450.47
Union Beach, Borough of	0	0%	$0.00
Upper Freehold, Township of	127	88%	$69,997,207.35
Wall, Township of	97	98%	$105,286,674.16
West Long Branch, Borough of	38	100%	$279,520,016.97

SOURCES: NJDEP, 2018; MONMOUTH COUNTY OFFICE OF GIS; MONMOUTH COUNTY JURISDICTIONS; NJOIT, 2017; NJ DIVISION OF TAXATION, 2017

Table 4.5-5 Total Number and RCV for General Building Stock with Risk of Dam Failure shows the number and percentage of general building stock with risk of dam failure, as well as the estimated replacement cost value (RCV) of the building stock. RCV was calculated by approximating the market value of the improvements on each of the parcels in the State using MOD-IV and taxation rates from 2017[27].

Table 4.5 - 5 Total Number and RCV for General Building Stock with Risk of Dam Failure

Jurisdiction	Number of General Building Stock with Risk of Dam Failure	Percentage of General Building Stock with Risk of Dam Failure	RCV of General Building Stock with Risk of Dam Failure	Percentage of RCV of General Building Stock with Risk of Dam Failure
Aberdeen, Township of	5,474	84%	$1,884,318,460.50	87%
Allenhurst, Borough of	336	100%	$609,198,196.00	100%
Allentown, Borough of	671	100%	$195,452,395.39	100%
Asbury Park, City of	4,041	100%	$1,525,788,924.28	100%
Atlantic Highlands, Borough of	708	44%	$252,437,724.00	34%
Avon-By-The-Sea, Borough of	698	77%	$599,322,359.42	66%
Belmar, Borough of	2,591	100%	$1,537,961,925.00	100%
Bradley Beach, Borough of	2,131	100%	$1,217,367,591.26	100%
Brielle, Borough of	1,919	100%	$1,378,928,018.00	100%

[27] NJ Office of Information Technology (NJOIT). 2017. New Jersey Real Estate MOD-IV Tax List Search Plus Database, 2017; NJ Division of Taxation. 2017. General and Effective Tax Rates by County and Municipality. https://www.state.nj.us/treasury/taxation/lpt/taxrate.shtml.

Jurisdiction	Number of General Building Stock with Risk of Dam Failure	Percentage of General Building Stock with Risk of Dam Failure	RCV of General Building Stock with Risk of Dam Failure	Percentage of RCV of General Building Stock with Risk of Dam Failure
Colts Neck, Township of	1,783	96%	$1,368,589,074.95	94%
Deal, Borough of	855	97%	$1,914,604,153.00	95%
Eatontown, Borough of	3,453	99%	$2,264,513,356.52	99%
Englishtown, Borough of	679	100%	$257,580,182.40	100%
Fair Haven, Borough of	2,065	99%	$1,642,562,169.33	99%
Farmingdale, Borough of	405	100%	$144,138,098.90	100%
Freehold, Borough of	2,316	73%	$688,971,511.40	68%
Freehold, Township of	10,993	88%	$5,128,891,377.40	81%
Hazlet, Township of	1,689	25%	$639,025,877.20	25%
Highlands, Borough of	0	0%	$0.00	0%
Holmdel, Township of	2,872	63%	$2,280,011,298.07	65%
Howell, Township of	18,116	80%	$4,975,592,731.94	74%
Interlaken, Borough of	421	100%	$272,811,426.00	100%
Keansburg, Borough of	0	0%	$0.00	0%
Keyport, Borough of	1,460	69%	$477,553,706.00	72%
Lake Como, Borough of	907	100%	$359,418,769.00	100%
Little Silver, Borough of	1,092	45%	$715,655,987.90	44%
Loch Arbour, Village of	139	100%	$154,541,627.00	100%
Long Branch, City of	4,721	60%	$2,548,230,157.95	64%
Manalapan, Township of	9,628	68%	$4,871,671,588.73	75%
Manasquan, Borough of	2,146	67%	$1,312,756,346.77	61%
Marlboro, Township of	8,361	59%	$4,599,207,784.33	60%
Matawan, Borough of	2,513	100%	$964,777,908.90	100%
Middletown, Township of	10,534	45%	$5,667,994,008.27	55%
Millstone, Township of	2,950	77%	$1,431,039,168.81	78%
Monmouth Beach, Borough of	0	0%	$0.00	0%
Neptune City, Borough of	1,362	100%	$466,477,593.50	100%
Neptune, Township of	10,771	100%	$4,191,748,637.46	99%
Ocean, Township of	9,246	100%	$4,962,728,302.34	100%
Oceanport, Borough of	893	47%	$482,909,825.50	44%
Red Bank, Borough of	3,946	100%	$1,988,886,695.34	100%
Roosevelt, Borough of	360	100%	$86,568,171.62	100%
Rumson, Borough of	393	17%	$605,735,031.82	18%
Sea Bright, Borough of	0	0%	$0.00	0%
Sea Girt, Borough of	1,217	100%	$2,187,411,317.00	100%
Shrewsbury, Borough of	624	42%	$526,611,438.42	49%
Shrewsbury, Township of	394	100%	$52,612,591.09	100%
Spring Lake, Borough of	1,705	100%	$3,625,497,281.00	100%
Spring Lake Heights, Borough of	2,155	100%	$1,170,083,168.00	100%
Tinton Falls, Borough of	5,818	91%	$2,168,293,964.26	82%
Union Beach, Borough of		0%	$0.00	0%
Upper Freehold, Township of	2,681	90%	$1,046,962,567.74	90%
Wall, Township of	8,649	89%	$4,625,300,568.18	84%

Jurisdiction	Number of General Building Stock with Risk of Dam Failure	Percentage of General Building Stock with Risk of Dam Failure	RCV of General Building Stock with Risk of Dam Failure	Percentage of RCV of General Building Stock with Risk of Dam Failure
West Long Branch, Borough of	2,464	100%	$1,288,703,228.71	100%

SOURCES: NJDEP, 2018; NJOIT, 2017; NJ DIVISION OF TAXATION, 2017

4.5.8 POTENTIAL FOR FUTURE DEVELOPMENT TO IMPACT HAZARD VULNERABILITY

Out of the 25 jurisdictions in Monmouth County with mapped dam failure hazard areas, only five have potentially developable undeveloped parcels in mapped dam failure hazard areas. The total area of these parcels is approximately 381 acres. In other words, only about one percent of the County's potentially developable undeveloped land is in areas potentially susceptible to dam failure. Table 4.5 - 6 Potential for Future Development to Impact Dam Failure Hazard Vulnerability presents a snapshot of the dam failure hazard, future development trends, the acreage of potentially developable parcels subject to dam failure, and the potential for future development of undeveloped parcels to substantially increase dam failure hazard vulnerability under existing conditions.

Jurisdictions with a potential for future development to substantially increase dam failure hazard vulnerability under existing conditions should: (a) include dam failure mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development. Please note that all municipalities are not listed in the following table. Only municipalities that contain state-regulated dams are listed.

Table 4.5 - 6 Potential for Future Development to Impact Dam Failure Hazard Vulnerability

Jurisdiction	Dam Failure Hazard Areas Present	Relative Population Trend (2010-2040)[28]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Dam Failure Hazard Areas	Percent of Potentially Developable Undeveloped Land in Dam Failure Hazard Areas	Local Characterization of Development Trends[29]	Potential for Future Development on Undeveloped Parcels in Mapped Dam Failure Hazard Areas	Potential for Future Development on Undeveloped Parcels in Mapped Dam Failure
Allentown, Borough of	L	Negligible increase	6	0	0.0%	Little if any development expected		
Colts Neck, Township of	L	Low level increase	793	0	0.0%	Predominantly greenfield development		
Englishtown, Borough of	L	Substantial	77	0	0.0%	Mix of greenfield		

28 Relative population trend, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.

29 Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Dam Failure Hazard Areas Present	Relative Population Trend (2010-2040)[28]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Dam Failure Hazard Areas	Percent of Potentially Developable Undeveloped Land in Dam Failure Hazard Areas	Local Characterization of Development Trends[29]	Potential for Future Development on Undeveloped Parcels in Mapped Dam Failure Hazard Areas	Potential for Future Development on Undeveloped Parcels in Mapped Dam Failure
		increase				development, infill and redevelopment		
Freehold, Township of	L	Substantial increase	2622	0	0.0%	Predominantly greenfield development		
Howell, Township of	L	Moderate increase	6606	43	0.7%	Mix of greenfield development, infill and redevelopment	•	•
Manalapan, Township of	L	Moderate increase	3194	0	0.0%	Predominantly greenfield development		
Matawan, Borough of	L	Substantial increase	140	0	0.0%	Mix of greenfield development, infill and redevelopment		
Middletown, Township of	L	Moderate increase	2313	8	0.3%	Mix of greenfield development, infill and redevelopment	•	•
Millstone, Township of	L	Negligible increase	3169	0	0.0%	Mix of greenfield development, infill and redevelopment		
Neptune, Township of	L	Substantial increase	833	2	0.2%	Mix of greenfield development, infill and redevelopment	•	•
Tinton Falls, Borough of	L	Substantial increase	1670	27	1.6%	Predominantly greenfield development	•	•
Upper Freehold, Township of	L	Negligible increase	1508	0	0.0%	Predominantly greenfield development		
Wall, Township of	L	Moderate increase	2446	300	12.3%	Predominantly greenfield development	•	•

Jurisdiction	Dam Failure Hazard Areas Present	Relative Population Trend (2010-2040)[28]	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Dam Failure Hazard Areas	Percent of Potentially Developable Undeveloped Land in Dam Failure Hazard Areas	Local Characterization of Development Trends[29]	Potential for Future Development on Undeveloped Parcels in Mapped Dam Failure Hazard Areas	Potential for Future Development on Undeveloped Parcels in Mapped Dam Failure
Monmouth County	L	Moderate increase	32323	381	1.2%	Mix of greenfield development, infill and redevelopment	•	•

4.6 DROUGHT

4.6.1 HAZARD DESCRIPTION

A prolonged period of less than normal precipitation such that the lack of water causes a serious hydrologic imbalance. Common effects of drought include crop failure, water supply shortages, and fish and wildlife mortality. High temperatures, high winds, and low humidity can worsen drought conditions and also make areas more susceptible to wildfire. Human demands and actions have the ability to hasten or mitigate drought-related impacts on local communities.

4.6.2 LOCATION

Droughts occur in all parts of the country and at any time of year, depending on temperature and precipitation over time. Similarly, droughts can occur in all parts of Monmouth County at any time of year, depending on temperature and precipitation over time. While arid regions of the United States are more susceptible to long-term or extreme drought conditions, other areas such as Monmouth County tend to be more susceptible to short-term, less severe droughts. It is impossible to delineate a drought hazard area for the County, per se, but it is generally assumed that drought is a county-wide hazard, with drought conditions being possible in all geographic areas.

4.6.3 EXTENT

The extent (i.e., magnitude or severity) of drought can depend on the duration, intensity, geographic extent, and the regional water supply demands made by human activities and vegetation. The intensity of the impact from drought could be minor to extreme damage in a localized area or regional damage affecting human health and the economy. Generally, impacts of drought evolve gradually, and regions of maximum intensity change with time. The severity of a drought is determined by areal extent as well as intensity and duration. The frequency of a drought is determined by analyzing the intensity for a given duration, which allows determination of the probability or percent chance of a more severe event occurring in a given mean return period.

The Palmer Drought Severity Index (PDSI) in one of many available drought indices used to assess the extent of a drought event. It was developed by Wayne Palmer in 1965 and indicates prolonged and abnormal moisture deficiency or excess. The PDSI tends to be used more commonly than other available indices, and is an important tool for evaluating the scope, severity, and frequency of prolonged periods of abnormally dry or wet weather. PDSI drought classifications are based on observed drought conditions and will range from -0.5 (incipient dry spell) to -4.0 (extreme drought). The PDSI also reflects excess precipitation using positive numbers. The PDSI is the most effective in determining long-term droughts; but has limitations in terms of use for short-term forecasts. To improve monitoring and measurement of drought severity from region to region within the State of New Jersey, NJDEP implemented a unique set of indices in January 2001specifically designed for the particular characteristics and needs of the State. This new set of statewide indicators supplements the Palmer Drought Severity Index (PDSI) with the measurement of regional precipitation, stream- flow, reservoir levels, and groundwater levels. New Jersey currently measures the status of each indicator as near or above normal, moderately dry, severely dry, or extremely dry. The status is based on a statistical analysis of historical values with generally the driest 10% being classified as extremely dry, from 10% to 30% as severely dry, and 30% to 50% as moderately dry.

4.6.4 PREVIOUS OCCURRENCES AND LOSSES

According to NCDC, 44 recorded instances of drought conditions have affected Monmouth County between 1997 and April 2019, causing significant losses to agricultural crops. Four instances occurred since the last plan update. An additional instance of drought conditions was profiled in the 2019 State HMP from October 2016 to April 2017, in which “Drought conditions were the worst faced by New Jersey in 14 years.”.

October 1997. Unseasonably dry weather with below normal rainfall, which became worse during the summer months, forced the Delaware River Basin Commission to declare a drought warning on October 27th. The commission urged the seven million residents within the basin's 13,539 square mile area to voluntarily conserve water. Water levels in the New York City Reservoirs, which are in the headwaters of the Delaware River, fell below 40 percent of capacity in late October. Precipitation deficits through October 31st averaged around five inches.

1998-1999. What began as unseasonably dry weather became a drought, which heavily impacted agriculture and water supplies. As reservoir levels continued to fall, the Delaware River Basin Commission declared a drought warning in December 1998. Also, in December, NJDEP declared a drought warning for the entire state. In late December, the Delaware River Basin Commission declared Stage Two of its drought warning. In July 1999, Governor Christie Whitman declared a water shortage alert and called for residents to voluntarily conserve water by not watering lawns or washing cars. In Monmouth County, a drought emergency was declared, and odd/even non-essential watering restrictions were implemented. The drought finally ended as Tropical Storm Floyd dumped significant rainfall amounts across the state. Agricultural losses throughout the state as a result of this long drought were estimated at $80 million.

October 2001 - October 2002. Unseasonably dry weather again turned to drought as precipitation levels fell short of normal levels. Continued dry weather, the drop-in stream flow and groundwater levels and the reduced levels in the New York State reservoirs prompted NJDEP to upgrade the drought watch to a drought warning for counties in the Delaware River Basin and southern New Jersey in November 2001, including Monmouth County. By October 2002, a drought disaster was declared by the U.S. Department of Agriculture for several states including New Jersey. Several rain events in October 2002 helped quench the drought and returned the area's reservoirs to normal levels.

August to September 2008. Excessive heat in June followed by an unseasonably dry August resulted in drought conditions in August of 2008. Rainfall returned to above normal levels in September but was too late to be helpful for farmers. Crops had already been damaged by the combination of excessive June heat and an August hail storm and drought. The United States Secretary of Agriculture issued a drought disaster declaration for ten central and southern New Jersey Counties on September 22nd. Mercer, Monmouth, Burlington, Ocean, Camden, Gloucester, Atlantic, Salem, Cumberland and Cape May Counties were included in the declaration. This made farmers who suffered thirty percent or more direct losses to be eligible for low interest emergency loans from the Farm Services Agency. Loans could cover up to 100 percent of the dollar value of crop losses.

August to October 2010. On August 5, the NJDEP issued a drought watch for northeast New Jersey including Morris County. On a statewide average, August 2010 was the 15th driest August on record (dating back to 1895) with 2.37 inches of rain. The meteorological summer was the 10th driest (8.65 inches) on record dating back to 1895 in New Jersey and was also the driest summer since 1966. At the Atlantic City International Airport, it was the fourth driest August (1.09 inches) and fifth driest meteorological summer (5.92 inches) on record. In Trenton, it was the third driest August (0.80 inches) and fifth driest meteorological summer (5.90 inches) on record.

September to December 2015. After a wet start to the meteorological summer in June, the weather became progressively drier as the summer progressed into September, especially in the northeast part of the state. The United States Drought Monitor reached moderate levels in that part of the state. The New Jersey Department of Environmental Protection issued a drought watch on the 23rd for the northeast part of the state and this included all or parts of Morris, Hunterdon, Somerset, Middlesex, Monmouth, Mercer and Ocean Counties. The drought watch continued into December 2015 and was prompted by continued rainfall deficits that have decreased reservoir, ground water and streamflow levels in the area. Signs of stress in water supply indicators started to occur. Drinking water supply indicators were showing signs of stress from the dry weather and high water demands, including stream flows and ground water levels, as well as declining reservoir storage in the New Jersey Water Supply Authority's Spruce Run and Manasquan Reservoirs in Hunterdon and Monmouth Counties, respectively. A side effect of the dry weather was an expected smaller (in size) pumpkin crop. Farmers have had to endure increased costs of water and electricity to irrigate their crops.

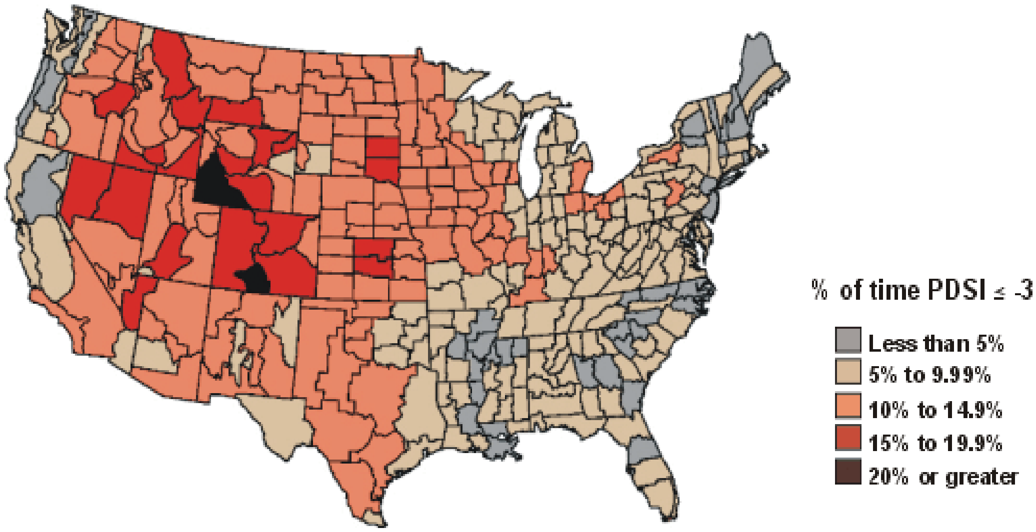
Other notable reports of historical drought events include the following, as identified by the Planning Committee:

- The Borough of Union Beach indicated that it has been put on water restrictions on many occasions due to the lack of water in the local reservoir.
- The Township of Upper Freehold has reportedly experienced severe drought conditions, which lowered the head pressure of potable water in wells and caused numerous wells to go dry. Most of the area depends on wells for potable water, so it is vitally important to maintain head pressure from the aquifers.

4.6.5 PROBABILITY OF FUTURE OCCURRENCE

Monmouth County faces a low to moderate probability of severe drought conditions, though short-term instances of drought will be a more frequent occurrence. Figure 4.6-1 Palmer Drought Severity Index Summary Map for the United States shows the PDSI Summary Map for the United States from 1895 to 1995. According to the PDSI map, Monmouth County is in a zone that experienced severe drought conditions less than 5 percent of the time between 1895 and 1995, but short- term, less severe drought conditions are more common and may occur several times in a decade.

Figure 4.6 - 1 Palmer Drought Severity Index Summary Map for the United States



4.6.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

Research from scientists at Rutgers University indicate that while heavy precipitation events are to increase with changing climate conditions, longer dry spells are also predicted to occur[30].

4.6.7 VULNERABILITY ASSESSMENT

Impacts

Droughts are slow onset hazards, but, over time, they can severely affect crops, municipal water supplies, recreational resources, and wildlife. If drought conditions extend over a number of years, the direct and indirect economic impacts can be significant. High temperatures, high winds, and low humidity can worsen drought conditions and also make areas more susceptible to wildfire. In addition, human actions and demands for water resources can accelerate drought-related impacts.

30 http://raritan.rutgers.edu/wp-content/uploads/2019/06/Broccoli_climate_change_Raritan_June_2019.pdf

Exposure and Damage Estimates

Because drought impacts large areas and crosses jurisdictional boundaries, all existing and future buildings, facilities and populations are considered to be exposed to this hazard and could potentially be impacted.

New Jersey maintains a real-time groundwater level monitoring system consisting of seven observation wells throughout the state. The network, a cooperative between the USGS and NJDEP, uses satellite telemetry to provide observations in four-hour increments. Observations are available on the USGS website at http://water.usgs.gov/nj/nwis/current/?type=gw. The primary purpose of the network is to provide information regarding the status of wells throughout the state and to anticipate potential shortages (NJDEP 2002). **Table 4.6-1 Total Number of Private Wells** lists the total number private wells that NJDEP tracks as part of their private well program, listed by number of wells.

Drought affects groundwater sources, but generally not as quickly as surface water supplies. Groundwater supplies generally take longer to recover. Reduced precipitation during a drought means that groundwater supplies are not replenished at a normal rate. This can lead to a reduction in groundwater levels and problems such as reduced pumping capacity or wells going dry. Shallow wells are more susceptible than deep wells. Reduced replenishment of groundwater affects streams also. Much of the flow in streams comes from groundwater, especially during the summer when there is less precipitation and after snowmelt ends. Reduced groundwater levels mean that even less water will enter streams when steam flows are lowest. Please note that all municipalities are not listed in the following table. Only municipalities private wells are listed.

Table 4.6 - 1 **Total Number of Private Wells by Jurisdiction (NJDEP, 2019)**

Jurisdiction	Number of Wells
Howell Township	1,277
Millstone Township	977
Colts Neck Township	788
Upper Freehold Township	584
Manalapan Township	395
Freehold Township	241
Marlboro Township	148
Wall Township	80
Middletown Township	38
Tinton Falls Borough	26
Holmdel Township	19
Ocean Township	11
Eatontown Borough	10
Fair Haven Borough	10
Freehold Borough	10
Interlaken Borough	10
Little Silver Borough	10
Neptune Township	10

Jurisdiction	Number of Wells
Oceanport Borough	10
Roosevelt Borough	10
Rumson Borough	10
West Long Branch Borough	10

However, drought impacts are mostly experienced in water shortages and crop losses on agricultural lands and have no impact on buildings. To estimate land exposure to drought, agricultural land acreage was acquired from land use classification data as provided by the Monmouth County Office of GIS[11]. Table 4.6- 2 Acreage of Agricultural Land by Jurisdiction shows agricultural land acreage in Monmouth County. Approximately 14 percent of land in Monmouth County is used for agriculture, orchards, and nurseries; located in 25 of the county's 53 communities.

Table 4.6 - 2 Acreage of Agricultural Land by Jurisdiction

Jurisdiction	Total Acres	Agricultural Land (Acres)	Percentage of Total
Aberdeen, Township of	3,588	14	0.40%
Allenhurst, Borough of	162	0	0.00%
Allentown, Borough of	399	11	2.80%
Asbury Park, City of	955	0	0.00%
Atlantic Highlands, Borough of	782	0	0.00%
Avon-By-The-Sea, Borough of	292	0	0.00%
Belmar, Borough of	888	0	0.00%
Bradley Beach, Borough of	382	0	0.00%
Brielle, Borough of	1,521	0	0.00%
Colts Neck, Township of	20,713	3,600	17.40%
Deal, Borough of	759	0	0.00%
Eatontown, Borough of	3,765	16	0.40%
Englishtown, Borough of	373	9	2.50%
Fair Haven, Borough of	1,345	0	0.00%
Farmingdale, Borough of	338	10	3.10%
Freehold, Borough of	1,249	2	0.10%
Freehold, Township of	24,673	2,662	10.80%
Hazlet, Township of	3,682	16	0.40%
Highlands, Borough of	463	0	0.00%
Holmdel, Township of	11,419	1,761	15.40%
Howell, Township of	39,425	4,359	11.10%
Interlaken, Borough of	247	0	0.00%
Keansburg, Borough of	748	0	0.00%
Keyport, Borough of	937	0	0.00%
Lake Como, Borough of	158	0	0.00%
Little Silver, Borough of	2,133	9	0.40%
Loch Arbour, Village of	77	0	0.00%
Long Branch, City of	3,408	0	0.00%
Manalapan, Township of	19,777	3,191	16.10%
Manasquan, Borough of	983	0	0.00%
Marlboro, Township of	19,676	1,850	9.40%

Jurisdiction	Total Acres	Agricultural Land (Acres)	Percentage of Total
Matawan, Borough of	1,510	0	0.00%
Middletown, Township of	25,829	982	3.80%
Millstone, Township of	23,910	6,279	26.30%
Monmouth Beach, Borough of	1,243	0	0.00%
Neptune City, Borough of	563	0	0.00%
Neptune, Township of	5,642	21	0.40%
Ocean, Township of	7,023	24	0.30%
Oceanport, Borough of	2,431	12	0.50%
Red Bank, Borough of	1,374	0	0.00%
Roosevelt, Borough of	1,251	323	25.80%
Rumson, Borough of	4,555	15	0.30%
Sea Bright, Borough of	651	0	0.00%
Sea Girt, Borough of	675	0	0.00%
Shrewsbury, Borough of	1,404	12	0.90%
Shrewsbury, Township of	62	0	0.00%
Spring Lake, Borough of	902	0	0.00%
Spring Lake Heights, Borough of	840	0	0.00%
Tinton Falls, Borough of	9,965	249	2.50%
Union Beach, Borough of	1,210	0	0.00%
Upper Freehold, Township of	30,134	16,660	55.30%
Wall, Township of	19,829	1,273	6.40%
West Long Branch, Borough of	1,842	18	1.00%
Monmouth County	308,162	43,378	14.00%

SOURCE: MONMOUTH COUNTY OFFICE OF GLS

The USDA 2017 Census of Agriculture for Monmouth County was used to analyze the exposure of Monmouth County crops to drought. The total market value of agricultural products sold in Monmouth County was $67,389,000 as of the 2017 Census of Agriculture. It was assumed that the exposure of crops was equal to the total value of crops sold ($67,389,000). This represents roughly a 0.3 percent increase since the last version of the plan ($67,185,000).

For the 2009 Plan, to estimate losses due to drought, NCDC historical drought loss data for Monmouth County was used to develop a drought stochastic (probability) model. In this model: losses were obtained for each jurisdiction and scaled for inflation. For all events impacting the entire county (loss data not provided for specific jurisdictions), losses were averaged across all 53 jurisdictions. Average historic drought damageability was used to generate losses for historical drought events where losses were not reported. Expected annualized losses were calculated through a non-linear regression of historical data. Probabilistic losses were scaled to account for would-be losses where no exposure/instrument was present at the time of the event. Using this method based on historical losses and crop market value exposure for Monmouth County, county-wide annualized expected crop losses in the 2009 Plan were estimated at approximately $108,098, with an annualized percent loss ratio of 0.13 percent.

For the plan update, NCDC historical drought loss data was once again queried, this time for records up to September 2018. The data includes over 40 drought days since June 1997. However, the event records estimated $0 in both property and crop damages for these events. This was presumed to be a function of ongoing changes to the NCDC data set, as opposed to true zero-dollar losses, because episode narratives did present descriptions of often significant losses for these same events, but not in a manner that would permit an accurate breakdown of losses by jurisdiction or even by county.

Given the lack of sufficiently detailed historical data on significant drought occurrences for Monmouth County, 2009 estimates were scaled to the present by assuming average annual damages would be the same ratio of losses to total crop value. In 2009, this ratio was 0.00128 ($108,098 average annual countywide losses/$84,280,384 total crop value); in 2019, using this same ratio applied to the 2018 crop value of $67,185,000 yields average annual losses of $85,997. Distributing across the 25 jurisdictions with land in agriculture would represent losses of $3,440 per jurisdiction, on average; though the exact number would vary significantly depending upon the specific type of crops planted and the acres of each crop in that community .Though unquantifiable, while any one event can have significant consequences, it is presumed that average annual crop losses are considered to be negligible (<$5,000) for each jurisdictions with land in agriculture.

4.7 EARTHQUAKE

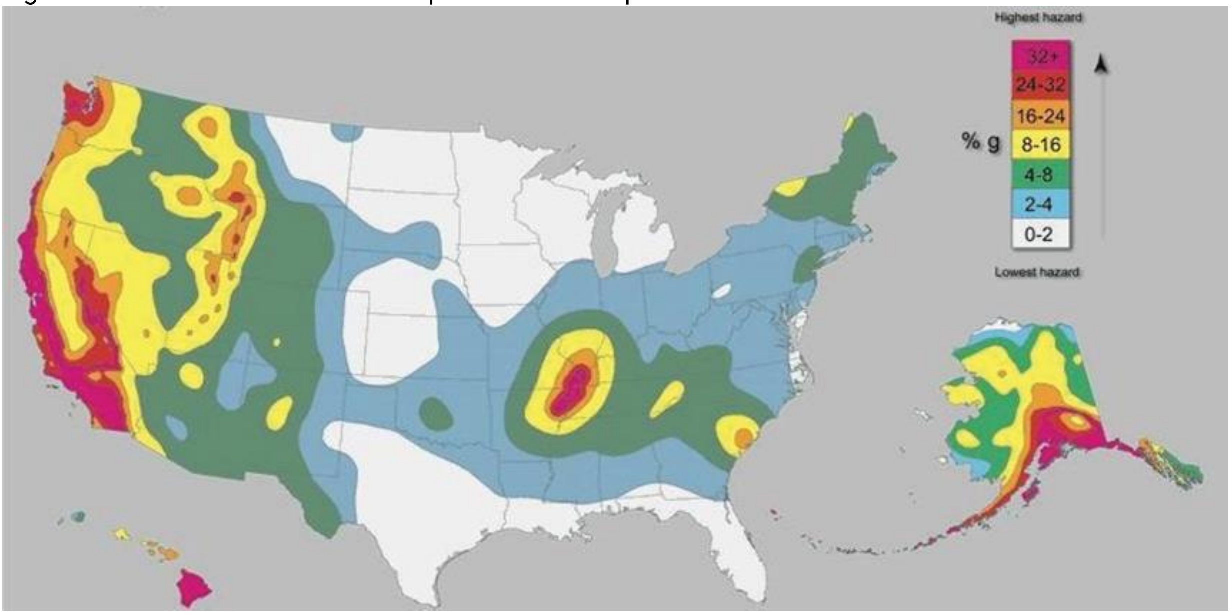
4.7.1 HAZARD DESCRIPTION

A sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the surface. This movement forces the gradual building and accumulation of energy. Eventually, strain becomes so great that the energy is abruptly released, causing the shaking at the earth's surface which we know as an earthquake. Roughly 90 percent of all earthquakes occur at the boundaries where plates meet, although it is possible for earthquakes to occur entirely within plates. Earthquakes can affect hundreds of thousands of square miles; cause damage to property measured in the tens of billions of dollars; result in loss of life and injury to hundreds of thousands of persons; and disrupt the social and economic functioning of the affected area.

4.7.2 LOCATION

The greatest earthquake threat in the United States is along tectonic plate boundaries and seismic fault lines located in the central and western states; however, the East Coast does face moderate risk to less frequent, less intense earthquake events. Figure 4.7-1 United States Earthquake Map shows relative seismic risk for the United States.

Figure 4.7 - 1 United States Earthquake Hazard Map



SOURCE: USGS

Figure 4.7-1 United States Earthquake Map shows the probability that ground motion will reach a certain level during an earthquake in Monmouth County and the surrounding region. The data shows peak horizontal ground acceleration (the fastest measured change in speed for a particle at ground level that is moving horizontally due to an earthquake) with a 10 percent probability of exceedance in 50 years. Monmouth County is located in an area with peak ground acceleration (PGA) values between 4%g and 5%g, which is a relatively low seismic risk but still enough to suggest that Monmouth County is susceptible to moderate, damaging earthquakes over time.

4.7.3 EXTENT

Earthquakes are measured in terms of their magnitude and intensity. Magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude. Each unit increase in magnitude on the Richter Scale corresponds to a 10-fold increase in wave amplitude, or a 32-fold increase in energy. Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale based on direct and indirect measurements of seismic effects. The scale levels are typically described using roman numerals, with a I corresponding to imperceptible (instrumental) events, IV corresponding to moderate (felt by people awake), to XII for catastrophic (total destruction). A detailed description of the Modified Mercalli Intensity Scale of earthquake intensity and its correspondence to the Richter Scale is given in **Table 4.7-1 Magnitude/Intensity Comparison for Earthquakes.**

Table 4.7 - 1 Magnitude/Intensity Comparison for Earthquakes

Magnitude	Typical Maximum Modified Mercalli Intensity	Abbreviated Modified Mercalli Intensity Scale
1.0 - 3.0	I	I. Not felt except by a very few under especially favorable conditions.
3.0 - 3.9	II - III	II. Felt only by a few persons at rest, especially on upper floors of buildings.

Magnitude	Typical Maximum Modified Mercalli Intensity	Abbreviated Modified Mercalli Intensity Scale
		III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0 - 4.9	IV - V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0 - 5.9	VI - VII	VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0 - 6.9	VII - IX	VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	VIII or higher	VII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

SOURCE: US GEOLOGICAL SURVEY (HTTP://EARTHQUAKE.USGS.GOV/LEARN/TOPICS/MAG_VS_INT.PHP, PAGE LAST MODIFIED SEPTEMBER 29, 2014)

4.7.4 PREVIOUS OCCURRENCES AND LOSSES

Earthquakes do occur on a fairly regular basis in New Jersey, though most are of very low magnitude (MMI intensity of less than II) and often not felt by people or capable of causing property damage. According to the New Jersey Geological Survey, there have been 150 recorded earthquakes in New Jersey since 1783, including seven with epicenters located in Monmouth County (as shown in **Figure 4.7-2 Historic Earthquake Epicenters in Monmouth County).** However, New Jersey's susceptibility to earthquakes extends to events located beyond state borders, and some of the most damaging earthquakes were associated with larger, more significant events occurring elsewhere along the East Coast (shown in Table 4.7-2 Earthquake Epicenters in Monmouth County). Most past earthquake damage in New Jersey has been to building contents and architectural damage, such as fallen chimneys, cracked plaster and masonry, and items falling off shelves. Some of the more notable earthquake events for the New Jersey region as well as the most recent are identified in Table 4.7-2 Earthquake Epicenters in Monmouth County.

Figure 4.7 - 2 Historic Earthquake Epicenters in Monmouth County

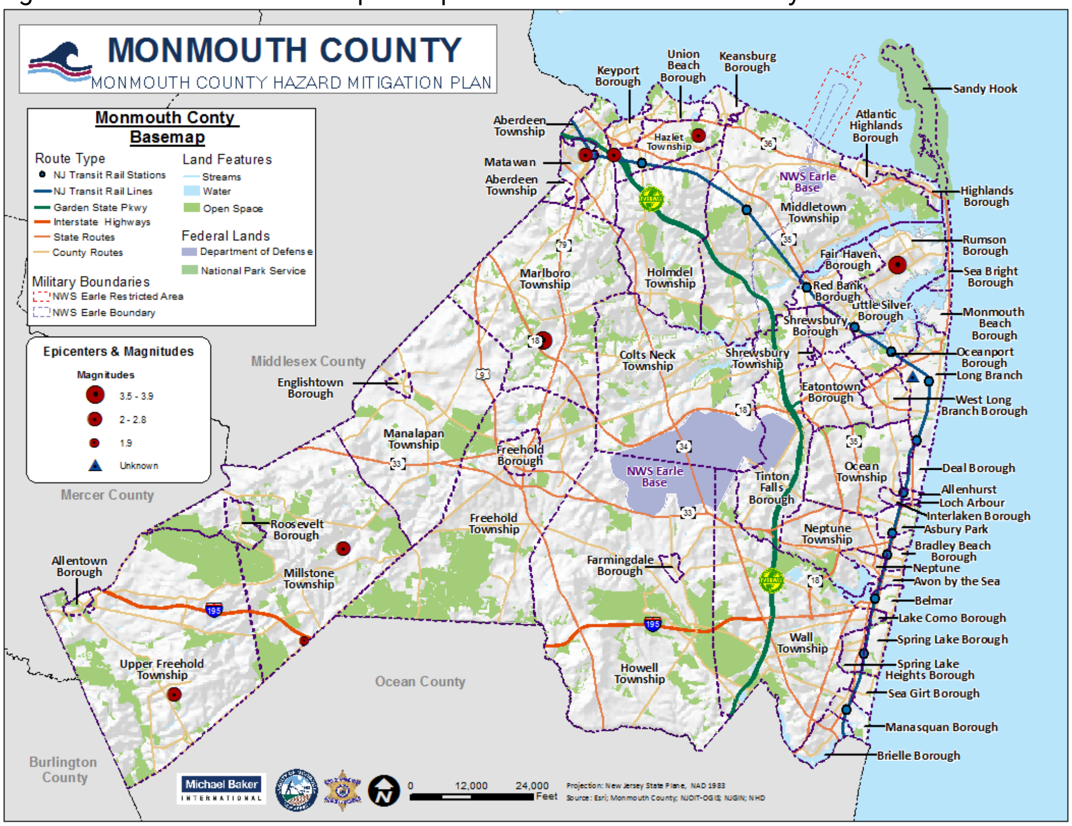


Table 4.7 - 2 Damaging Earthquakes Felt in the New Jersey Region

Date	Location	Richter Magnitude	Description
12/19/1737	Greater NYC Area	5.20	Chimneys down in New York City. Felt from Boston, MA to Philadelphia, PA.
11/30/1783	North-Central New Jersey	5.30	Felt from New Hampshire to Pennsylvania. Two foreshocks (11/24 and 11/30) and one aftershock (11/30); threw down chimneys.
08/10/1884	Greater NYC Area	5.20	Threw down chimneys; felt from Virginia to Maine
09/01/1895	Near High Bridge, NJ	7.70	Felt over a considerable area to the northeast and southwest. The total felt area covered points from Maine to Virginia in a long, narrow elliptical zone of about 92,000 square kilometers. Articles fell from shelves and buildings rocked (intensity VI) in several Hunterdon County towns. The shock was fairly sharp at Camden and Burlington. At Philadelphia, Pennsylvania, broken windows and overturned crockery were reported.
6/1/1927	Near Asbury Park, NJ	3.90	Occurred in the Asbury Park area. Three shocks were felt along the coast from Sandy Hook to Toms River. Maximum intensities of VII were observed at Asbury Park and Long Branch. Several chimneys fell, plaster cracked, and articles were thrown from shelves. The felt area extended over approximately 7,800 square kilometers.
1/25/1933	Near Trenton, NJ	0.00	A sharp jolt was felt over central New Jersey from Lakehurst to Trenton. Although there is some doubt whether the shock was of seismic origin, the event was felt most strongly at Lakehurst, where people reported they were rolled out of bed (intensity V). Other people reported pictures shaken from walls. The shock was also felt at Bordentown, Burlington, Columbus, Englishtown, Freehold, Hightstown, New Egypt, Robbinsville, and White Horse.
8/23/1938	Northeast of New Egypt, NJ	3.80	Caused minor damage at Gloucester City and Hightstown (intensity V). The total felt area was about 13,000 square kilometers, including bordering portions of Delaware and Pennsylvania. Glassware was broken at Gloucester City and Hightstown and some furniture was displaced at Pitman. A few windows and some glassware were reported broken at Ardmore, Pennsylvania. Four smaller shocks occurred on 8/23 and one on 8/26.
11/15/1939	Salem County, NJ	3.40	The disturbance was reportedly felt from Trenton to Baltimore, Maryland, and from Cape May to Philadelphia and its adjoining counties. About 16,000 square kilometers were affected. Small objects were reported to have overturned at Deepwater, but little or no damage was noted.
3/23/1957	Schooley's Mountain, NJ	2.90	A shock affected west-central New Jersey, near the site of the 1895 earthquake. Chimneys cracked (intensity VI), windows and dishes broke, and pictures fell at Lebanon. A cracked chimney was also reported from Hamden. At Long Valley, some walls were cracked, and

Date	Location	Richter Magnitude	Description
			plaster fell. The felt area was small in comparison with the other shocks previously described.
3/10/1979	Bernardsville, NJ (epicenter in Morris County)	3.10	"Cheesequake Earthquake" Felt by some people in Manhattan
10/19/1985	Ardsley, NY	4.00	Many people in the NYC area felt this earthquake.
10/23/1990	Hancock's Bridge, NJ	2.90	Felt in New Jersey, Delaware, and Pennsylvania
2/3/2009	3.5km South-Southwest of Rockaway, NJ	3.00	There were reports of people having felt this earthquake throughout New Jersey.
2/14/2009	5 km North-Northeast of Boonton, NJ	2.40	There were reports of people having felt this earthquake throughout New Jersey.
7/1/2009	2.25km East- Southeast of Pennsville, NJ	2.80	There were reports of people having felt this earthquake throughout New Jersey.
2/21/2010	Gladstone, NJ	2.60	This earthquake hit just before 9 a.m. and prompted numerous phone calls to police. No damages were reported. Many people in New Jersey reported having felt this earthquake. A 2.3 occurrence later in the day was also reported as having been felt by numerous people in New Jersey, and was most likely an aftershock.
6/6/2010	6 km Southeast of Sayreville, NJ	2.30	People reported having felt this earthquake throughout New Jersey.
8/23/2011	Central Virginia	5.80	A moderate earthquake occurred in central Virginia and was felt throughout most of the east, from Georgia to southern Canada and from Indiana to coastal Maine. It was followed by four aftershocks. In New Jersey, the intensity ranged from one to four (weak to light). Areas underlain by thick silt and clay felt a stronger ground motion than did those where rock was very close to the surface. The quake was felt in South Brunswick and residents were calling 911 wanting to know what happened; some thought it was an explosion. It was also felt in the offices of Alcatel-Lucent in Murray Hill (Union County). Ceiling tiles fell out at a Sears store in Middletown. In Plainfield (Union County), employees in the Park Madison building were evacuated after the tremor. Union County's administration building in Elizabeth reported continuous shaking. In New Brunswick (Middlesex County), employees were evacuated from the County administration building. Atlantic City (Atlantic County) went into emergency mode with evacuations of high rises, hospitals, schools, casinos, and hotels. The County OEM received reports of a crack in a wall in a house and broken water pipe in a building. There were minor scattered power outages reported throughout the state.
11/5/2012	3 km Southwest of Mahwah, NJ	2.00	People reported having felt this earthquake in various parts of New Jersey.
11/23/2012	Greater Philadelphia Area/New Jersey	2.20	Numerous reports of people having felt the earthquake in southwestern New Jersey.
6/23/2013	2.7 km SW of Morris Plains, NJ	1.00	No reference and/or no damage reported.

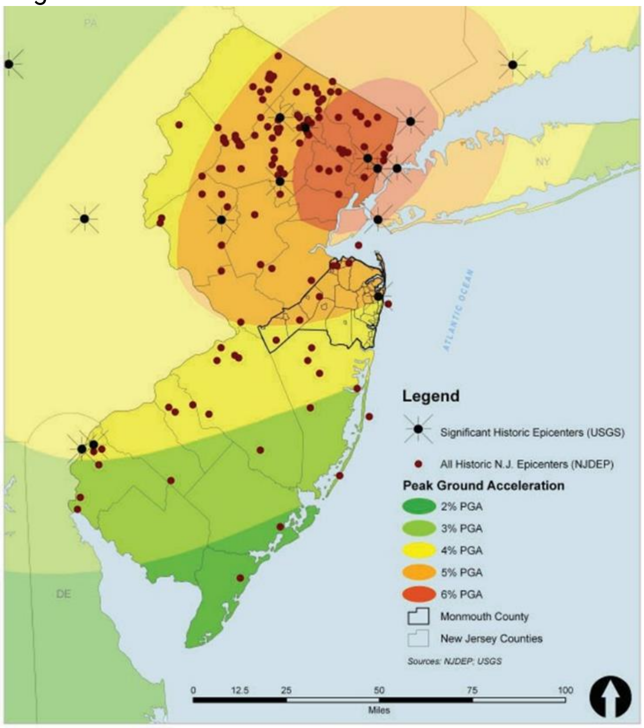
Date	Location	Richter Magnitude	Description
5/31/2014	3.7 km SW of Morris Plains, NJ	1.70	No reference and/or no damage reported.
6/19/2014	1.4 km S of Morris Plains, NJ	1.30	No reference and/or no damage reported.
7/8/2014	2.6 km W of Bellmawr, NJ	1.50	No reference and/or no damage reported.
7/18/2014	16.3 km E of Highlands, NJ	2.00	No reference and/or no damage reported.
9/3/2014	5 km NE of Wanaque, NJ	0.60	No reference and/or no damage reported.
12/13/2014	2 km N of Wanaque, NJ	1.00	No reference and/or no damage reported.
12/28/2014	1 km N of Butler, NJ	0.50	No reference and/or no damage reported.
3/27/2015	2.2 km SW of Clifton, NJ	0.80	No reference and/or no damage reported.
7/12/2015	1 km NW of Butler, NJ	1.10	No reference and/or no damage reported.
8/14/2015	4.4 km N of Butler, NJ	0.80	No reference and/or no damage reported.
8/22/2015	1.1 km NW of Butler, NJ	1.10	No reference and/or no damage reported.
1/2/2016	2.4 km NW of Ringwood, NJ	2.10	No reference and/or no damage reported.
2/19/2016	5 km WNW of Fairfield, NJ	1.40	No reference and/or no damage reported.
5/27/2016	3.5 km N of Bernardsville, NJ	2.70	No reference and/or no damage reported.
7/4/2016	2 km N of Wanaque, NJ	1.20	No reference and/or no damage reported.
7/31/2016	2 km SW of Clifton, NJ	1.20	No reference and/or no damage reported.
8/9/2016	2 km SW of Clifton, NJ	1.50	No reference and/or no damage reported.
8/9/2016	13 km SE of Twin Rivers, NJ	1.90	No reference and/or no damage reported.
9/20/2016	2 km S of Park Ridge, NJ	1.30	No reference and/or no damage reported.
11/6/2016	4 km SW of Ringwood, NJ	1.20	No reference and/or no damage reported.
11/6/2016	3 km W of Jersey City, NJ	1.60	No reference and/or no damage reported.
3/25/2017	13 km SW of Ramblewood, NJ	1.00	No reference and/or no damage reported.
9/25/2017	6 km N of Boonton, NJ	1.90	No reference and/or no damage reported.
9/30/2017	1 km E of Rockaway, NJ	2.10	No reference and/or no damage reported.
11/8/2017	3.5 km NW of Keansburg, NJ	1.40	Sandy Hook Bay

SOURCE: 2019 STATE HMP

4.7.5 PROBABILITY OF FUTURE OCCURRENCE

The probability of significant, damaging earthquake events affecting Monmouth County is low. According to the United States Geological Survey (USGS), an earthquake with a 10 percent probability of exceedance over 50 years would have PGA values between 4%g and 5%g, which would result in light to moderate perceived shaking and damages ranging from none to very light. More destructive earthquakes are very rare, low probability events for Monmouth County with highly infrequent recurrence periods.

Figure 4.7 - 3 Peak Ground Acceleration with a 10% Probability of Exceedance over 50 years



4.7.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

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. The potential impacts of global climate change on earthquake probability are unknown. Some scientists feel that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the Earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes.

Secondary impacts of earthquakes could be magnified by future climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity because of the increased saturation. Dams storing increased volumes of water from changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

4.7.7 VULNERABILITY ASSESSMENT

Impacts

Most earthquake-related property damage and deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the extent and duration of the shaking. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (in mountain regions and along hillsides), and liquefaction.

Exposure and Damage Estimates

Because earthquakes often impact large areas and cross jurisdictional boundaries, all existing and future buildings, facilities and populations are considered to be exposed to this hazard and could potentially be impacted.

To assess the vulnerability of Monmouth County to earthquakes, probabilistic scenarios of various potential events were created using HAZUS-MH. HAZUS-MH default ground shaking data, inventory and damage functions, and methodology was used to determine the potential estimated losses for 100-, 500-, 1000-, and 2500-year frequency events and annual expected loss at the census tract level, as well as exceeding probability curves. Table 4.7 - 3 Peak Ground Acceleration (Ground Motion) for 100- and 500-Year Earthquake Events lists the expected peak ground acceleration (PGA) for 100- and 500-year earthquake events by jurisdiction.

Table 4.7 - 3 Peak Ground Acceleration (Ground Motion) for 100- and 500-Year Earthquake Events

Jurisdiction	100-year PGA	500-year PGA
Aberdeen, Township of	0.0084	0.0443
Allenhurst, Borough of	0.0084	0.0408
Allentown, Borough of	0.0084	0.0414
Asbury Park, City of	0.0084	0.0402
Atlantic Highlands, Borough of	0.0084	0.0441
Avon-By-The-Sea, Borough of	0.0084	0.0396
Belmar, Borough of	0.0084	0.0390
Bradley Beach, Borough of	0.0084	0.0396
Brielle, Borough of	0.0078	0.0378
Colts Neck, Township of	0.0084	0.0427
Deal, Borough of	0.0084	0.0408
Eatontown, Borough of	0.0084	0.0419
Englishtown, Borough of	0.0084	0.0426
Fair Haven, Borough of	0.0084	0.0432
Farmingdale, Borough of	0.0084	0.0408
Freehold, Borough of	0.0084	0.0422
Freehold, Township of	0.0084	0.0423
Hazlet, Township of	0.0084	0.0449
Highlands, Borough of	0.0084	0.0440
Holmdel, Township of	0.0084	0.0442
Howell, Township of	0.0084	0.0405
Interlaken, Borough of	0.0084	0.0408
Keansburg, Borough of	0.0084	0.0456
Keyport, Borough of	0.0084	0.0447
Lake Como, Borough of	0.0084	0.0387
Little Silver, Borough of	0.0084	0.0432
Loch Arbour, Village of	0.0084	0.0408
Long Branch, City of	0.0084	0.0418

Jurisdiction	100-year PGA	500-year PGA
Manalapan, Township of	0.0084	0.0426
Manasquan, Borough of	0.0078	0.0378
Marlboro, Township of	0.0084	0.0435
Matawan, Borough of	0.0084	0.0444
Middletown, Township of	0.0084	0.0440
Millstone, Township of	0.0084	0.0415
Monmouth Beach, Borough of	0.0084	0.0428
Neptune City, Borough of	0.0084	0.0396
Neptune, Township of	0.0084	0.0397
Ocean, Township of	0.0084	0.0407
Oceanport, Borough of	0.0084	0.0422
Red Bank, Borough of	0.0084	0.0431
Roosevelt, Borough of	0.0084	0.0416
Rumson, Borough of	0.0084	0.0432
Sea Bright, Borough of	0.0084	0.0432
Sea Girt, Borough of	0.0082	0.0382
Shrewsbury, Borough of	0.0084	0.0425
Shrewsbury, Township of	0.0084	0.0420
Spring Lake, Borough of	0.0084	0.0386
Spring Lake Heights, Borough of	0.0084	0.0384
Tinton Falls, Borough of	0.0084	0.0416
Union Beach, Borough of	0.0084	0.0453
Upper Freehold, Township of	0.0084	0.0417
Wall, Township of	0.0082	0.0393
West Long Branch, Borough of	0.0084	0.0416

SOURCE: HAZUS-MH

Earthquakes with higher levels of PGA cause more damage but have a low probability of occurrence. Conversely, earthquakes with low PGA levels such as those which could potentially impact Monmouth County, have a higher probability of occurrence but would only cause negligible to minor damage due to light shaking. In comparison to PGA levels above 0.25g which can cause strong to violent shaking and major damage, expected PGA levels for Monmouth County will likely only cause negligible to light shaking and negligible to minor damage. Estimated losses for a 100-year earthquake event in Monmouth County are considered to be negligible. **Table 4.7 - 4 Estimated Potential Losses From 500, 1000-, and 2500-year Earthquake Events** shows estimated potential losses for 500-, 1000-, and 2500-year events as estimated using HAZUS-MH.

Table 4.7 - 4 Estimated Potential Losses From 500-, 1000-, and 2500-year Earthquake Events

Jurisdiction	Total Assessed Value of Improvements (2018 Values)	Potential Total Building Losses		
		500-Year Event	1000-Year Event	2500-Year Event
Aberdeen, Township of	$1,074,509,800	$145,702	$554,251	$2,219,463
Allenhurst, Borough of	$217,949,000	$15,300	$61,673	$240,255
Allentown, Borough of	$127,734,200	$14,541	$57,598	$215,917

Jurisdiction	Total Assessed Value of Improvements (2018 Values)	Potential Total Building Losses		
		500-Year Event	1000-Year Event	2500-Year Event
Asbury Park, City of	$1,267,473,400	$99,049	$382,977	$1,489,772
Atlantic Highlands, Borough of	$364,693,600	$29,839	$112,177	$451,322
Avon-By-The-Sea, Borough of	$266,879,900	$35,162	$139,381	$547,865
Belmar, Borough of	$553,347,900	$46,772	$185,904	$726,386
Bradley Beach, Borough of	$462,112,100	$45,693	$180,337	$703,055
Brielle, Borough of	$669,338,900	$45,558	$171,132	$721,801
Colts Neck, Township of	$927,454,500	$206,131	$799,310	$3,119,044
Deal, Borough of	$822,100,400	$48,889	$199,607	$765,911
Eatontown, Borough of	$1,314,725,700	$145,071	$541,382	$2,137,386
Englishtown, Borough of	$158,314,100	$14,000	$52,905	$207,824
Fair Haven, Borough of	$785,619,700	$65,975	$264,710	$1,029,722
Farmingdale, Borough of	$109,883,900	$13,507	$53,238	$213,692
Freehold, Borough of	$771,202,500	$95,057	$363,043	$1,416,529
Freehold, Township of	$4,433,974,800	$506,748	$1,994,078	$7,729,864
Hazlet, Township of	$1,215,098,000	$188,270	$703,630	$2,859,162
Highlands, Borough of	$342,874,400	$31,168	$119,059	$470,753
Holmdel, Township of	$2,104,382,100	$293,341	$1,087,287	$4,438,487
Howell, Township of	$4,204,216,400	$410,949	$1,633,774	$6,453,109
Interlaken, Borough of	$125,000,500	$7,686	$31,700	$121,192
Keansburg, Borough of	$343,826,000	$56,689	$209,243	$852,219
Keyport, Borough of	$434,885,600	$65,573	$242,252	$978,713
Lake Como, Borough of	$140,566,300	$13,713	$53,245	$219,521
Little Silver, Borough of	$873,512,700	$93,787	$371,362	$1,467,610
Loch Arbour, Village of	$69,262,800	$6,475	$25,993	$101,016
Long Branch, City of	$2,478,681,000	$300,104	$1,173,700	$4,477,453
Manalapan, Township of	$4,619,949,900	$506,010	$1,995,211	$7,736,671
Manasquan, Borough of	$799,826,975	$70,607	$263,824	$1,112,968
Marlboro, Township of	$4,435,729,800	$569,182	$2,221,700	$8,695,621
Matawan, Borough of	$517,395,800	$73,585	$275,161	$1,107,426
Middletown, Township of	$5,895,810,731	$754,468	$2,886,614	$11,595,502
Millstone, Township of	$1,232,191,160	$120,621	$474,485	$1,816,839
Monmouth Beach, Borough of	$501,592,200	$56,789	$219,803	$852,612
Neptune City, Borough of	$305,279,900	$28,661	$114,605	$451,771
Neptune, Township of	$2,431,214,700	$174,810	$696,709	$2,743,219
Ocean, Township of	$2,684,842,000	$253,909	$1,006,121	$3,879,220
Oceanport, Borough of	$562,875,800	$50,299	$200,184	$771,248
Red Bank, Borough of	$1,194,733,400	$180,882	$681,906	$2,732,305
Roosevelt, Borough of	$50,136,700	$2,363	$9,408	$35,909
Rumson, Borough of	$1,600,650,400	$191,344	$750,342	$2,919,729
Sea Bright, Borough of	$235,586,800	$30,545	$116,866	$458,524
Sea Girt, Borough of	$732,097,100	$42,930	$167,468	$694,073
Shrewsbury, Borough of	$608,635,700	$60,219	$232,768	$942,075
Shrewsbury, Township of	$30,450,000	$1,280	$4,861	$18,292
Spring Lake, Borough of	$1,028,817,800	$99,426	$386,353	$1,603,950
Spring Lake Heights, Borough of	$525,407,200	$41,772	$161,219	$663,718
Tinton Falls, Borough of	$1,691,986,800	$178,442	$705,864	$2,733,580

Jurisdiction	Total Assessed Value of Improvements (2018 Values)	Potential Total Building Losses		
		500-Year Event	1000-Year Event	2500-Year Event
Union Beach, Borough of	$387,844,700	$41,785	$156,910	$644,080
Upper Freehold, Township of	$851,779,300	$108,502	$433,180	$1,761,797
Wall, Township of	$3,053,292,400	$288,015	$1,104,844	$4,525,289
West Long Branch, Borough of	$889,026,200	$76,347	$301,003	$1,159,864
Monmouth County	$63,526,773,666	$7,043,540	$27,332,356	$108,031,327

SOURCE: HAZUS-MH

Table 4.7 - 5 Potential Annualized Losses from Earthquake by Jurisdiction shows potential annualized property losses and percent loss ratios resulting from earthquake for each jurisdiction in Monmouth County.

Table 4.7 - 5 Potential Annualized Losses from Earthquake by Jurisdiction

Jurisdiction	Estimated Population At Risk	Total Assessed Value of Improvements (2018 Values)	Total Annualized Expected Property Losses	Annualized Percent Loss Ratio
Aberdeen, Township of	18,372	$1,074,509,800	$2,244	0.00%
Allenhurst, Borough of	506	$217,949,000	$249	0.00%
Allentown, Borough of	1,890	$127,734,200	$223	0.00%
Asbury Park, City of	15,830	$1,267,473,400	$1,591	0.00%
Atlantic Highlands, Borough of	4,322	$364,693,600	$465	0.00%
Avon-By-The-Sea, Borough of	1,814	$266,879,900	$562	0.00%
Belmar, Borough of	5,719	$553,347,900	$752	0.00%
Bradley Beach, Borough of	4,262	$462,112,100	$724	0.00%
Brielle, Borough of	4,738	$669,338,900	$689	0.00%
Colts Neck, Township of	10,018	$927,454,500	$3,279	0.00%
Deal, Borough of	579	$822,100,400	$778	0.00%
Eatontown, Borough of	12,258	$1,314,725,700	$2,377	0.00%
Englishtown, Borough of	2,131	$158,314,100	$226	0.00%
Fair Haven, Borough of	6,015	$785,619,700	$1,052	0.00%
Farmingdale, Borough of	1,470	$109,883,900	$231	0.00%
Freehold, Borough of	11,938	$771,202,500	$1,548	0.00%
Freehold, Township of	35,429	$4,433,974,800	$8,242	0.00%
Hazlet, Township of	20,082	$1,215,098,000	$2,935	0.00%
Highlands, Borough of	4,880	$342,874,400	$489	0.00%
Holmdel, Township of	16,648	$2,104,382,100	$4,583	0.00%
Howell, Township of	52,076	$4,204,216,400	$6,738	0.00%
Interlaken, Borough of	825	$125,000,500	$122	0.00%
Keansburg, Borough of	9,868	$343,826,000	$874	0.00%
Keyport, Borough of	7,138	$434,885,600	$1,033	0.00%
Lake Como, Borough of	1,518	$140,566,300	$217	0.00%
Little Silver, Borough of	5,917	$873,512,700	$1,538	0.00%
Loch Arbour, Village of	195	$69,262,800	$105	0.00%
Long Branch, City of	30,751	$2,478,681,000	$4,819	0.00%

Jurisdiction	Estimated Population At Risk	Total Assessed Value of Improvements (2018 Values)	Total Annualized Expected Property Losses	Annualized Percent Loss Ratio
Manalapan, Township of	40,096	$4,619,949,900	$8,070	0.00%
Manasquan, Borough of	5,824	$799,826,975	$1,070	0.00%
Marlboro, Township of	40,466	$4,435,729,800	$8,927	0.00%
Matawan, Borough of	8,898	$517,395,800	$1,148	0.00%
Middletown, Township of	65,952	$5,895,810,731	$11,766	0.00%
Millstone, Township of	10,522	$1,232,191,160	$1,917	0.00%
Monmouth Beach, Borough of	3,247	$501,592,200	$889	0.00%
Neptune City, Borough of	27,728	$305,279,900	$476	0.00%
Neptune, Township of	4,749	$2,431,214,700	$2,865	0.00%
Ocean, Township of	27,006	$2,684,842,000	$4,122	0.00%
Oceanport, Borough of	5,762	$562,875,800	$819	0.00%
Red Bank, Borough of	12,220	$1,194,733,400	$3,005	0.00%
Roosevelt, Borough of	808	$50,136,700	$37	0.00%
Rumson, Borough of	6,874	$1,600,650,400	$3,003	0.00%
Sea Bright, Borough of	1,304	$235,586,800	$488	0.00%
Sea Girt, Borough of	1,714	$732,097,100	$688	0.00%
Shrewsbury, Borough of	4,051	$608,635,700	$1,029	0.00%
Shrewsbury, Township of	1,117	$30,450,000	$19	0.00%
Spring Lake, Borough of	2,980	$1,028,817,800	$1,603	0.00%
Spring Lake Heights, Borough of	4,645	$525,407,200	$666	0.00%
Tinton Falls, Borough of	17,902	$1,691,986,800	$2,900	0.00%
Union Beach, Borough of	5,634	$387,844,700	$651	0.00%
Upper Freehold, Township of	6,899	$851,779,300	$1,903	0.00%
Wall, Township of	26,020	$3,053,292,400	$4,758	0.00%
West Long Branch, Borough of	7,944	$889,026,200	$1,251	0.00%
Monmouth County	627,551	$63,526,773,666	$112,754	0.00%

SOURCE: HAZUS-MH

4.8 LANDSLIDE

4.8.1 HAZARD DESCRIPTION

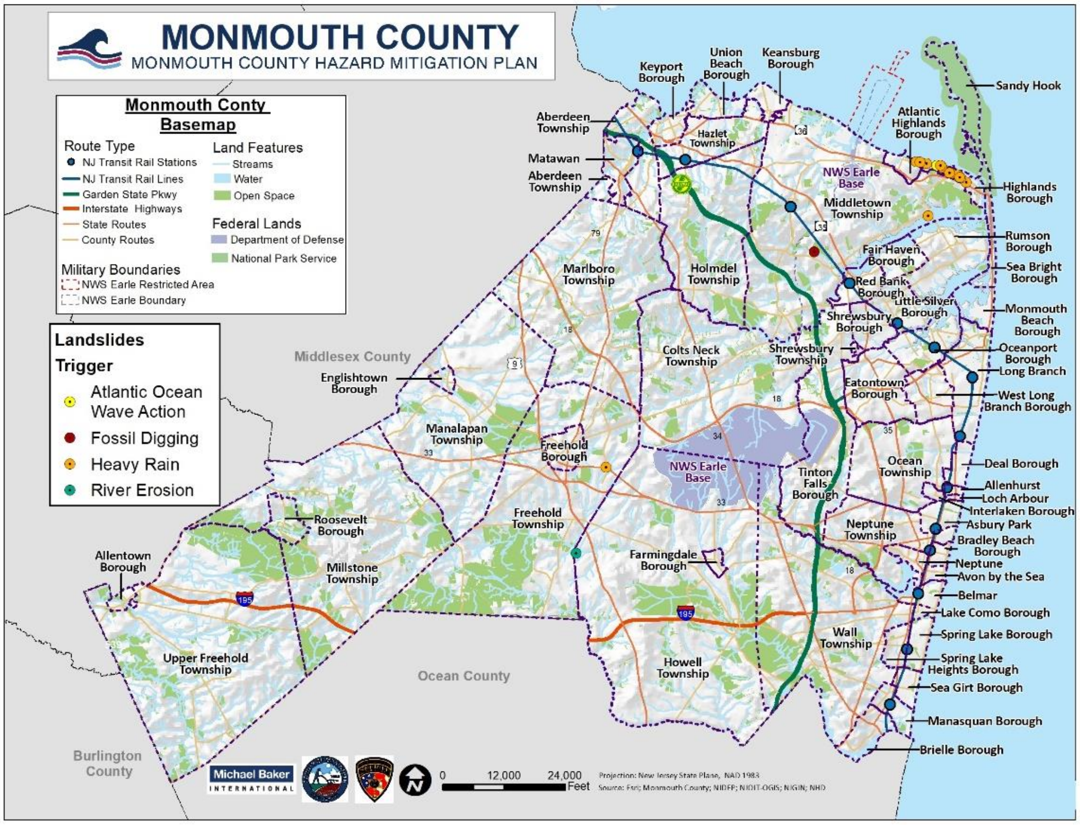
Landslide is defined as the movement of a mass of rock, debris, or earth down a slope when the force of gravity pulling down the slope exceeds the strength of the earth materials that comprise to hold it in place. Slopes greater than 10 degrees are more likely to slide, as are slopes where the height from the top of the slope to its toe is greater than 40 feet. Slopes are also more likely to fail if vegetation cover is low and/or soil water content is high.

4.8.2 LOCATION

Landslide incidence data from the New Jersey Geological and Water Survey (NJGWS), published in 2019, depicts a concentration of previous landslide occurrences in the boroughs of Atlantic Highlands and Highlands. These events were all triggered by heavy rainfall. The four other landslide events outside of these boroughs occurred in Middletown Township, Freehold Township, and Howell Township

(NJGWS 2019). The United States Geological Survey (USGS) maintains a U.S. Landslide Inventory as a part of its USGS Landslide Hazard Program. The inventory is based on the NJGWS data from 2018, so incidents depicted in the NJGWS data match that in the USGS inventory except for one additional event in Middletown Township (USGS 2019). Historic landslide occurrences as recorded by the NJGWS are depicted in Figure 4.8 – 1 Previous Occurrences of Landslides in Monmouth County and their Triggers.

Figure 4.8 - 1 Previous Occurrences of Landslides in Monmouth County and their Triggers



The 2009 NJGWS classified the landslide susceptibility of Monmouth County based on slope angle, geologic material on a slope, and groundwater level as a part of the Earthquake Loss Estimation Study for Monmouth County, New Jersey: Geologic Component. Landslide susceptibility classifications correspond to those from the HAZUS User's Manual, Table 9.2 (National Institute of Building Sciences, 1997). While this data depicts varying levels of landslide susceptibility throughout the County, highly susceptible soils (Landslide Classes CVII-CX) are concentrated in northeastern Monmouth County (Atlantic Highlands Borough, Highlands Borough, and Middletown Township), Howell Township, and Upper Freehold Township. An analysis of Monmouth County's landslide susceptibility by census tract also from this study illustrates Extremely High (HAZUS Class 10) landslide susceptibility in Atlantic Highlands and Highlands Borough.

Mapping of landslide susceptibility from the USGS used in the 2015 HMP identified the extreme northeast portion of Monmouth County as highly susceptible to landslides. NJGWS mapping from the 2015 HMP also identified the following communities as areas of high landslide susceptibility: Atlantic

Highlands Borough, Fair Haven Borough, Highlands Borough, Little Silver Borough, Middletown Township, Oceanport Borough, and Rumson Borough. Additionally, the previous plan update also noted Freehold Township, Howell Township, and Tinton Falls as communities with historical occurrences of landslides.

For the purposes of this 2020 plan update, the County integrated the analysis conducted in the 2015 plan update with the 2009 NJGWS landslide susceptibility data for Monmouth County and added the eleventh municipality, Upper Freehold Township, to the list of municipalities that may be highly susceptible to landslides. The 11 municipalities now include Fair Haven Borough, Middletown Township, Little Silver Borough, Oceanport Borough, Rumson Borough, Freehold Township, Howell Township, Upper Freehold Township, Atlantic Highlands Borough, Highlands Borough, and Tinton Falls Borough. As part of this plan update, each of the 11 municipalities have a mitigation action to mitigate against landslides. Additional municipalities may also have some areas susceptible to landslides. For a complete inventory of the land area susceptible to landslides in Monmouth County, please refer to Table 4.8-2 Total Land Located in Landslide Areas (NJGWS).

4.8.3 EXTENT

Areas that are generally prone to landslide hazards include previous landslide areas, the bases of steep slopes, the bases of drainage channels and developed hillsides where leach-field septic systems are used. Slopes greater than 10 degrees are more likely to slide, as are slopes where the height from the top of the slope to its toe is greater than 40 feet. Slopes are also more likely to fail if vegetative cover is low and/or soil water content is high. Landslides occur when the slope or soil stability changes from stable to unstable, which may be caused by earthquakes, storms, volcanic eruptions, erosion, fire, or additional human-induced activities. Although in New Jersey landslides are not as common as in other areas of the United States, they are a geologic hazard in areas with steep to moderate slopes or geologic units prone to failure. According to the NJOEM, the largest landslide events in New Jersey occur in the form of slumping along the coastal bluffs of the Navesink Highlands area of Monmouth County (including the Boroughs of Atlantic Highlands and Highlands and Township of Middletown). While originally attributed to coastal erosion, slumping has reportedly begun anew in the last 30 years likely due to development at the bottom of slopes, an unusually high water table and changes in vegetative patterns.

4.8.4 PREVIOUS OCCURRENCES AND LOSSES

According to NJGWS, 20 historical landslide events have occurred in Monmouth County, as listed in Table 4.8-1 Previous Landslide Occurrences in Monmouth County, 1782-2017. These events caused minor property damages and three injuries.

Table 4.8 - 1 Historical Landslide Events in Monmouth County, 1782-2017

Event Date	Location	Type	Damage	Deaths	Injuries	Description
Unknown	Atlantic Highlands	Slump	No	0	0	Historic slump area, older landslide, probably hundreds of years old, estimated location.

Event Date	Location	Type	Damage	Deaths	Injuries	Description
April 1782	Highlands	Slump	No	0	0	1782 landslide from newspaper account possibly triggered by undercutting wave action, small landslide in 1972.
October 1903	Highlands	Debris flow	Yes	0	0	Big landslide reported at Waterwitch, just below the long pier, shut down the Central Railroad of NJ, estimated location.
1972	Highlands	Debris flow	No	0	0	Small landslide in 1972. No further details available.
November 1977	Highlands	Slump	No	0	0	Landslide after heavy rain.
January 1999	Highlands	Debris flow	Yes	0	2	Landslide, possibly due to fill material failure after heavy rain, one condominium unit destroyed, three others damaged.
September 1999	Middletown	Debris flow	No	0	1	A man digging for fossils in a 45-foot embankment along Big Brook was buried alive and seriously injured. Estimated location
August 2002	Middletown	Slump	No	0	0	Recent small slump in slump block possibly hundreds of years old on Navesink River bluff.
2003	Howell	Slump	Yes	0	0	Riverbank slumping on 26-foot high bank due to undercutting from the Manasquan River along 200 feet of Bergerville Road. Some road damage.
October 2005	Freehold Township	Debris flow	Yes	0	0	Landslide partially blocked road after heavy rain during road construction.
October 2005	Atlantic Highlands	Slump	Yes	0	0	Small backyard slump caused by water saturation after heavy rain, some property damage, estimated location.
April 2007	Highlands	Slump	Yes	0	0	Landslide on the bluff between Linden Avenue and Shore Drive, west of Waterwitch Drive in the Atlantic Highlands.
April 2010	Highlands	Debris flow	Yes	0	0	Triggered by nor'easter of March 31- April 1. Located on bluff between Linden Avenue and Shore Drive west of Waterwitch Drive. 50 feet wide 170 feet long. Deck and house threatened.
April 2010	Atlantic Highlands	Debris flow	Yes	0	0	Exact date unknown, first noticed in early April after back-to-back nor'easters of March/April.
April 2010	Atlantic Highlands	Debris flow	Yes	0	0	Exact date unknown, first noticed in early April after back-to-back nor'easters of March/April.
April 2010	Atlantic Highlands	Slump	No	0	0	Reactivation of old slump block.

Event Date	Location	Type	Damage	Deaths	Injuries	Description
August 2011	Highlands	Debris flow	Yes	0	0	Large landslide above condo complex triggered by heavy rain from Tropical Storm Irene damages condo complex.
August 2011	Highlands	Debris flow	Yes	0	0	Large landslide above condo complex triggered by heavy rain from Tropical Storm Irene damages condo complex. Reactivation of prior landslide.
April 2014	Atlantic Highlands	Slump	Yes	0	0	A landslide at 160 Ocean Boulevard in Atlantic Highlands on April 30-May 1, 2014 during heavy rains that supposedly "sent hundreds of thousands of cubic yards of dirt, sand, and rock" onto the Henry Hudson Trail at the base of the slope.
April 2017	Atlantic Highlands	Slump	Yes	0	0	Slump below a house along steep slope on Sandy Hook Bay.

SOURCE: NEW JERSEY GEOLOGICAL AND WATER SURVEY, 2019

Other notable reports of historical landslide events include the following, as identified by the Planning Committee:

- The Borough of Atlantic Highlands and surrounding municipalities have been dealing with the fundamental problem of geologic instability, slope fragility and slumping for years. The problem in this high elevation area of Monmouth County has been so clearly established that it has a specific geological name: slump blocking. Slump blocking is characterized as an entire block of land slips downward, and there are numerous reports of large slump block occurrences in the area's recent geologic past, including those listed above. Specifically Mount Mitchill is an area of concern, but the extent of landslide risk has been described as the entire bluff along the south side of Sandy Hook Bay for a distance of four miles from Atlantic Highlands Yacht Harbor to the mouth of the Navesink River.

- The Borough of Highlands indicated that much of its hillside areas have suffered major erosion and smaller landslides are a common occurrence after most storms, occasionally causing property damage and frequently blocking roadways. Specifically, Bayside Drive (main road connecting Highlands to Atlantic Highlands) has been closed more often than not during the past 10 years (before the previous plan update) due to erosion of the hillside and regular landslide activity.

- The Borough of Tinton Falls has an ongoing issue with areas of slumping along Water Street due to undercutting from the adjacent Pine Brook during periods of high flood flows along the Pine Brook. Most recently, in 2011, high floodwaters during Hurricane Irene caused Water Street's embankment to be undermined, causing slope failures and significant roadway damage in three areas. Photos of the damage and some of the repair work are shown immediately below.

Road closures and detours were required as both temporary and permanent repairs were made over the following months. Local officials note similar issues along Jumping Brook.

4.8.5 PROBABILITY OF FUTURE OCCURRENCE

According to the 2019 State HMP, data to estimate the probability of future occurrences of landslides is not available at the time of this plan update, however the frequency of hazards such as earthquakes, heavy rain, floods, or wildfire events, are known to trigger landslides and can be used as an indicator of future landslide events. Of these hazards, frequent heavy rain events are most likely to precipitate landslides because ground saturation before a significant storm is a necessary prerequisite for a major landslide event.

Based on past occurrences described in Table 4.8 - 1 Historical Landslide Events in Monmouth County, 1782-2017 and depicted alongside landslide susceptibility in Figure 4.8-1 Previous Occurrences of Landslides in Monmouth County and their Triggers, it is likely that future landslide events (primarily slumps and slump blocking) may occur in the northeast portion of Monmouth County, including the municipalities of Atlantic Highlands Borough, Highlands Borough, and Middletown Township. In addition to climate change, future development may also impact the frequency of landslide events (NJ State HMP).

4.8.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

According to the 2019 State HMP, landslide frequency may be influenced by the frequency of other natural hazards also influenced by climate change. Climate change may increase the frequency and severity of precipitation events and thus landslide events as well. Warming temperature may also cause drought and wildfire events that burn stabilizing vegetation along steep slopes.

4.8.7 VULNERABILITY ASSESSMENT

Impacts

The speed of a landslide event can vary from a change in inches per year to feet per second based on topographic conditions. An analysis of climate and geologic conditions landslide monitoring methods may help to determine the location, type of movement, and movement speed before a landslide event occurs. That said, "there is no practical warning system for individual landslides" (2019 State HMP). For more information on severity and warning time, please refer to the State HMP.

According to the State of New Jersey 2019 HMP, secondary effects of landslides include the disruption of traffic, power failure, communication failure, and the destabilization of building foundations. Landslide events disrupt and damage ecosystems, by destroying terrestrial and riverine habitats, changing topography, and causing soil and sediment runoff. An estimated 2,516 people (0.3%) in Monmouth County are located in NJGWS-Defined Landslide Susceptible Areas.

Exposure and Damage Estimate

As previously mentioned, the NJGWS determined landslide susceptibility for Monmouth County in 2009 as a part of the Earthquake Loss Estimation Study for Monmouth County, New Jersey: Geologic Component. The total land area located in landslide hazard areas was calculated for each municipality, as presented in Table 4.7-2 Total Land Located in Landslide Areas (NJGWS) below. Based upon the analysis using NJGWS data, Upper Freehold Township (approximately 603 acres) has the greatest area delineated with landslide susceptible soils, while Highlands Borough (10.7%) and Atlantic Highlands Borough (9.6%) have the greatest percent of their land area delineated with landslide susceptible soils.

Table 4.8 - 2 Total Land Located in Landslide Areas (NJGWS)

Jurisdiction	Total Land Area of Municipality (Acres)	Total Land Area in NJGWS-Defined Landslide Susceptibility Area (Acres)	Percent of Total Land Area in NJGWS-Defined Landslide Susceptibility Area (Acres)
Aberdeen, Township of	3,615.25	92.16	2.5%
Allenhurst, Borough of	166.78	0.00	0.0%
Allentown, Borough of	396.12	5.38	1.4%
Asbury Park, City of	975.75	0.00	0.0%
Atlantic Highlands, Borough of	791.22	76.09	9.6%
Avon-By-The-Sea, Borough of	318.09	0.00	0.0%
Belmar, Borough of	951.2	0.00	0.0%
Bradley Beach, Borough of	413.35	0.00	0.0%
Brielle, Borough of	1,442.06	15.60	1.1%
Colts Neck, Township of	20,322.35	161.81	0.8%
Deal, Borough of	770.84	0.00	0.0%
Eatontown, Borough of	3,769.62	0.00	0.0%
Englishtown, Borough of	378.34	0.00	0.0%
Fair Haven, Borough of	1,335.93	0.00	0.0%
Farmingdale, Borough of	336.8	0.00	0.0%
Freehold, Borough of	1,235.59	0.00	0.0%
Freehold, Township of	24,881.36	80.57	0.3%
Hazlet, Township of	3,628.55	11.35	0.3%
Highlands, Borough of	547.83	58.56	10.7%
Holmdel, Township of	11,561.04	275.29	2.4%
Howell, Township of	39,148.96	181.76	0.5%
Interlaken, Borough of	254.6	0.00	0.0%
Keansburg, Borough of	776.33	0.00	0.0%
Keyport, Borough of	927.85	2.45	0.3%
Lake Como, Borough of	161.35	0.00	0.0%
Little Silver, Borough of	2,035.66	0.00	0.0%
Loch Arbour, Village of	73.96	0.00	0.0%
Long Branch, City of	3,505.50	0.00	0.0%
Manalapan, Township of	19,759.34	54.00	0.3%
Manasquan, Borough of	1,002.69	0.00	0.0%
Marlboro, Township of	19,477.44	186.06	1.0%
Matawan, Borough of	1,542.15	127.49	8.3%
Middletown, Township of	27,864.65	481.94	1.7%
Millstone, Township of	23,800.31	361.89	1.5%
Monmouth Beach, Borough of	1,261.94	0.00	0.0%
Neptune City, Borough of	574	0.00	0.0%
Neptune, Township of	5,550.08	93.24	1.7%
Ocean, Township of	7,030.46	31.72	0.5%
Oceanport, Borough of	2,621.24	0.00	0.0%
Red Bank, Borough of	1,382.60	0.01	0.0%
Roosevelt, Borough of	1,246.51	11.99	1.0%
Rumson, Borough of	4,537.77	0.00	0.0%

Jurisdiction	Total Land Area of Municipality (Acres)	Total Land Area in NJGWS-Defined Landslide Susceptibility Area (Acres)	Percent of Total Land Area in NJGWS-Defined Landslide Susceptibility Area (Acres)
Sea Bright, Borough of	781.65	0.00	0.0%
Sea Girt, Borough of	714.88	0.00	0.0%
Shrewsbury, Borough of	1,393.02	0.00	0.0%
Shrewsbury, Township of	62.75	0.00	0.0%
Spring Lake Hts., Borough of	837.15	0.00	0.0%
Spring Lake, Borough of	945.86	0.00	0.0%
Tinton Falls, Borough of	9,989.22	72.68	0.7%
Union Beach, Borough of	1,203.10	0.00	0.0%
Upper Freehold, Township of	30,311.34	603.30	2.0%
Wall, Township of	20,288.47	307.50	1.5%
West Long Branch, Borough of	1,850.28	0.00	0.0%
Monmouth County	310,751.18	3,292.83	1.1%

SOURCE: NJOIT 2016, NJGWS 2016

Landslide risk to critical facilities was determined by intersecting the georeferenced critical facility data points within the landslide susceptibility zones determined by the New Jersey Geological and Water Survey. Only one jurisdiction (Matawan) has a critical facility with landslide risk. The estimated market value of the improvements on this parcel is zero. No jurisdictions have critical infrastructure with landslide risk. Seven jurisdictions (Allentown Borough, Highlands Borough, Holmdel Township, Matawan Borough, Middletown Township, Millstone Township, and Upper Freehold Township) have historical and cultural resources with landslide risk. It should be noted that Middletown Township has 17 (3.6%) historical and cultural resources with landslide risk.

Table 4.8-3 Total Number and Total RCV of Critical Facilities in Landslide Areas and Table 4.8-4 Total Number and Total RCV of Historic and Cultural Resources in Landslide Areas shows the number, percentage, and RCV of critical facilities, critical infrastructure, and historic and cultural resources located within a landslide area. Please note that all municipalities are not listed in the following table. Only municipalities that have critical facilities in the NJGWS-delineated landslide susceptibility areas are listed.

Table 4.8 - 3 Total Number and Total RCV of Critical Facilities in Landslide Areas

Jurisdiction	Number of Critical Facilities in Landslide Areas	Percentage of Critical Facilities in Landslide Areas	RCV of Critical Facilities in Landslide Areas
Matawan Borough	1	10%	$0.00

Table 4.8 - 4 Total Number and Total RCV of Historical and Cultural Resources in Landslide Areas

Jurisdiction	Number of Historic & Cultural Resources in Landslide Areas	Percentage of Historic & Cultural Resources in Landslide Areas	RCV of Historic & Cultural Resources in Landslide Areas
Allentown Borough	1	0.4%	$598,736.00
Highlands Borough	2	12.5%	$470,964.00
Holmdel Township	2	2.9%	$4,371,140.00
Matawan Borough	1	1.8%	$0.00
Middletown Township	17	3.6%	$23,520,371.00

Jurisdiction	Number of Historic & Cultural Resources in Landslide Areas	Percentage of Historic & Cultural Resources in Landslide Areas	RCV of Historic & Cultural Resources in Landslide Areas
Millstone Township	2	1.1%	$5,608.98
Upper Freehold Township	2	1.6%	$394,796.00

SOURCE: NJGWS, MONMOUTH COUNTY OFFICE OF GIS, NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS, NJOIT, NJ DIVISION OF TAXATION

4.8.8 POTENTIAL FOR FUTURE DEVELOPMENT TO IMPACT HAZARD VULNERABILITY

Infill development and redevelopment would not be likely to substantially increase a jurisdiction's overall exposure to landslides because existing structures would be replaced with new structures, and the new structures would be built to higher codes and standards offering a certain degree of protection from the hazard. Greenfield development would be more likely, however, to have the potential to substantially increase a jurisdiction's overall vulnerability to the hazard because a new structure would be placed on previously undeveloped land.

As of the previous Plan Update, out of the 10 jurisdictions in Monmouth County with landslide hazard susceptibility, 7 have potentially developable vacant parcels in mapped landslide hazard areas. The total area of these parcels is approximately 521 acres. In other words, between one and two percent of the County's potentially developable vacant land is in areas potentially susceptible to landslides. Table 4.8 - 5 Potential for Future Development (PFD) to Impact Landslide Hazard Vulnerability presents a snapshot of the landslide hazard, future development trends, the acreage of potentially developable parcels subject to landslides, and the potential for future development of vacant parcels to substantially increase landslide hazard vulnerability under existing conditions.

Jurisdictions with a potential for future development to substantially increase landslide hazard vulnerability under existing conditions should: (a) include landslide mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development. Please note that all municipalities are not listed in the following table. Only the 10 municipalities found to be susceptible to landslides as determined by the previous plan are listed.

Table 4.8 - 5 Potential for Future Development (PFD) to Impact Landslide Hazard Vulnerability

Jurisdiction	Landslide Hazard Areas Present	Relative Population Trend[31] (2010-2040)	Acres of Potentially Developable Vacant Parcels	Acres of Potentially Developable Vacant Parcels in Mapped Landslide Hazard Areas	Percent of Potentially Developable Vacant Land in Mapped Landslide Hazard Areas	Local Characterization of Development Trends[32]	PFD on Vacant Parcels in mapped Landslide Hazard Areas	PFD on vacant parcels in mapped landslide hazard areas to substantially increase storm surge hazard vulnerability under existing conditions
Atlantic Highlands, Borough of	H	Moderate increase	60	39	65.1%	Mix of greenfield development, infill and redevelopment	•	•
Fair Haven, Borough of	M	Low level increase	25	9	35.4%	Mix of greenfield development, infill and redevelopment	•	
Freehold, Township of	L	Substantial increase	2,622	0	0.0%	Predominantly greenfield development		
Highlands, Borough of	H	Moderate increase	58	58	100.0%	Mix of greenfield development, infill and redevelopment	•	•
Howell, Township of	L	Moderate increase	6,606	0	0.0%	Mix of greenfield development, infill and redevelopment		
Little Silver, Borough of	M	Moderate increase	54	1	2.8%	Mix of greenfield development, infill and redevelopment	•	
Middletown Township	M	Moderate increase	2,313	180	7.8%	Mix of greenfield development, infill and redevelopment	•	•
Oceanport, Borough of	L	Substantial increase	218	5	2.3%	Mix of greenfield development, infill and redevelopment	•	
Rumson, Borough of	M	Low level increase	126	126	100.0%	Mix of greenfield development, infill and redevelopment	•	•

31 Relative population trend, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.
32 Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Landslide Hazard Areas Present	Relative Population Trend[31] (2010-2040)	Acres of Potentially Developable Vacant Parcels	Acres of Potentially Developable Vacant Parcels in Mapped Landslide Hazard Areas	Percent of Potentially Developable Vacant Land in Mapped Landslide Hazard Areas	Local Characterization of Development Trends[32]	PFD on Vacant Parcels in mapped Landslide Hazard Areas	PFD on vacant parcels in mapped landslide hazard areas to substantially increase storm surge hazard vulnerability under existing conditions
Tinton Falls, Borough of	M	Substantial increase	1,670	0	0.0%	Predominantly greenfield development		
Monmouth County	M	Moderate increase	32,323	521	4.6%	Mix of greenfield development, infill, and redevelopment	•	•

4.9 WILDFIRE

4.9.1 HAZARD DESCRIPTION

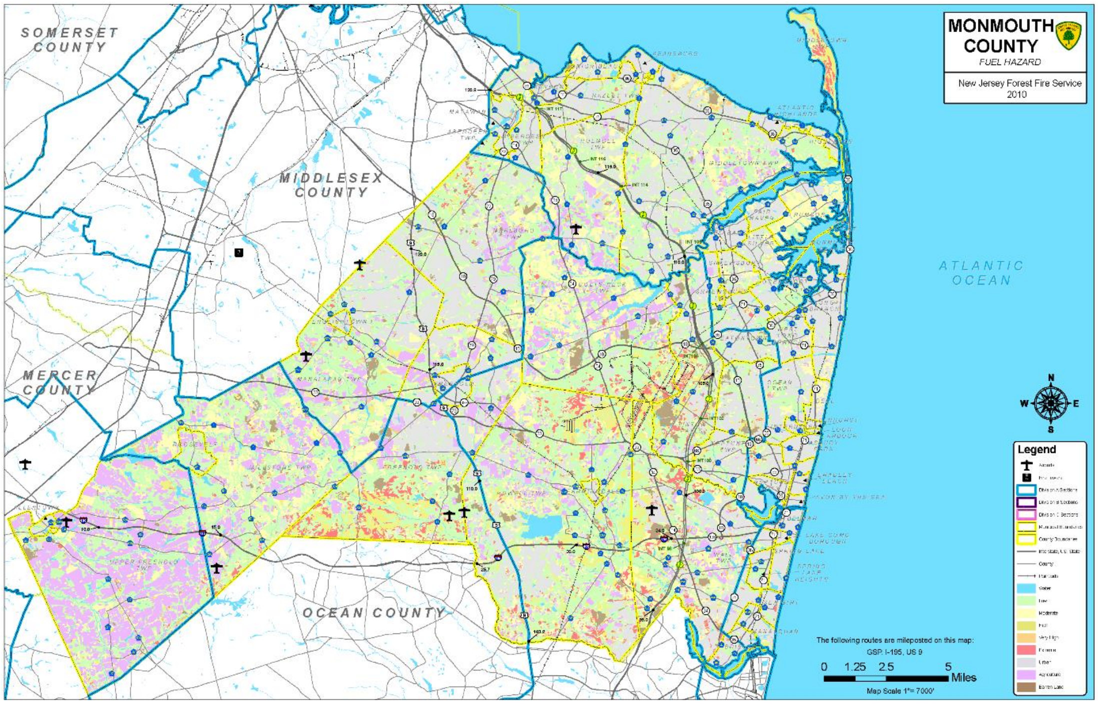
An uncontrolled fire burning in an area of vegetative fuels such as grasslands, brush, or woodlands. Heavier fuels with high continuity, steep slopes, high temperatures, low humidity, low rainfall, and high winds all work to increase risk for people and property located within wildfire hazard areas or along the urban/wildland interface. Wildfires are part of the natural management of forest ecosystems, but most are caused by human factors. Over 80 percent of forest fires are started by negligent human behavior such as smoking in wooded areas or improperly extinguishing campfires. The second most common cause for wildfire is lightning.

4.9.2 LOCATION

The New Jersey Forest Fire Service (NJFFS) recently conducted a wildfire hazard assessment[33] for much of the State and has published maps of wildfire hazard areas in Monmouth County. NJFFS defines wildfire as hazard plus risk; the hazard is what burns and risk is what causes the fire. Figure 4.9-1 Fuel Hazard in Monmouth County and Figure 4.8-2 Fire Risk in Monmouth County illustrate both the hazard and the risk for Monmouth County.

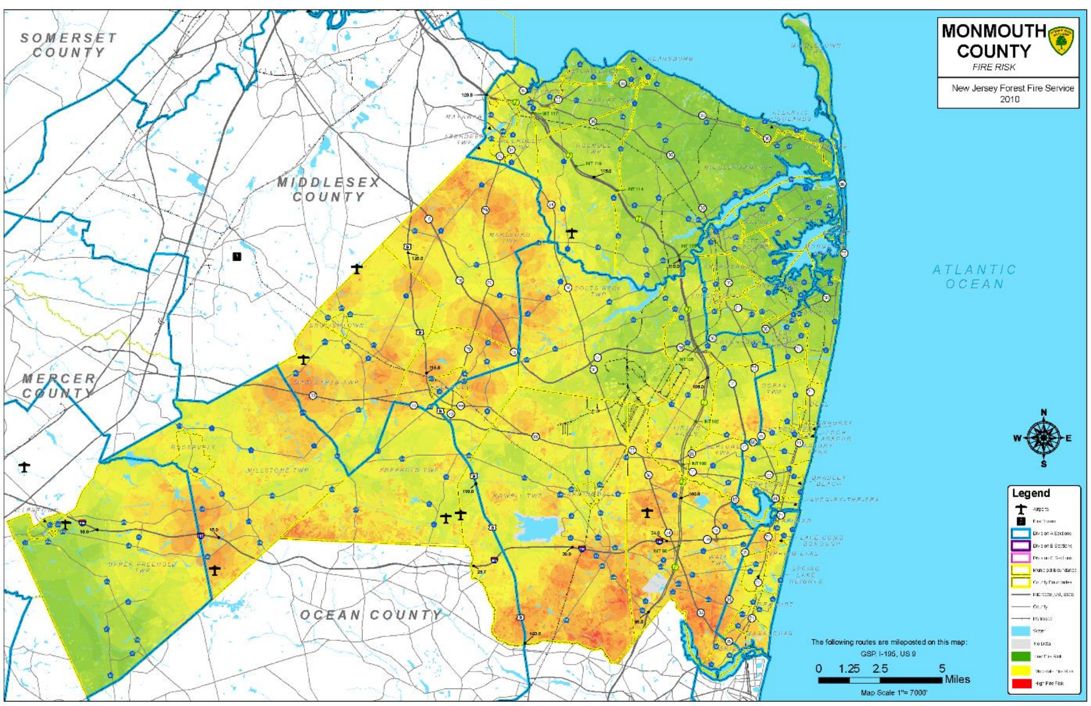
33 The methodological basis for the NJFFS wildfire risk assessment in Monmouth County was based on a correlation of fire risk to vegetation type as recorded in 1996 data for Land Use / Land Cover data.

Figure 4.9 - 1 Fuel Hazard in Monmouth County



SOURCE: NJFFS

Figure 4.9 - 2 Fire Risk in Monmouth County



SOURCE: NJFFS, 2020

4.9.3 EXTENT

The extent (that is, magnitude or severity) of wildfires depends on weather and human activity. NJFFS uses two indices to measure and monitor dryness of forest fuels and the possibility of fire ignitions becoming wildfires. The State HMP notes that these indices include the National Fire Danger Rating System's Buildup Index, and the Keetch-Byram Drought Index. Both are used for fire preparedness planning, which includes the following: campfire and burning restrictions, fire patrol assignments, staffing of fire lookout towers, and readiness status for both observation and firefighting aircraft.

- The Buildup Index (BUI) is a number that reflects the combined cumulative effects of daily drying and precipitation in fuels with a 10-day time lag constant. The BUI can represent three to four inches of compacted litter or can represent up to six inches or more of loose litter (North Carolina Forest Service 2009).
- The Keetch-Byram Drought Index (KBDI) is a drought index designed for fire potential assessment as defined by the United States Department of Agriculture Forest Service. It is a number representing the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff and upper soil layers. The index increases each day without rain and decreases when it rains. The scale ranges from zero (no moisture deficit) to 800 (maximum drought possible). The Florida Forest Service states that the range of the index is determined by assuming that 8 inches of moisture in a saturated soil is readily available to the vegetation. For different soil types, the depth of soil required to hold eight inches of moisture varies. A prolonged drought influences fire intensity, largely because more fuel is available for combustion. The drying of organic material in the soil can lead to increased difficulty in fire suppression.

There are also many other scales and fire weather indices that evaluate wildfire potential on any given day considering factors such as daily weather and vegetation condition information, fuel moisture, fuel hazard, moisture content in the lower atmosphere, etc.

4.9.4 PREVIOUS OCCURRENCES AND LOSSES

According to data made available through NJFFS, Monmouth County averages approximately 50 wildfire events per year though most of these are kept fairly small and are suppressed rather quickly (burning less than one acre). The 10-year average for number of wildfires in Monmouth County is 51 incidents per year, and the average number of acres burned was 35 per year (0.69 acres per fire). A sampling of notable events includes the following:

September 7-10, 1838. The New York Herald reported a fire south and east of Bordentown in Burlington and Monmouth counties 14 miles wide by 20 miles long (approximately 179,200 acres). A good deal of property damage was reported, along with possible loss of life.

April 15, 1977. A local newspaper reported that approximately 300 acres of woods were burned in Howell Township. The fire was fanned by winds of 15 mph which swept across Yellowbrook Road. Approximately 20 fire departments assisted. Yellowbrook Road and a portion of Route 33 were closed for several hours.

April 30, 2001. The unseasonably dry weather during the second half of April continued to make it easy for brush and wildfires to begin and then spread quickly. Three such wildfires occurred during the afternoon and evening on the 30th across central New Jersey. In Port Monmouth, a four-acre fire consumed vegetation. No property damage was reported.

May 1, 2001. The extremely dry and unseasonably warm weather of early May made New Jersey primed for wild and forest fires. In the Belford section of Middletown Township, a wildfire consumed four grassy acres before it was under control. One home's siding was damaged when the fire crept close to it. Two smaller brush fires occurred that afternoon within the township off of County Route 520 and Harbor Way. No damage or injuries were reported.

March 10, 2002. A brush fire, largely exacerbated by strong gusty winds, scorched about 200 acres of brush in the Port Monmouth section of Middletown. The fire began near Main Street and Broadway. The strong winds fanned the fire and brought it close to several houses on Park Avenue, but none were damaged. About 100 firefighters fought the blaze. It was extinguished about two hours later.

February 19, 2011. The combination of the strong west-northwest winds, low humidity levels, and recent dry weather helped cause the rapid spread of wildfires across New Jersey during the day on February 19. In all, 10 wildfires were reported across the State. In Manalapan, a brush fire reached 200 yards in length on Smithburg Road before it was contained. Other wildfires were reported in Sayreville and Old Bridge.

Other notable reports of historical wildfire events include the following, as identified by the Planning Committee:

- The Township of Ocean has several large wooded areas that are a part of the Green Acres Preserve and has a history of wildfires. Due to lightning or human-caused incidents, local fire departments respond to these areas several times on an annual basis. Many of these areas are not accessible by traditional fire apparatus.
- The Borough of Roosevelt is located next to Assunpink Wildlife Preserve which has several brush fires per year.

4.9.5 PROBABILITY OF FUTURE OCCURRENCE

Wildfire probability depends on local weather conditions; outdoor activities such as camping, debris burning, and construction; and the degree of public cooperation with fire prevention measures. Wildfire events will continue to have a high probability of occurrence in Monmouth County, and the probability of future occurrences in Monmouth County is certain. However, these events are typically contained and extinguished rather quickly and those events causing major property damage or life/safety threats are much less likely to occur.

4.9.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

Fire is determined by climate variability, local topography, and human intervention. Hot, dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. When climate alters fuel loads and fuel moisture, this changes the forest susceptibility to wildfires. Climate changes also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

4.9.7 VULNERABILITY ASSESSMENT

Impacts

Wildfires have the potential to destroy large portions of a community. Firefighters are at risk during the time that they are trying to contain and control the blaze. Loss of life and injuries are possible for people living, working, or traveling through an impacted area. Beyond the loss of vegetation that wildfires leave in their wake, structures in the wildland/urban interface can be severely damaged or destroyed. Following a large wildfire, the possibility exists for significant increases in stormwater runoff and landslides which can lead to downstream flooding. Depending on the scale of the impacted area and the type and numbers of buildings and infrastructure impacted, secondary effects are possible on local economies and the social fabric of communities following the event.

Exposure and Damage Estimates

To estimate exposure to wildfire, the determination of value and population at-risk was calculated through GIS analysis by calculating the proportion of a parcel or census block located within areas of wildfire susceptibility (low/moderate and high/extreme) and applying that same ratio to the census block population and parcel value to estimate population at risk and value of improvements at risk. Over 28 percent of total assessed improvements in the county are located in wildfire hazard areas; however, only about two percent is located in high or extreme susceptibility areas. Table 4.9 - 1 Exposure to Wildfire by Jurisdiction shows exposure to wildfire by jurisdiction.

Table 4.9 - 1 Exposure to Wildfire by Jurisdiction

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located in Low/Moderate Susceptibility Areas	Total Assessed Value of Buildings Located in High/Extreme Susceptibility Areas	Total Assessed Value of Buildings Located in All Wildfire Susceptibility Areas	% of Total Building Value Exposed to Wildfire
Aberdeen, Township of	4,807	$1,074,509,800	$114,850,832	$14,679,413	$129,530,245	10.87%
Allenhurst, Borough of	41	$217,949,000	$6,157,580	$0	$6,157,580	3.34%
Allentown, Borough of	331	$127,734,200	$13,586,008	$304,795	$13,890,802	9.58%
Asbury Park, City of	50	$1,267,473,400	$4,508,187	$63,607	$4,571,794	0.49%
Atlantic Highlands, Borough of	530	$364,693,600	$23,010,040	$1,092,465	$24,102,505	8.50%
Avon-By-The-Sea, Borough of	33	$266,879,900	$2,017,036	$0	$2,017,036	0.52%
Belmar, Borough of	162	$553,347,900	$6,365,145	$32,305	$6,397,451	1.12%
Bradley Beach, Borough of	73	$462,112,100	$267,281	$0	$267,281	0.06%
Brielle, Borough of	569	$669,338,900	$39,989,567	$8,450,672	$48,440,239	8.77%
Colts Neck,	7,132	$927,454,500	$1,439,242,429	$34,885,768	$1,474,128,197	77.96%

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located in Low/Moderate Susceptibility Areas	Total Assessed Value of Buildings Located in High/Extreme Susceptibility Areas	Total Assessed Value of Buildings Located in All Wildfire Susceptibility Areas	% of Total Building Value Exposed to Wildfire
Township of						
Deal, Borough of	172	$822,100,400	$173,800,267	$1,291,908	$175,092,174	30.39%
Eatontown, Borough of	2,627	$1,314,725,700	$173,989,488	$9,985,942	$183,975,430	14.10%
Englishtown, Borough of	373	$158,314,100	$10,600,125	$5,585,933	$16,186,059	11.43%
Fair Haven, Borough of	963	$785,619,700	$80,849,500	$1,092,045	$81,941,545	12.34%
Farmingdale, Borough of	241	$109,883,900	$9,460,258	$0	$9,460,258	7.46%
Freehold, Borough of	970	$771,202,500	$44,203,739	$0	$44,203,739	6.17%
Freehold, Township of	10,122	$4,433,974,800	$846,689,194	$96,118,658	$942,807,853	21.22%
Hazlet, Township of	2,744	$1,215,098,000	$82,733,776	$14,163,682	$96,897,457	7.10%
Highlands, Borough of	893	$342,874,400	$20,496,944	$1,384,346	$21,881,291	6.87%
Holmdel, Township of	8,373	$2,104,382,100	$999,682,193	$24,656,407	$1,024,338,601	43.60%
Howell, Township of	24,032	$4,204,216,400	$767,893,008	$121,284,330	$889,177,338	24.81%
Interlaken, Borough of	78	$125,000,500	$7,900,841	$0	$7,900,841	7.65%
Keansburg, Borough of	506	$343,826,000	$9,400,553	$2,203,252	$11,603,805	2.95%
Keyport, Borough of	764	$434,885,600	$12,211,020	$6,728,450	$18,939,470	3.98%
Lake Como, Borough of	20	$140,566,300	$658,368	$0	$658,368	0.38%
Little Silver, Borough of	1,637	$873,512,700	$204,127,451	$4,058,669	$208,186,120	24.72%
Loch Arbour, Village of	0	$69,262,800	$3,062	$0	$3,062	0.01%
Long Branch, City of	1,939	$2,478,681,000	$165,802,250	$2,604,609	$168,406,859	6.38%
Manalapan, Township of	12,752	$4,619,949,900	$977,193,924	$53,142,859	$1,030,336,783	24.12%
Manasquan, Borough of	347	$799,826,975	$18,311,984	$1,586,564	$19,898,548	2.44%
Marlboro, Township of	15,752	$4,435,729,800	$1,052,902,707	$54,272,171	$1,107,174,878	24.91%
Matawan, Borough of	1,929	$517,395,800	$51,426,704	$1,299,805	$52,726,509	9.33%
Middletown, Township of	16,794	$5,895,810,731	$1,171,793,040	$91,226,396	$1,263,019,436	22.52%
Millstone, Township of	8,419	$1,232,191,160	$857,728,391	$42,611,138	$900,339,529	80.39%
Monmouth Beach, Borough of	392	$501,592,200	$26,272,478	$7,592,373	$33,864,852	6.64%

Jurisdiction	Estimated Population at Risk	Total Assessed Value of Improvements (2018 Values)	Total Assessed Value of Buildings Located in Low/Moderate Susceptibility Areas	Total Assessed Value of Buildings Located in High/Extreme Susceptibility Areas	Total Assessed Value of Buildings Located in All Wildfire Susceptibility Areas	% of Total Building Value Exposed to Wildfire
Neptune City, Borough of	351	$305,279,900	$7,197,377	$358,185	$7,555,562	2.79%
Neptune, Township of	3,505	$2,431,214,700	$85,511,919	$27,849,858	$113,361,777	6.61%
Ocean, Township of	4,995	$2,684,842,000	$264,385,276	$75,457,148	$339,842,424	14.46%
Oceanport, Borough of	1,084	$562,875,800	$138,618,911	$2,930,362	$141,549,273	24.24%
Red Bank, Borough of	788	$1,194,733,400	$30,502,178	$4,690,339	$35,192,517	2.63%
Roosevelt, Borough of	499	$50,136,700	$10,718,572	$275,106	$10,993,677	24.02%
Rumson, Borough of	3,501	$1,600,650,400	$1,038,574,243	$15,008,068	$1,053,582,311	66.26%
Sea Bright, Borough of	174	$235,586,800	$10,741,971	$7,319	$10,749,290	4.01%
Sea Girt, Borough of	66	$732,097,100	$15,333,056	$2,574,643	$17,907,699	3.39%
Shrewsbury, Borough of	1,113	$608,635,700	$112,514,197	$2,387,409	$114,901,606	20.80%
Shrewsbury, Township of	65	$30,450,000	$37,474	$0	$37,474	0.12%
Spring Lake, Borough of	93	$1,028,817,800	$22,779,792	$10,001	$22,789,793	1.93%
Spring Lake Hts., Borough of	569	$525,407,200	$12,974,169	$243,568	$13,217,737	2.58%
Tinton Falls, Borough of	6,207	$1,691,986,800	$409,789,186	$134,558,675	$544,347,862	23.99%
Union Beach, Borough of	931	$387,844,700	$24,749,178	$7,626,019	$32,375,198	11.24%
Upper Freehold, Township of	4,521	$851,779,300	$481,074,000	$20,979,182	$502,053,182	54.98%
Wall, Township of	7,295	$3,053,292,400	$602,934,601	$87,961,925	$690,896,526	26.64%
West Long Branch, Borough of	979	$889,026,200	$79,966,017	$18,929,447	$98,895,464	11.17%
Monmouth County	163,328	$63,526,773,666	$12,764,527,487	$1,004,245,819	$13,768,773,307	22.17%

NOTE: EXPOSURE CALCULATED BY GIS ANALYSIS USING LOCAL ASSESSED VALUES

Given the lack of historical loss data on significant wildfire occurrences resulting in large-scale structural losses in Monmouth County, it is assumed that while one major event may result in significant losses, annualizing structural losses over a long period of time would most likely yield a negligible annualized loss estimate in each jurisdiction exposed to this hazard.

Table 4.9- 2 Total Number of Critical Facilities, Critical Infrastructure, and Historic & Cultural Resources Located in Wildfire Hazard Areas shows the number and percentage of critical facilities located in wildfire fuel hazard areas obtained from the New Jersey Fire Service (2009). Georeferenced critical

facility data points were selected for their intersection with all fuel hazard areas, moderate and low areas, and extreme, very high, and high areas.

Table 4.9 - 2 Total Number of Critical Facilities, Critical Infrastructure, and Historic & Cultural Resources Located in Wildfire Hazard Areas

Jurisdiction	Number of Critical Facilities in Wildfire Hazard Areas			Percentage of Critical Facilities in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Aberdeen Township	3	2	1	12%	8%	4%
Allenhurst Borough	0	0	0	0%	0%	0%
Allentown Borough	1	1	0	17%	17%	0%
Asbury Park City	1	1	0	4%	4%	0%
Atlantic Highlands Borough	0	0	0	0%	0%	0%
Avon-by-the-Sea Borough	1	1	0	17%	17%	0%
Belmar Borough	1	1	0	8%	8%	0%
Bradley Beach Borough	0	0	0	0%	0%	0%
Brielle Borough	3	3	0	27%	27%	0%
Colts Neck Township	3	1	2	17%	6%	11%
Deal Borough	1	1	0	17%	17%	0%
Eatontown Borough	1	1	0	5%	5%	0%
Englishtown Borough	0	0	0	0%	0%	0%
Fair Haven Borough	1	1	0	10%	10%	0%
Farmingdale Borough	1	1	0	8%	8%	0%
Freehold Borough	0	0	0	0%	0%	0%
Freehold Township	6	5	1	7%	6%	1%
Hazlet Township	3	3	0	8%	8%	0%
Highlands Borough	2	2	0	22%	22%	0%
Holmdel Township	0	0	0	0%	0%	0%
Howell Township	8	7	1	11%	10%	1%
Interlaken Borough	2	2	0	100%	100%	0%
Keansburg Borough	2	2	0	13%	13%	0%
Keyport Borough	3	3	0	16%	16%	0%
Lake Como Borough	0	0	0	0%	0%	0%
Little Silver Borough	1	1	0	10%	10%	0%
Loch Arbour Village	0	0	0	0%	0%	0%
Long Branch City	2	2	0	5%	5%	0%
Manalapan Township	10	9	1	21%	19%	2%
Manasquan Borough	2	2	0	18%	18%	0%
Marlboro Township	12	10	2	23%	19%	4%
Matawan Borough	0	0	0	0%	0%	0%
Middletown Township	14	13	1	13%	12%	1%
Millstone Township	3	3	0	27%	27%	0%
Monmouth Beach Borough	0	0	0	0%	0%	0%
Neptune City Borough	2	1	1	20%	10%	10%
Neptune Township	4	4	0	8%	8%	0%
Ocean Township	2	2	0	6%	6%	0%
Oceanport Borough	0	0	0	0%	0%	0%
Red Bank Borough	0	0	0	0%	0%	0%
Roosevelt Borough	0	0	0	0%	0%	0%

Jurisdiction	Number of Critical Facilities in Wildfire Hazard Areas			Percentage of Critical Facilities in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Rumson Borough	2	2	0	14%	14%	0%
Sea Bright Borough	0	0	0	0%	0%	0%
Sea Girt Borough	1	1	0	14%	14%	0%
Shrewsbury Borough	2	2	0	14%	14%	0%
Shrewsbury Township	0	0	0	0%	0%	0%
Spring Lake Borough	1	1	0	13%	13%	0%
Spring Lake Heights Borough	0	0	0	0%	0%	0%
Tinton Falls Borough	4	3	1	9%	7%	2%
Union Beach Borough	1	1	0	8%	8%	0%
Upper Freehold Township	6	6	0	50%	50%	0%
Wall Township	6	5	1	11%	9%	2%
West Long Branch Borough	0	0	0	0%	0%	0%
Monmouth County	118	106	12	11%	9%	1%

Jurisdiction	Number of Critical Infrastructure in Wildfire Hazard Areas			Percentage of Critical Infrastructure in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Allenhurst Borough	1	1	0	100%	100%	0%
Asbury Park City	1	1	0	100%	100%	0%
Bradley Beach Borough	1	1	0	100%	100%	0%
Hazlet Township	1	1	0	100%	100%	0%
Little Silver Borough	1	1	0	100%	100%	0%
Long Branch City	2	2	0	100%	100%	0%
Manasquan Borough	1	1	0	100%	100%	0%
Matawan Borough	1	1	0	100%	100%	0%
Middletown Township	1	1	0	100%	100%	0%
Neptune Township	1	1	0	100%	100%	0%
Oceanport Borough	1	1	0	100%	100%	0%
Red Bank Borough	2	2	0	20%	20%	0%
Shrewsbury Borough	1	1	0	100%	100%	0%
Spring Lake Borough	1	1	0	100%	100%	0%
Tinton Falls Borough	6	6	0	43%	43%	0%
Wall Township	2	1	1	17%	8%	8%
Monmouth County	24	23	1	42%	40%	2%

Jurisdiction	Number of Historic & Cultural Resources in Wildfire Hazard Areas			Percentage Historic & Cultural Resources in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Aberdeen Township	7	7	0	30%	30%	0%
Allenhurst Borough	3	3	0	1%	1%	0%
Allentown Borough	10	10	0	4%	4%	0%
Asbury Park City	7	7	0	16%	16%	0%
Atlantic Highlands Borough	8	8	0	40%	40%	0%
Avon-by-the-Sea Borough	3	3	0	10%	10%	0%
Belmar Borough	5	5	0	33%	33%	0%
Bradley Beach Borough	4	4	0	17%	17%	0%
Brielle Borough	6	6	0	26%	26%	0%
Colts Neck Township	71	69	2	50%	48%	1%
Deal Borough	8	8	0	33%	33%	0%
Eatontown Borough	19	19	0	39%	39%	0%
Englishtown Borough	5	5	0	18%	18%	0%
Fair Haven Borough	2	2	0	7%	7%	0%
Farmingdale Borough	15	15	0	48%	48%	0%
Freehold Borough	15	15	0	11%	11%	0%
Freehold Township	46	41	5	51%	45%	5%
Hazlet Township	3	3	0	25%	25%	0%
Highlands Borough	5	5	0	24%	24%	0%
Holmdel Township	50	49	1	45%	44%	1%
Howell Township	69	63	6	69%	63%	6%
Interlaken Borough	5	5	0	31%	31%	0%
Keansburg Borough	7	6	1	19%	17%	3%
Keyport Borough	5	5	0	2%	2%	0%
Lake Como Borough	0	0	0	0%	0%	0%
Little Silver Borough	16	16	0	38%	38%	0%
Loch Arbour Village	0	0	0	0%	0%	0%
Long Branch City	23	23	0	23%	23%	0%
Manalapan Township	52	50	2	57%	54%	2%
Manasquan Borough	7	7	0	13%	13%	0%
Marlboro Township	36	35	1	20%	20%	1%
Matawan Borough	8	8	0	12%	12%	0%
Middletown Township	10	10	0	17%	17%	0%
Millstone Township	62	57	5	29%	27%	2%
Monmouth Beach Borough	6	6	0	24%	24%	0%
Neptune City Borough	1	1	0	100%	100%	0%
Neptune Township	13	13	0	1%	1%	0%
Ocean Township	15	15	0	43%	43%	0%
Oceanport Borough	8	8	0	15%	15%	0%
Red Bank Borough	11	10	1	11%	10%	1%
Roosevelt Borough	23	23	0	9%	9%	0%
Rumson Borough	3	3	0	17%	17%	0%
Sea Bright Borough	9	9	0	39%	39%	0%
Sea Girt Borough	4	3	1	17%	13%	4%
Shrewsbury Borough	39	38	1	42%	41%	1%
Shrewsbury Township	0	0	0	0%	0%	0%

Jurisdiction	Number of Historic & Cultural Resources in Wildfire Hazard Areas			Percentage Historic & Cultural Resources in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Spring Lake Borough	8	8	0	10%	10%	0%
Spring Lake Heights Borough	1	1	0	6%	6%	0%
Tinton Falls Borough	34	29	5	46%	39%	7%
Union Beach Borough	8	7	1	62%	54%	8%
Upper Freehold Township	57	54	3	40%	38%	2%
Wall Township	34	31	3	34%	31%	3%
West Long Branch Borough	12	11	1	32%	29%	3%
Monmouth County	878	839	39	16%	15%	1%

Table 4.9-3 Total Replacement Cost Value of Critical Facilities in Wildfire Hazard Areas by Jurisdiction shows the estimated replacement cost value (RCV) of critical facilities, critical infrastructure, and historic and cultural resources in wildfire fuel hazard areas. First, we approximated the market value of improvements on each of the parcels in the state using MOD-IV and taxation rates from 2017 (NJ Office of Information Technology (OIT), 2017; NJ Division of Taxation, 2017). Georeferenced critical facility data points were then intersected with the parcel layer to attribute the parcel's market value of improvements to each critical facility. Some critical facilities had been geolocated to the nearest road centerline and thus were not captured when intersected with parcels. As a proxy, we calculated the median market value for improvements from the critical facilities geolocated on their proper parcels and attributed this median value to all other critical facilities.

Table 4.9 - 3 Total Replacement Cost Value of Critical Facilities in Wildfire Hazard Areas by Jurisdiction

Jurisdiction	Total RCV Critical Facilities in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Aberdeen Township	$3,895,526.12	$3,030,916.96	$864,609.16
Allenhurst Borough	$0.00	$0.00	$0.00
Allentown Borough	$495,530.88	$495,530.88	$0.00
Asbury Park City	$2,555,397.56	$2,555,397.56	$0.00
Atlantic Highlands Borough	$0.00	$0.00	$0.00
Avon-by-the-Sea Borough	$385,048.86	$385,048.86	$0.00
Belmar Borough	$0.00	$0.00	$0.00
Bradley Beach Borough	$0.00	$0.00	$0.00
Brielle Borough	$2,647,744.43	$2,647,744.43	$0.00
Colts Neck Township	$0.00	$0.00	$0.00
Deal Borough	$3,826,416.27	$3,826,416.27	$0.00
Eatontown Borough	$5,444,142.46	$5,444,142.46	$0.00
Englishtown Borough	$0.00	$0.00	$0.00
Fair Haven Borough	$495,758.75	$495,758.75	$0.00
Farmingdale Borough	$238,511.20	$238,511.20	$0.00
Freehold Borough	$0.00	$0.00	$0.00
Freehold Township	$25,430,323.11	$25,430,323.11	$0.00
Hazlet Township	$1,267,593.77	$1,267,593.77	$0.00
Highlands Borough	$364,301.21	$364,301.21	$0.00
Holmdel Township	$0.00	$0.00	$0.00

Jurisdiction	Total RCV Critical Facilities in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Howell Township	$6,261,741.35	$4,829,795.14	$1,431,946.21
Interlaken Borough	$508,634.31	$508,634.31	$0.00
Keansburg Borough	$666,365.72	$666,365.72	$0.00
Keyport Borough	$5,825,211.16	$5,825,211.16	$0.00
Lake Como Borough	$0.00	$0.00	$0.00
Little Silver Borough	$2,993,970.10	$2,993,970.10	$0.00
Loch Arbour Village	$0.00	$0.00	$0.00
Long Branch City	$33,949,111.71	$33,949,111.71	$0.00
Manalapan Township	$14,583,234.84	$13,549,624.98	$1,033,609.87
Manasquan Borough	$2,529,848.52	$2,529,848.52	$0.00
Marlboro Township	$27,067,171.99	$19,368,896.86	$7,698,275.13
Matawan Borough	$0.00	$0.00	$0.00
Middletown Township	$13,588,310.03	$13,588,310.03	$0.00
Millstone Township	$2,456,277.54	$2,456,277.54	$0.00
Monmouth Beach Borough	$0.00	$0.00	$0.00
Neptune City Borough	$681,376.43	$681,376.43	$0.00
Neptune Township	$29,441,310.26	$29,441,310.26	$0.00
Ocean Township	$4,119,333.73	$4,119,333.73	$0.00
Oceanport Borough	$0.00	$0.00	$0.00
Red Bank Borough	$0.00	$0.00	$0.00
Roosevelt Borough	$0.00	$0.00	$0.00
Rumson Borough	$8,985,959.60	$8,985,959.60	$0.00
Sea Bright Borough	$0.00	$0.00	$0.00
Sea Girt Borough	$0.00	$0.00	$0.00
Shrewsbury Borough	$480,439.92	$480,439.92	$0.00
Shrewsbury Township	$0.00	$0.00	$0.00
Spring Lake Borough	$716,299.73	$716,299.73	$0.00
Spring Lake Heights Borough	$0.00	$0.00	$0.00
Tinton Falls Borough	$108,876,302.24	$108,876,302.24	$0.00
Union Beach Borough	$1,099,681.11	$1,099,681.11	$0.00
Upper Freehold Township	$5,736,963.91	$5,736,963.91	$0.00
Wall Township	$36,817,390.70	$21,933,191.64	$14,884,199.06
West Long Branch Borough	$0.00	$0.00	$0.00
Monmouth County	$354,431,229.53	$328,518,590.10	$25,912,639.43

Jurisdiction	Total RCV Critical Infrastructure in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Allenhurst Borough	$0.00	$0.00	$0.00
Asbury Park City	$0.00	$0.00	$0.00
Bradley Beach Borough	$0.00	$0.00	$0.00
Hazlet Township	$0.00	$0.00	$0.00
Little Silver Borough	$0.00	$0.00	$0.00
Long Branch City	$0.00	$0.00	$0.00
Manasquan Borough	$0.00	$0.00	$0.00
Matawan Borough	$81,906.17	$81,906.17	$0.00
Middletown Township	$0.00	$0.00	$0.00

Jurisdiction	Total RCV Critical Infrastructure in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Neptune Township	$0.00	$0.00	$0.00
Oceanport Borough	$0.00	$0.00	$0.00
Red Bank Borough	$0.00	$0.00	$0.00
Shrewsbury Borough	$0.00	$0.00	$0.00
Spring Lake Borough	$0.00	$0.00	$0.00
Tinton Falls Borough	$24,564,367.90	$24,564,367.90	$0.00
Wall Township	$701,838.28	$655,327.33	$46,510.95
Monmouth County	$25,348,112.34	$25,301,601.39	$46,510.95

Jurisdiction	Total RCV Historic & Cultural Resources in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Aberdeen Township	$178,603.29	$178,603.29	$0.00
Allenhurst Borough	$1,309,120.68	$1,309,120.68	$0.00
Allentown Borough	$1,880,927.31	$1,880,927.31	$0.00
Asbury Park City	$2,392,990.34	$2,392,990.34	$0.00
Atlantic Highlands Borough	$691,610.71	$691,610.71	$0.00
Avon-by-the-Sea Borough	$1,063,416.58	$1,063,416.58	$0.00
Belmar Borough	$4,083,629.39	$4,083,629.39	$0.00
Bradley Beach Borough	$2,382,586.08	$2,382,586.08	$0.00
Brielle Borough	$10,333,062.94	$10,333,062.94	$0.00
Colts Neck Township	$52,230,351.34	$31,959,394.02	$20,270,957.32
Deal Borough	$11,620,408.05	$11,620,408.05	$0.00
Eatontown Borough	$158,758,642.99	$158,758,642.99	$0.00
Englishtown Borough	$241,766.46	$241,766.46	$0.00
Fair Haven Borough	$433,315.09	$433,315.09	$0.00
Farmingdale Borough	$459,032.27	$459,032.27	$0.00
Freehold Borough	$14,180,792.50	$14,180,792.50	$0.00
Freehold Township	$3,464,928.48	$2,678,012.35	$786,916.14
Hazlet Township	$283,633.15	$283,633.15	$0.00
Highlands Borough	$1,769,747.42	$1,769,747.42	$0.00
Holmdel Township	$60,594,355.56	$60,594,355.56	$0.00
Howell Township	$3,113,168.19	$2,847,322.07	$265,846.12
Interlaken Borough	$1,260,032.56	$1,260,032.56	$0.00
Keansburg Borough	$12,916,548.65	$12,916,548.65	$0.00
Keyport Borough	$2,252,416.34	$2,252,416.34	$0.00
Lake Como Borough	$0.00	$0.00	$0.00
Little Silver Borough	$5,797,978.38	$5,797,978.38	$0.00
Loch Arbour Village	$0.00	$0.00	$0.00
Long Branch City	$11,021,674.70	$11,021,674.70	$0.00
Manalapan Township	$7,062,832.01	$6,371,261.14	$691,570.87
Manasquan Borough	$15,758,653.04	$15,758,653.04	$0.00
Marlboro Township	$5,210,888.74	$5,210,888.74	$0.00
Matawan Borough	$737,761.45	$737,761.45	$0.00
Middletown Township	$6,874,120.52	$6,874,120.52	$0.00
Millstone Township	$6,977,501.23	$6,605,145.30	$372,355.94
Monmouth Beach Borough	$3,127,203.93	$3,127,203.93	$0.00

Jurisdiction	Total RCV Historic & Cultural Resources in Wildfire Hazard Areas		
	Overall	Low and Moderate Areas	High, Very High, and Extreme Areas
Neptune City Borough	$122,319.02	$122,319.02	$0.00
Neptune Township	$3,306,489.34	$3,306,489.34	$0.00
Ocean Township	$11,699,414.69	$11,699,414.69	$0.00
Oceanport Borough	$55,638,962.71	$55,638,962.71	$0.00
Red Bank Borough	$5,198,045.66	$4,795,271.03	$402,774.63
Roosevelt Borough	$4,788,828.00	$4,788,828.00	$0.00
Rumson Borough	$244,087.95	$244,087.95	$0.00
Sea Bright Borough	$238,223.72	$238,223.72	$0.00
Sea Girt Borough	$22,603,561.62	$22,603,561.62	$0.00
Shrewsbury Borough	$142,352,844.21	$142,352,844.21	$0.00
Shrewsbury Township	$0.00	$0.00	$0.00
Spring Lake Borough	$549,624.19	$549,624.19	$0.00
Spring Lake Heights Borough	$4,132,186.46	$4,132,186.46	$0.00
Tinton Falls Borough	$4,076,552.33	$4,071,414.97	$5,137.37
Union Beach Borough	$1,245,552.91	$1,245,552.91	$0.00
Upper Freehold Township	$24,476,248.74	$23,844,169.28	$632,079.46
Wall Township	$93,477,365.55	$93,477,365.55	$0.00
West Long Branch Borough	$12,505,211.08	$12,505,211.08	$0.00
Monmouth County	$797,119,218.56	$773,691,580.73	$23,427,637.84

SOURCE: NJFFS, MONMOUTH COUNTY OFFICE OF GIS, NJDEP, NJGIN, MONMOUTH COUNTY JURISDICTIONS, NJOIT, NJ DIVISION OF TAXATION

4.9.8 POTENTIAL FOR FUTURE DEVELOPMENT TO IMPACT HAZARD VULNERABILITY

Infill development, redevelopment and greenfield are susceptible to wildfire if the future development is located near wildfire hazard areas. Ways to mitigate future development from the risk of wildfire is to regulate development in or near wildfire hazard areas through land use planning, such as conserving open space or a wildland-urban boundary zones to separate developed areas from high-hazard areas.

All 53 jurisdictions in Monmouth County have mapped wildfire hazard areas; 40 have potentially developable undeveloped parcels in mapped wildfire hazard areas (high or extreme). The total area of these parcels is approximately 16,940 acres. In other words, between one and two percent of the County's potentially developable undeveloped land is in areas potentially susceptible to wildfires. Table 4.9- 4 Potential for Future Development to Impact Wildfire Hazard Vulnerability presents a snapshot of the wildfire hazard, future development trends, the acreage of potentially developable parcels subject to wildfires, and the potential for future development to substantially increase wildfire hazard vulnerability under existing conditions.

Jurisdictions with a potential for future development to substantially increase wildfire hazard vulnerability under existing conditions should: (a) include wildfire mitigation measures in their mitigation strategies; and/or (b) select jurisdictional plan integration initiatives for the next plan maintenance phase that can potentially reduce risk for future development.

Table 4.9 - 4 Potential for Future Development (PFD) to Impact Wildfire Hazard Vulnerability

Jurisdiction	Wildfire Hazard Areas Present	Relative Population Trend [34](2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wildfire Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wildfire Hazard Areas	Local Characterization of Development Trends[35]	PFD on Undeveloped Parcels in mapped Wildfire Hazard Areas	PDF on undeveloped parcels in mapped wildfire hazard areas to substantially increase storm surge hazard vulnerability under existing conditions
Aberdeen, Township of	L	Substantial increase	415	129	31.2%	Mix of greenfield development, infill and redevelopment	•	•
Allenhurst, Borough of	L	Negligible increase	4	0	0.0%	Little if any development expected		
Allentown, Borough of	H	Negligible increase	6	0.4	5.7%	Little if any development expected	•	
Asbury Park, City of	L	Substantial increase	39	0	0.0%	Mix of greenfield development, infill and redevelopment		
Atlantic Highlands, Borough of	L	Moderate increase	60	20	33.5%	Mix of greenfield development, infill and redevelopment	•	•
Avon-by-the-Sea, Borough of	L	Negligible increase	7	0	0.0%	Little if any development expected		
Belmar, Borough of	L	Low level increase	13	0	0.0%	Mix of greenfield development, infill and redevelopment		
Bradley Beach, Borough of	L	Moderate increase	14	0	0.0%	Mix of greenfield development, infill and redevelopment		
Brielle, Borough of	L	Low level increase	131	93	70.6%	Mix of greenfield development, infill and redevelopment	•	•
Colts Neck, Township of	M	Low level increase	793	408	51.4%	Predominantly greenfield development	•	•
Deal, Borough of	L	Negligible increase	40	2	5.0%	Little if any development expected	•	

34 Relative population trends, where: negligible is defined as an increase of 0 to 50 people per square mile; low is defined as an increase of 50 to 100 people per square mile; moderate is defined as an increase of 100 to 150 people per square mile; and high is defined as an increase of over 150 people per square mile.

35 Local characterization of development trends based on municipal worksheet assessment

Jurisdiction	Wildfire Hazard Areas Present	Relative Population Trend [34](2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wildfire Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wildfire Hazard Areas	Local Characterization of Development Trends[35]	PFD on Undeveloped Parcels in mapped Wildfire Hazard Areas	PDF on undeveloped parcels in mapped wildfire hazard areas to substantially increase storm surge hazard vulnerability under existing conditions
Eatontown, Borough of	L	Substantial increase	347	54	15.4%	Mix of greenfield development, infill and redevelopment	•	•
Englishtown, Borough of	L	Substantial increase	77	43	56.1%	Mix of greenfield development, infill and redevelopment	•	•
Fair Haven, Borough of	L	Low level increase	25	7	27.4%	Mix of greenfield development, infill and redevelopment	•	
Farmingdale, Borough of	L	Substantial increase	69	0	0.0%	Mix of greenfield development, infill and redevelopment		
Freehold, Borough of	L	Substantial increase	50	0	0.0%	Mix of greenfield development, infill and redevelopment		
Freehold, Township of	L	Substantial increase	2,622	1,432	54.6%	Predominantly greenfield development	•	•
Hazlet, Township of	L	Substantial increase	249	150	60.3%	Mix of greenfield development, infill and redevelopment	•	•
Highlands, Borough of	L	Moderate increase	58	20	33.8%	Mix of greenfield development, infill and redevelopment	•	•
Holmdel, Township of	M	Substantial increase	593	147	24.8%	Predominantly greenfield development	•	•
Howell, Township of	H	Moderate increase	6,606	4,024	60.9%	Mix of greenfield development, infill and redevelopment	•	•
Interlaken, Borough of	L	Negligible increase	7	0	0.0%	Little to no development expected		
Keansburg, Borough of	L	Substantial increase	85	21	24.9%	Mix of greenfield	•	•

Jurisdiction	Wildfire Hazard Areas Present	Relative Population Trend [34] (2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wildfire Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wildfire Hazard Areas	Local Characterization of Development Trends[35]	PFD on Undeveloped Parcels in mapped Wildfire Hazard Areas	PDF on undeveloped parcels in mapped wildfire hazard areas to substantially increase storm surge hazard vulnerability under existing conditions
						development, infill and redevelopment		
Keyport, Borough of	L	Substantial increase	68	36	52.7%	Mix of greenfield development, infill and redevelopment	•	•
Lake Como, Borough of	L	Negligible increase	8	0	0.0%	Little to no development expected		
Little Silver, Borough of	L	Moderate increase	54	9	16.7%	Mix of greenfield development, infill and redevelopment	•	
Loch Arbour, Village of	L	Low level increase	2	0	0.0%	Little to no development expected		
Long Branch, City of	L	Substantial increase	288	15	5.3%	Mix of greenfield development, infill and redevelopment	•	•
Manalapan, Township of	L	Moderate increase	3,194	1,452	45.5%	Predominantly greenfield development	•	•
Manasquan, Borough of	L	Moderate increase	39	2	5.2%	Mix of greenfield development, infill and redevelopment	•	
Marlboro, Township of	L	Moderate increase	2,014	1,237	61.4%	Predominantly greenfield development	•	•
Matawan, Borough of	L	Substantial increase	140	11	7.6%	Mix of greenfield development, infill and redevelopment	•	•
Middletown, Township of	L	Moderate increase	2,313	703	30.4%	Mix of greenfield development, infill and redevelopment	•	•
Millstone, Township of	M	Negligible increase	3,169	1,743	55.0%	Predominantly greenfield development	•	•
Monmouth Beach, Borough of	L	Negligible increase	57	20	34.8%	Mix of greenfield development, infill and redevelopment	•	•

Jurisdiction	Wildfire Hazard Areas Present	Relative Population Trend [34](2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wildfire Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wildfire Hazard Areas	Local Characterization of Development Trends[35]	PFD on Undeveloped Parcels in mapped Wildfire Hazard Areas	PDF on undeveloped parcels in mapped wildfire hazard areas to substantially increase storm surge hazard vulnerability under existing conditions
Neptune City, Borough of	L	Substantial increase	38	11	28.6%	Mix of greenfield development, infill and redevelopment	•	•
Neptune, Township of	L	Substantial increase	833	478	57.4%	Mix of greenfield development, infill and redevelopment	•	•
Ocean, Township of	L	Moderate increase	1,009	544	53.9%	Mix of greenfield development, infill and redevelopment	•	•
Oceanport, Borough of	L	Substantial increase	218	108	49.7%	Mix of greenfield development, infill and redevelopment	•	•
Red Bank, Borough of	L	Substantial increase	79	9	11.1%	Mix of greenfield development, infill and redevelopment	•	
Roosevelt, Borough of	H	Negligible increase	65	48	74.0%	Little to no development expected	•	•
Rumson, Borough of	M	Low level increase	126	43	33.9%	Mix of greenfield development, infill and redevelopment	•	•
Sea Bright, Borough of	L	Moderate increase	38	5	14.0%	Mix of greenfield development, infill and redevelopment	•	
Sea Girt, Borough of	L	Negligible increase	20	0	0.0%	Little to no development expected		
Shrewsbury, Borough of	L	Substantial increase	126	46	36.4%	Mix of greenfield development, infill and redevelopment	•	•
Shrewsbury, Township of	L	Substantial increase	0	0	0.0%	Little to no development expected		
Spring Lake, Borough of	L	Negligible increase	17	0	0.0%	Mix of greenfield		

Jurisdiction	Wildfire Hazard Areas Present	Relative Population Trend [34](2010-2040)	Acres of Potentially Developable Undeveloped Parcels	Acres of Potentially Developable Undeveloped Parcels in Mapped Wildfire Hazard Areas	Percent of Potentially Developable Undeveloped Land in Mapped Wildfire Hazard Areas	Local Characterization of Development Trends[35]	PFD on Undeveloped Parcels in mapped Wildfire Hazard Areas	PDF on undeveloped parcels in mapped wildfire hazard areas to substantially increase storm surge hazard vulnerability under existing conditions
						development, infill and redevelopment		
Spring Lake Heights, Borough of	L	Low level increase	113	1	1.3%	Little to no development expected	•	
Tinton Falls, Borough of	M	Substantial increase	1,670	943	56.4%	Predominantly greenfield development	•	•
Union Beach, Borough of	L	Low level increase	278	247	88.8%	Mix of greenfield development, infill and redevelopment	•	•
Upper Freehold, Township of	L	Negligible increase	1,508	866	57.4%	Predominantly greenfield development	•	•
Wall, Township of	H	Moderate increase	2,446	1,796	73.4%	Predominantly greenfield development	•	•
West Long Branch, Borough of	L	Substantial increase	84	18	21.8%	Mix of greenfield development, infill and redevelopment	•	•
Monmouth County	M	Moderate increase	32,323	16,940	52.4%	Mix of greenfield development, infill and redevelopment	•	•

4.10 CIVIL UNREST

4.10.1 HAZARD DESCRIPTION

Civil disturbance is a broad term that is typically used by law enforcement to describe one or more forms of disturbance caused by a group of people. Civil disturbance is typically a symptom of, and a form of protest against, major socio-political problems. Typically, the severity of the action coincides with the level of public outrage. In addition to a form of protest against major socio-political problems, civil disturbances can also arise out of union protest, institutional population uprising, or from large celebrations that become disorderly.

Civil disturbances can take the form of small gatherings or large groups blocking or impeding access to a building or disrupting normal activities by generating noise and intimidating people. Demonstrations can range from a peaceful sit-in to a full-scale riot, in which a mob burns or otherwise destroys property and terrorizes individuals. Even in its more passive forms, a group that blocks roadways, sidewalks, or buildings interferes with public order. Often protests intended to be a peaceful demonstration to the public and the government can escalate into general chaos.

There are two types of large gatherings typically associated with civil disturbances: a crowd and a mob. A crowd may be defined as a casual, temporary collection of people without a strong, cohesive relationship. A mob can be defined as a large disorderly crowd or throng. Mobs are usually emotional, loud, tumultuous, violent, and lawless.

In the State of New Jersey, a municipality in which a civil disorder occurs bears the first and primary responsibility to control the disturbance. Civil unrest that remains uncontrolled warrants local mutual aid from neighboring municipal and/or county resources. If the civil unrest remains beyond the capabilities of local law enforcement agencies alone, limited State Police assistance may be requested. If the restoration of law and order is beyond local, county and state abilities, the Governor may declare a State of Emergency calling on federal support such as the New Jersey National Guard to restore order.

4.10.2 LOCATION

Government facilities, landmarks, prisons, and universities are common sites where crowds and mobs may gather. The concentration of buildings in and density of northeastern New Jersey, and State government buildings in Trenton may be targets of civil disturbance. New Jersey also has correctional facilities, treatment units, and youth development centers, as well as federal prison facilities and local and private facilities throughout the State that may be targets for civil unrest.

4.10.3 EXTENT

The magnitude or severity of a civil unrest situation coincides with the level of public outrage. They can take the form of small gatherings or large groups blocking access to buildings or disrupting normal activities. Civil unrest situations can also be peaceful sit-ins or a full-scale riot.

4.10.4 PREVIOUS OCCURRENCES AND LOSSES

According to the State HMP there has been one instance of civil unrest in Monmouth County:

July 7, 1970. The Asbury Park civil disturbance began when a group of young people started breaking some windows after a youth dance at the West Side Community Center on the night of July 4. The violence increased in intensity and scope over the course of the next 7 nights. While extensive and far reaching, the rioting and damage was essentially limited to the major entertainment, business, and retail district of the Springwood Avenue, on the west side of Main Street. Before it was all over, there would be over $4 million in property damage, 167 arrests, 180 injured including 15 police, and countless numbers of families made homeless.

4.10.5 PROBABILITY OF FUTURE OCCURRENCE

Although there is a low probability of occurrence, civil unrest incidents are still possible. As discussed in the Location section above, areas that are important to the State, region, and greater United States may be targets for civil unrest. These areas include universities, landmarks, correctional facilities, major industrial facilities, and others similar in nature. It is also worth noting that while the last major civil disturbance in New Jersey occurred in the 1970s, it is still possible for a future event to occur. Societal trends and emerging social issues should be watched closely as these types of issues have led to instances in the past.

4.10.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

While civil unrest is a human-caused hazard, civil unrest may arise in response to changing climate conditions and public policy. Research into the connection between climate change and civil unrest is ongoing: not enough to make a definitive statement on their connection, but not little enough to ignore a possible connection.

4.10.7 VULNERABILITY ASSESSMENT

Impacts

Civil unrest and civil disturbances can range from minor to significant events that can disrupt the functioning of a community for weeks or months. A worst case-scenario for a civil disturbance would be an incident that takes place in a large urban environment and lasts for an extended period of time. Although an event could be short in duration, the impacts and disruptions to the community can last from a day to several decades depending on social, economic, and cultural factors related to the event.

Civil disturbances often occur with little to no warning; however, certain events may trigger riots. As demonstrated in the Past Occurrences and Losses section and discussions regarding severity, riots can occur as a result of controversial court rulings, unfair working conditions, political controversy or general unrest. Riots can also be triggered as a result of favorable or unfavorable sports outcomes. Thus, generally there will be a certain degree of warning time that a riot may occur; however, achieving certainty that an incident is imminent is not possible.

Civil unrest can result in numerous secondary hazards. Depending on the size and scope of the incident, civil unrest may lead to widespread urban fire, transportation interruption, and environmental hazards. The most significant impact of civil unrest is the secondary hazard of interruption of continuity of government, which can also lead to several of the aforementioned secondary hazards. The extent of secondary hazards will vary significantly based on the extent and nature of the civil unrest.

Normally, instance of civil unrest will have a minimum impact on the environment. However, if petroleum or other chemical facilities were a target for vandalism or large-scale fires occurred, the impact on the environment could be significant.

Exposure and Damages

For the purposes of measuring exposure, the entire population of Monmouth County is exposed to the civil unrest hazard. Those that live in densely populated areas, those living near colleges/universities, correctional facilities, landmarks, and other areas of significance may have a higher exposure and are thus more vulnerable to the effects of civil unrest.

Measuring the economic impact of civil unrest in Monmouth County is difficult. Elements that contribute to this are the volatility of the nature of civil disturbances, and the uncertainty of the duration of an incident. Local economies may be affected by a civil disturbance, as was the case during the Asbury Park Riots, which targeted the business sector in the community during the peak of tourist season. For the purposes of this assessment, the entire Monmouth County economy is considered exposed to the effects of civil disturbances. Should a large-scale civil unrest incident occur, the economy of Monmouth County will be affected and is therefore vulnerable. For example, a prolonged strike will affect production and tax revenues. Also, if a widespread riot occurred it would interrupt daily commerce, thus affecting the economy.

Critical facilities may be targets for civil unrest disturbances. Disruptions to critical facilities may have cascading secondary effects such as power outages. Because these facilities are vulnerable to civil unrest and may be a focal point during a protest, these facilities will need to be protected during incidents. It is difficult to quantify the potential losses to critical facilities because of the unpredictability of civil disturbances and their duration. The replacement cost value for critical facilities provides a total risk exposure.

4.11 CYBER ATTACK

4.11.1 HAZARD DESCRIPTION

Cyber terrorism is the use of existing computers and information, particularly over the Internet, to cause physical or financial harm or a severe disruption of infrastructure service. Transportation, public safety, and utility services are all critical, and are highly dependent on information technology. The motive behind such disruptions can be driven by religious, political, or other objectives.

4.11.2 LOCATION

Cyber threats to critical infrastructures can be posed by anyone with the capability, technology, opportunity, and intent to do harm. Potential threats can be foreign or domestic, internal or external, State-sponsored or a single rogue element. Terrorists, insiders, disgruntled employees, and hackers are included in this profile. The fact that most of the nation's vital services are delivered by private companies creates a significant challenge in assigning the responsibility for protecting our critical infrastructures from cyber-attacks. Across Monmouth County, countless systems rely on computers for day-to-day operations including but not limited to traffic signals, power plants, HVAC systems, as well as systems responsible for ensuing Monmouth County’s local governments can operate. While these are just a few examples of critical systems vulnerable to cyber-attacks, it should be noted that an attack could cripple not only the operations of Monmouth County’s systems but also the economy.

4.11.3 EXTENT

The magnitude of extent of an incident will vary greatly based on the extent and duration of the impact. Additionally, the extent will vary based upon which specific system is affected by an attack, the warning time, and ability to preempt an attack. Attacks can be carried out by single individuals, domestic or foreign terror organizations, or even nation-states. Cyber-attacks can also vary in regard to their geographic extent; all levels of government from municipal to national are at risk.

The New Jersey Cybersecurity and Communications Integration Cell (NJCCIC) profiles different threats to various systems that can be impacted by an attack, providing some context of the extent an attack could have. Table 4.11 - 1 Threat of Malware to Different Systems describes the malware that can impact different systems.

Table 4.11 - 1 Threat of Malware to Different Systems

Threat	Description of Malware
Android	Malicious software designed to exploit the Android operating systems (OS) running on smartphones, tablets, and other devices. Some variants of Android malware have the capability of disabling the device, allowing a malicious actor to remotely control the device, track the user's activity, lock the device, or encrypt or steal personal information transmitted from or stored on the device. As users are increasingly turning to mobile devices for both business and personal use, cyber threat actors are devoting their efforts to developing malware designed to compromise the device software.
Botnets	A group of internet-connected computers and devices that have been infected by malware that allows a malicious actor to control them remotely. The malicious actor then uses the botnet for nefarious purposes such as sending spam email, stealing data, spreading additional malware infections to other devices, generating illicit advertising revenue through click-fraud, mining cryptocurrencies, or conducting distributed denial-of-service (DDoS) attacks. In the cases where botnets are used to conduct DDoS attacks, these infected devices are used to generate an excessive amount of network traffic designed to overwhelm a website, server, or online service to the point that legitimate users cannot access it.
Exploit Kits	Toolkits that automate the exploitation of vulnerabilities in popular software applications to maximize successful infections and serve as a platform to deliver malicious payloads such as Trojans, spyware, ransomware, and other malicious software. Most users will encounter EKs from visiting seemingly legitimate, high-traffic websites that either contain links to EKs embedded within malicious advertising (malvertising) or have malicious code hidden directly within the website itself. Malicious URLs linking to EKs are commonly distributed through spam email and spear-phishing campaigns.
ICS	A collective term for several types of control systems and other equipment used to operate and/or automate industrial processes, and includes supervisory control and data acquisition (SCADA) systems – often incorrectly used interchangeably with ICS – and distributed control systems (DCS).
IOS	Malicious software designed to exploit Apple's iOS operating system running on smartphones, tablets, and other devices. Some variants of iOS malware have the capability of disabling the device, allowing a malicious actor to remotely control the device, track the user's activity, lock the device, or encrypt or steal personal information transmitted from or stored on the device. As users are increasingly turning to mobile devices for both business and personal use, cyber threat actors are increasingly devoting their efforts to developing malware designed to compromise mobile devices, including operating systems, like iOS, and applications, like those available in the App Store. Android devices have historically seen more malware threats than iOS largely due to the open-source operating system; however, malware specifically targeting iOS has increased in the last two years.

Threat	Description of Malware
MACOS	Though the majority of known malware targeting operating systems are made to exploit Microsoft Windows, devices running macOS are vulnerable as well. Furthermore, as macOS has become increasingly popular, more malware has been created to target macOS. More macOS malware was discovered in the second quarter of 2017 than in all of 2016.
Point of Sale (PoS)	Malicious software designed to steal credit and debit card data from payment processing systems, known as point-of-sale (PoS) terminals.
Ransomware	Malicious software (malware) that attempts to extort money from victims by restricting access to a computer system or files. The most prevalent form of this profit-motivated malware is crypto-ransomware, which encrypts files into encoded messages that can only be decrypted (decoded) with a key held by the malicious actor.
Trojans	A type of malware that, unlike viruses and worms, does not self-replicate. Named after the mythological wooden horse used to sneak Greek warriors through the gates of Troy, trojans are often disguised as legitimate software to avoid detection or trick users into installing the trojan onto their system. Users can be exposed to trojans through numerous vectors, such as clicking on links or opening attachments in phishing emails, other forms of social engineering, malicious advertising (malvertisting), or by visiting compromised websites, known as drive-by downloads. Once a trojan executes, it often downloads other malware onto the system or provides an attacker with a backdoor to gain access and conduct further malicious activity, such as stealing, deleting, or modifying data.

SOURCE: NJCCIC, 2017

4.11.4 PREVIOUS OCCURRENCES AND LOSSES

Cyber terrorism is an emerging hazard that can impact the county's computer infrastructure and the systems and services that are provided to the public. Across the United States, concerns over cyber terrorism are growing; former FBI director Louis Freeh warns that cyber-terrorism could have a crippling effect in the United States (ANI, 2013).

In 2016, New Jersey released the annual statistics on cyber breaches for the first time. The information released details breaches that involve the unauthorized access to personal information, such as a name, social security number, driver's license number, bank account, etc. The state police had 676 data breaches reported to them in 2016, affecting over 116,000 New Jersey account holders (Department of Law and Public Safety, Office of the Attorney General, 2016). In 2017, 958 data breaches were reported to the New Jersey State Police. This is a 41% increase in security breaches from 2016[36].

In 2018, a hacker maliciously attacked a small business in Asbury Park, stealing their domain name, hacking emails, and taking over the business' social media accounts. As a result, the business had to rename their company[37]

4.11.5 PROBABILITY OF FUTURE OCCURRENCE

Security experts describe the threat of cyber terrorism as eminent and highly likely to occur in any given year in New Jersey. As illustrated by the Freeh comments, cyber terrorism is expected to have a significant impact on the United States and New Jersey. The level of success of an attack and the

36 https://www.nj.gov/oag/newsreleases18/pr20181023b.html

37 https://www.app.com/story/money/business/consumer/press-on-your-side/2019/01/22/asbury-park-small-business-nearly-killed-hacker-afterrain-epoch-trading-post/2265025002/

subsequent damage it can create will vary greatly. Intrusion detection systems log thousands of attempts in a single month.

Although number of attempts are increasing, municipalities have also been investing in capabilities to reduce the vulnerability to cyber-attack.

4.11.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

This plan does not recognize the link between cyber-attack and climate change.

4.11.7 VULNERABILITY ASSESSMENT

Impacts

A cyber-attack can have potentially severe consequences. The following are potential impacts.

Table 4.11 - 2 Cyber Attack Impact Summary

Consideration	Description
General Public	Direct loss of life may occur when systems like Next Generation 9-1-1 (NG911) are attacked[38]. Indirect injuries or deaths may result from secondary effects to critical life-sustaining resources such as energy and water.
Response Personnel	No direct affects to the health and safety of response personnel are expected; however, critical response systems may be affected.
Property, Facilities and Infrastructure	Effects can range from annoyance to complete shutdown of critical infrastructures caused by infiltration of supervisory control and data acquisition (SCADA) systems. Secondary effects could disturb public welfare and property by denying services or providing false readings.
Economic	Because of the heavy reliance on the electronic transfer of economic and commercial information, the economy could be affected by communication difficulties.
Environment	Generally, cyber terrorism has no direct effect on the environment; however, the environment may be affected should a release of a hazardous material occur because of critical infrastructure failure.
Continuity of Operations	Severe effects to continuity of operations could result if a cyber-attack reached critical operational systems or systems that were needed to carry out the operation.
Reputation of the Entity	If exposed vulnerabilities were known and not reduced or eliminated before the attack, the entity would suffer major damage to their reputation for not taking action before the incident.
Delivery of Services	Cyber-attacks may affect delivery of services if the system was infiltrated and directed to malfunction by self-destructing or overloading.
Regulatory and Contractual Operations	Cyber-attacks would have no significant effect on regulatory or contractual obligations, other than the possible elimination of electronic records, which would affect both.

A cyber terrorism attack can occur with relatively little or no warning. The New Jersey Office of Homeland and Preparedness is charged with gathering intelligence and monitoring cyber-terrorism threats affecting the State. At the federal level, numerous agencies (such as FBI and CIA) are working collaboratively to thwart cyber-terrorism attacks. The warning time depends upon the ability of these

38 https://www.dhs.gov/sites/default/files/publications/Cybersecurity%20Risks%20for%20NG9-1-1%20%28100418%29_508C_FINAL.pdf

agencies to recognize that a threat exists and their ability to stop the attack. Even with these agencies on task to monitor cyber threats, a cyberattack can occur with no warning.

Because virtually all critical systems are reliant upon computer systems, the secondary hazards that could result from a cyber-terrorism attack could be devastating. For example, many of New Jersey's roadway systems rely on sophisticated traffic control systems that prevent gridlock and accidents daily. Without these systems, the risk of not only auto accidents increases, but also hazardous materials in-transit incidents. Additionally, a cyber-attack on a nuclear power plant could have devastating consequences should the plant suffer an intentional catastrophic failure. A cyber-attack could also completely incapacitate the communications infrastructure not only in New Jersey but across the United States, leading to disturbing secondary consequences and hazards. Because the power grid is also largely controlled by computer systems, a widespread power outage is also a possibility. A failure of the power grid would impact individuals reliant on power such as those with medical needs. The number of critical systems reliant on computer systems are numerous, thus disruption of one or more of the systems would cause severe secondary-cascading hazards.

Exposure and Damages

For the purposes of this plan, the entire population of New Jersey is considered exposed to the effects of a cyber-terrorism attack. Because it is difficult to predict the particular target of cyber terrorism, assessing vulnerability to the hazard is also difficult. All populations who directly use a computer or those receiving services from automated systems are vulnerable to cyber terrorism. Although all individuals in New Jersey are vulnerable to an attack, certain types of attacks would impact specific segments of the population.

- If the cyber-attack targeted the State's power or utility grid, individuals with medical needs would be impacted the greatest. These populations are most vulnerable because many of the life-saving systems they rely on require power. Also, if an attack occurred during months of extreme hot or cold weather, New Jersey's elderly population (those 65 years of age and older) would be vulnerable to the effects of the lack of climate control. These individuals would require shelter or admission to a hospital. Other populations vulnerable to the secondary effects of cyber terrorism are young children.

- If a cyber-attack targeted a facility storing or manufacturing hazardous materials, individuals living adjacent to these facilities would be vulnerable to the secondary effects, should the attack successfully cause a critical failure at that facility. Individuals living within 10 miles of a nuclear power plant would be vulnerable should an attack occur at that caused a failure at a facility.

While these examples illustrate the vulnerability of specific populations to cyber-attacks, it is important to reiterate that because of the reliance on computerized systems, the entire population of New Jersey is vulnerable to cyber terrorism.

A significant portion of Monmouth County's economy is exposed to the effects of cyber-terrorist attacks. Cyber-crimes against banks and other financial institutions can cost many hundreds of millions of dollars every year. Cyber theft of intellectual property and business-confidential information can cost developed economies billions of dollars—how many billions is an open question. These losses could be considered simply the cost of doing business, or they could be a major new risk for companies and nations as these illicit acquisitions damage global economic competitiveness and undermine technological advantage (McAfee, 2013).

The cost of malicious cyber activity involves more than the loss of financial assets or intellectual property. Cyber-crimes can cause damage to a company's brand and reputation, consumer losses from fraud, the opportunity costs of service disruption and "cleaning up" after cyber incidents, and the cost of increased spending on cybersecurity (McAfee, 2013). In the United States, the costs of cyber terrorism is estimated somewhere between $24 billion and $120 billion annually. These costs represent approximately 0.2% to 0.8% of the total GDP in the United States (McAfee, 2013).

Given the proliferation of electronic commerce and the reliance on electronics, virtually all elements of New Jersey's economy are vulnerable to cyber-attacks. The secondary impacts of a significant attack would be devastating to the economy. For example, an attack that caused the loss of power to hundreds of thousands of businesses during peak holiday shopping months could potentially cost the State millions of dollars in tax revenue if these businesses were closed. Additionally, a disruption in New Jersey's manufacturing, agricultural, or tourism sectors would have devastating impacts on the economy. While it is difficult to quantitatively measure the economic impact of a cyber-terrorism attack, it is safe to say that the impact would be great, thus the economy is vulnerable to cyber-terrorism attacks.

Critical facilities are vulnerable to cyber-terrorism attacks based on the significance of the facilities, and the potential to interrupt critical systems in the county. As previously mentioned, many critical facilities are reliant upon computer networks to monitor and control critical functions. An example is nuclear power plants, which rely on sophisticated networks to prevent catastrophic failure. A cyber-terrorist attack could result in catastrophic failure of one of these facilities. Likewise, the power grid is reliant upon computer systems to distribute power to the county. These are just two examples of how critical facilities are vulnerable to cyber-terrorism attacks. Given the importance of critical facilities to daily living activities, these facilities are highly vulnerable to cyber-terrorism attacks.

It is difficult to quantify the potential losses to state facilities caused by a cyber-attack. As noted in the vulnerability assessment above, the physical facilities would not be damaged, other than the value of computer equipment damaged. The more significant loss would be to the functions of the facilities targeted and their value to the population of Monmouth County during the period of malfunction.

4.12 ECONOMIC DISRUPTION

4.12.1 HAZARD DESCRIPTION

Economic Disruption is a breakdown in normal commerce facilitated by actions such as the destabilization of currency and/or hyperinflation, which results in social chaos or civil unrest. The term describes a variety of economic conditions from severe depressions with high unemployment and bankruptcy such as the Depression of the 1930s in the United States, to breakdowns of normal economic conditions such as hyperinflation or the effects of a sharp decline in population that causes an economic downturn.

4.12.2 LOCATION

An economic disruption may impact some or all of Monmouth County, depending on the size and scope of the crisis. A major economic disruption would likely extend beyond Monmouth County and affect the entire State of New Jersey if not the nation. While social chaos and civil unrest could occur in specific locations, the effects of a severe and long-term event would eventually extend to all segments of the population.

4.12.3 EXTENT

Economic disruption can be accompanied by social chaos and civil unrest. See Section 4.11 Civil Unrest for extent information regarding civil unrest.

4.12.4 PREVIOUS OCCURRENCES AND LOSSES

Two previous occurrences of a major economic disruption in New Jersey include the Great Recession of 2007, and the Great Depression of the 1930s. Both examples are described in the sections below.

The Great Depression

The Great Depression began when the stock market crashed on October 29, 1929, which marked the official beginning of the depression. Following the stock market crash, there was a run on the banks, forcing many thousands of banks to close. Businesses and segments of industry were also affected. Having lost much of their own capital in either the Stock Market Crash or the bank closures, many businesses started cutting back their workers' hours or wages. In turn, consumers began to curb their spending, refraining from purchasing such things as luxury goods. This lack of consumer spending caused additional businesses to cut back wages or, more drastically, to lay off some of their workers. Even with these cuts, many businesses could not stay open and soon closed their doors, leaving all their workers unemployed (Rosenberg, 2017).

The Great Depression continued through the 1930s until the bombing of Pearl Harbor and the entrance of the United States into World War II. Once the United States was involved in the war, both the United States people and industry became essential to the war effort. Weapons, artillery, ships, and airplanes were needed quickly. Men were trained to become soldiers and the women were kept on the home-front to keep the factories going. Food needed to be grown to feed the national population and to send overseas (Rosenberg, 2017).

In the United States, 13 million people were unemployed, and in 1932, 34 million people belonged to a family with no regular full-time wage earner. Industrial production fell nearly 45% and homebuilding dropped by 80% between 1929 and 1932. Unemployment rates soared across the country, peaking at 80% in Toledo, Ohio. Finally, from 1929 through 1933 the stock market lost approximately 90% of its value.

Before the Depression, New Jersey was experiencing the prosperity felt throughout the country in the 1920s. Developments brought many people a sense of hope for the future. However, this progress came crashing down with the onset of the Great Depression. New Jersey was severely hit when thousands of workers were laid off and had to rely on relief checks to survive. The impacted factories could not sell what they produced. The State attempted to aid the unemployed by establishing the Emergency Relief Administration, which gave $10 million to bankrupt areas. Franklin D. Roosevelt's Works Progress

Administration (WPA) was a significant program in the New Deal that helped New Jersey succeed in establishing a strong workforce. WPA workers helped to improve roads, buildings, and other facilities and work from writers and artists aided in preserving the history of the time period (Kiefer, 2005).

Great Recession 2007

The Great Recession of 2007 affected the global economy and is the most recent example of a financial crisis affecting Monmouth County. The official time period of the recession occurred from December 2007 through June 2009. However, the effects of the recession continue to linger to the present. While the specific triggers of the recession have been debated, a combination of bursting of the United States housing bubble and subsequent foreclosures, subprime lending, mortgage fraud, predatory lending, high private debt limits, and mortgage underwriting are all cited as triggers that contributed to the financial crisis.

In the United States, the effects of the Great Recession were severe and far-reaching. The gross domestic product (GDP) contracted nearly $850 billion or 5.5% below its potential level, from 2008 through 2010 (FRED, 2013). The unemployment rate rose from its pre-recession level of 5% to over 10% at its peak late in 2009 (FRED, 2013). The number of unemployed individuals in the United States rose to 15 million at its peak in 2009, up from 7 million at the pre-crisis level (FRED, 2013). The housing market was particularly hard hit as housing prices fell approximately 30% from their peak in mid-2006 (FRED, 2013). Additionally, the stock market was affected as the Standard & Poor's (S&P) 500 index fell 57% from the October 2007 peak of 1,565, to a low of 676 in March 2009. Stock prices rose to pre-recession peak levels in April 2013.

New Jersey's recession began in January 2008, one month after it started nationally, and lasted through July 2009. The State lost 161,300 jobs, or 4 percent of its employment base. During the recession's first year, the State and national job bases declined at the same rate, but in 2009, the Garden State had shed jobs at a slower pace: 1.8 percent compared to the 2.9 percent national rate. With the deepening recession, New Jersey's unemployment rate increased sharply, from 4.5 percent in December 2007 to 6.8 percent 1 year later, and to 9.8 percent in September 2009. At the same time, growth in personal income fell, from 5.7 percent in 2007 to 3. percent in 2008 (Manas, 2009). The Great Recession also led to a significant tightening of the State budget. In fact, in 2009 New Jersey had a budget gap of $9 billion, or roughly 25 percent of the State's budget (Deitz et al. 2010). It is forecasted that it will take until 2019 for New Jersey to fully recover from the recession (Manas, 2009). Although this recession has adversely affected the State, its effects pale in comparison to the Great Depression of the 1930s.

Although the Great Recession and the Great Depression were significant economic disruptions, they still do not represent true economic collapses. The effects of a true economic disruption on society would be much more severe than the effects experienced during these past occurrences.

4.12.5 PROBABILITY OF FUTURE OCCURRENCES

The probability of an economic disruption is low, especially in New Jersey and in the United States as a whole. Although it was the closest the United States has come to a complete economic disruption, the Great Depression of the 1930s was not an economic disruption in the true sense of the definition.

4.12.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

Sea level rise influenced by climate change may force affected property values lower. This could have an impact on revenue and local and state debt. Unlike prior housing downturns, there will not be a recovery to these property values.

4.12.7 VULNERABILITY ASSESSMENT

Impacts

Events that include characteristics of economic disruption can range in severity from severe recessions (2007) and depressions (1930s) to complete economic failure. A complete economic disruption is characterized by hyperinflation, high unemployment rates, and societal breakdown. As mentioned, a complete economic disruption has never occurred in the United States.

Economic disruptions can occur quickly with relatively little warning (such as Black Tuesday). However, many experts believe they are able to recognize and warn against the signs of an economic disruption. Social disruption such as coups and wars can trigger an economic disruption to quickly follow.

Civil unrest is one of the primary secondary effects of economic disruption. During periods of economic instability, societal conditions may deteriorate, leading to civil unrest. Additionally, during or near economic disruptions workers may go on strike, as did the ditch diggers who went on strike in New Jersey during the Great Depression.

Another secondary hazard during economic disruption is pandemic. Because many families are unable to meet basic hygiene needs, diseases historically spread quickly through communities. During the Great Depression, the spread of tuberculosis significantly impacted large segments of the population.

Exposure and Damages

Because an economic disruption would affect all segments of the population, all Monmouth County residents are vulnerable to the impact of this hazard. Although all of the population would be affected, the very young and elderly would be more vulnerable to the secondary hazard of pandemic than the rest of the population. Also, very young and elderly residents are vulnerable to the effects of malnutrition, which often results during these incidents. Aside from the health effects during economic disruption, lower-income individuals who struggle to cover average costs of living during thriving financial times would be greatly affected by economic disruption and would therefore be more vulnerable.

The entire Monmouth County economy is exposed to the effects of economic disruption. In today's global economy, Monmouth County's economy is vulnerable to disruption, and the effects of financial disruptions of governments around the world. The Great Recession demonstrated how economic conditions in one nation affect others around the world, demonstrating that counties and sub-national governments are vulnerable to the effects of economic disruption. The Great Recession also illustrated the ways in which state governments are vulnerable. During the most recent recession, New Jersey experienced a $9 million budget shortfall. Also, it is apparent the economic recovery can take years, even decades; as of 2013, the United States is still recovering from the Great Recession.

Critical facilities are also exposed to the effects of economic disruption. Maintaining these facilities and infrastructure systems will be particular challenging when agencies managing these facilities lose operating capital, and thus cannot maintain the facilities. This may lead to critical infrastructure failure.

Whether they are privately or publicly owned, all critical facilities will be vulnerable to economic disruption.

4.13 PANDEMIC

4.13.1 HAZARD DESCRIPTION

A pandemic is a global outbreak of disease. Pandemics happen when a new virus emerges to infect people and can spread between people sustainably. Because there is little to no pre-existing immunity against the new virus, it spreads worldwide. Conversely, an epidemic is much more limited in effect and impact and is usually restricted to one locale (CDC, 2020).

In New Jersey, a municipality in which a pandemic occurs bears the first and primary responsibility to control the epidemic. Pandemics that remain uncontrolled warrant local mutual aid from neighboring municipal and/or county and state resources. If the epidemic remains beyond the capabilities of local law enforcement agencies alone, limited state police assistance may be requested. If the restoration of public health is beyond local, county, and state abilities, the Governor may declare a State of Emergency calling on Federal and worldwide support.

This section discusses some of the most severe global disease outbreaks that affected New Jersey within the last 100 years.

Foodborne Disease Outbreaks

Food-borne illness is caused by consuming contaminated foods or beverages. Many different disease-causing microbes or pathogens can contaminate foods, so there are many different types of food-borne illnesses. Food-borne illness, caused by a variety of bacteria, viruses, and parasites, can be caused by consuming improperly prepared food items, poor hygiene among food handlers, or contamination in food processing facilities or farms. (NJDOH, 2020).

Mumps

Mumps is a contagious disease that is caused by a virus. It typically starts with a few days of fever, headache, muscle aches, tiredness, and loss of appetite (CDC, 2020).

Norovirus

Norovirus is a very contagious virus that spreads easily and causes vomiting and diarrhea in people. People with norovirus illness can shed billions of norovirus particles however only a few virus particles can make other people sick. The norovirus is not related to Influenza. (CDC, 2020).

Influenza

Influenza, known as the flu, comes in four type of viruses: A, B, C and D. Human influenza A and B viruses cause seasonal epidemics of disease (known as the flu season) almost every winter in the United States. Influenza A viruses are the only influenza viruses known to cause flu pandemics. Pandemics happen when new (novel) influenza A viruses emerge which are able to infect people easily and spread from person to person in an efficient and sustained way (CDC, 2020).

West Nile Virus

West Nile Virus is the leading cause of mosquito-borne disease in the continental United States. There are no vaccines to prevent or medications to treat the virus in people. Fortunately, most people infected do not feel sick. About 1 in 5 people who are infected develop a fever and other symptoms. About 1 out of 150 infected people develop a serious, sometimes fatal, illness (CDC, 2020).

Zika Virus

Zika Virus disease is caused by the Zika virus, which is spread to people primarily through the bite of an infected mosquito. The illness is usually mild with symptoms lasting up to a week, and many people do not have symptoms or will have only mild symptoms. However, Zika virus infection during pregnancy can cause a serious birth defect called microcephaly and other severe brain defects (CDC, 2020).

Coronavirus

Three versions of the coronavirus have affected New Jersey in the last two decades; Severe Acute Respiratory Syndrome (SARS-CoV), Middle East Respiratory Syndrome (MERS-CoV), and "SARS-CoV-2" also named Coronavirus Disease 2019 (COVID-19). Coronaviruses are a large family of viruses that are common in people and many different species of animals, including camels, cattle, cats, and bats. Animal coronaviruses can infect people and then spread between people, which is how SARS, MERS, and COVID-19 originated (CDC, 2020).

- SARS was first reported in Asia in February 2003 and spread to more than two dozen countries in North America, South America, Europe, and Asia before the SARS global outbreak of 2003 was contained. SARS causes mild to moderate upper respiratory tract illness in humans, including the common cold. No single medicine can effectively treat SARS. Different types of treatment regimens have been used for people who are severely ill and hospitalized including antibiotics, antivirals and steroids. Currently, there is no known SARS transmission anywhere in the world (CDC, 2020).

- MERS was first reported in Saudi Arabia in September 2012, however after further investigation, the first known cases of MERS occurred in Jordan in April 2012. Most MERS patients developed severe respiratory illness with symptoms of fever, cough and shortness of breath. About 3 or 4 out of every 10 patients reported with MERS have died (CDC, 2020).

- COVID-19 was first detected in Wuhan, Hubei Province, China and which has now been detected in more than 150 locations internationally, including in the United States. The complete clinical picture with regard to COVID-19 is not fully known. Reported illnesses have ranged from very mild (including some with no reported symptoms) to severe, including illness resulting in death. While information so far suggests that most COVID-19 illness is mild, a report out of China suggests serious illness occurs in 16% of cases. Older people and people of all ages with severe chronic medical conditions, such as heart disease, lung disease, and diabetes, seem to be at higher risk of developing serious COVID-19 illness. On March 11, 2020, the COVID-19 outbreak was characterized as a pandemic by the World Health Organization. (CDC, 2020).

4.13.2 LOCATION

This section covers common ways diseases are transmitted over a wide geographic area.

Foodborne Disease Outbreaks

Many outbreaks are local in nature. They are recognized when a group of people realize that they all became ill after a common meal. However, outbreaks are increasingly being recognized that are more widespread, that affect persons in many different places, and that are spread out over several weeks (NJDOH, 2020).

Mumps

Although the Measles, Mumps, and Rubella (MMR) vaccine helps limit the size, duration, and spread of mumps outbreaks, they can still occur in communities of people who previously had one or two doses of the MMR vaccine. This is particularly common in close-contact settings including households, schools, universities, athletics teams and facilities, church groups, workplaces, and large parties and events (CDC, 2020).

Norovirus

Anyone can get infected and sick with norovirus. The virus is spread by accidently getting tiny particles of feces or vomit from an infected person by direct contact with an infected person, consuming contaminated food or water, and/or touching contaminated surfaces then putting your unwashed hands in your mouth (CDC, 2020).

Influenza

In terms of pandemic influenza, all counties may experience pandemic influenza outbreak caused by factors such as population density and the nature of public meeting areas. Densely populated areas will spread diseases quicker than less densely populated areas.

West Nile Virus

West Nile Virus is most commonly spread to people by the bite of an infected mosquito. Cases of West Nile Virus occur during mosquito season, which starts in the summer and continues through fall.

Zika Virus

Zika is spread mostly by the bite of an infected Aedes species mosquito. These mosquitoes bite during the day and night. Zika can be passed from a pregnant woman to her fetus. Infection during pregnancy can cause certain birth defects. The virus is also spread through sex and blood transfusions, although blood transfusion transmittal has not been confirmed (CDC, 2020). New Jersey is particularly vulnerable to travel-related cases because there is a significant segment of residents who travel back and forth to Puerto Rico, where a National Emergency was declared in 2016 due to the virus.

Coronavirus

- Transmission of SARS-CoV is primarily from person to person. It appears to have occurred mainly during the second week of illness, which corresponds to the peak of virus excretion in respiratory secretions and stool, and when cases with severe disease start to deteriorate clinically. Most cases of human-to-human transmission occurred in the health care setting, in the absence of adequate infection control precautions. Implementation of appropriate infection control practices brought the global outbreak to an end (WHO, 2020).

- MERS-CoV has spread from ill people to others through close contact, such as caring for or living with an infected person (CDC, 2020).

- The COVID-19 virus is thought to spread mainly from person-to-person. The virus can spread by people who are in close contact with one another (within about 6 feet) or through respiratory droplets produced when an infected person coughs or sneezes (CDC, 2020).

4.13.3 EXTENT

The exact size and extent of an infected population depends on how easily the illness is spread, the mode of transmission, and the amount of contact between infected and uninfected individuals. The transmission rates of pandemic illnesses are often higher in more densely populated areas. The transmission rate of infectious diseases will depend on the mode of transmission of a given illness.

The magnitude of a pandemic may be exacerbated by the fact that an influenza pandemic will cause outbreaks across the United States, limiting the ability to transfer assistance from one jurisdiction to another. Additionally, effective preventative and therapeutic measures, including vaccines and other medications, will likely be in short supply or will not be available.

During a pandemic wave in a community, during a six to eight-week outbreak, between 25 percent and 3 percent of persons will become ill. Among working-aged adults, illness attack rates will be lower than in the community as a whole. A CDC model suggests that at the peak of pandemic disease, about 10% of the workforce will be absent because of illness or caring for an ill family member. Impacts will likely vary between communities and work sites and may be greater if significant absenteeism occurs because persons stay home for fear of becoming infected (Global Security, 2011).

In 1999, the World Health Organization (WHO) Secretariat published guidance for pandemic influenza and defined the six phases of a pandemic. Updated guidance was published in 2009 to redefine these phases. This schema is designed to provide guidance to the international community and to national governments on preparedness and response for pandemic threats and pandemic disease.

In New Jersey, health and supporting agency responses to a pandemic are defined by the WHO phases and federal pandemic influenza stages, and further defined by New Jersey pandemic situations. The State's situations are similar, but not identical to the United States Department of Homeland Security federal government response stages. Refer to the State HMP Table 5.21-2 for the Federal and New Jersey Pandemic Phases and Situations in detail.

Vaccination Rates in Monmouth County

In Monmouth County, approximately 92.9% of children in Childcare, Pre-K, Kindergarten, and Grade 6 were immunized during the 2017-2018 school year, down from 93.7% during the 2016-2017 school year (Annual Immunization Status Reports, Communicable Disease Service, New Jersey Department of Health). Of the approximately 7% of non-immunized children, approximately 4.7% claimed a Religious Exemption, up from 3.6% during the 2016-2017 school year. Monmouth County has the second highest percent of Religious Exemptions in the State of New Jersey for the 2017-2018 school year behind Hunterdon County (5.1%). Only 0.4% of enrolled children claimed a medical exemption during the 2016-2017 and 2017-2018 school years (Annual Immunization Status Reports, Communicable Disease Service, New Jersey Department of Health).

4.13.4 PREVIOUS OCCURRENCES AND LOSSES

Table 4.13 - 1 Previous Pandemic Occurrences provides details on pandemic events that have impacted New Jersey.

Table 4.13 - 1 Previous Pandemic Occurrences

Date(s) of Event	Event Type	Area Affected	Description
1918-1919	1918 "Spanish" Influenza Pandemic	Statewide	The influenza pandemic of 1918-1919 caused between 20 and 40 million deaths, more than World War I. This pandemic has been cited as the most devastating pandemic in recorded history. More people died of influenza in a single year than in the four years of the Black Death Bubonic Plague from 1347 to 1351. By September 27, 1918, the State health officer announced that the disease "was unusually prevalent" throughout New Jersey. The State was reporting that 2,000 cases had been reported in the preceding three days. On October 10, State officials formally banned all public gatherings. By October 15, officials had reported 88,256 cases of influenza. By the October 22, State authorities estimated that there were at least 149,540 cases, with 4,398 deaths being officially reported. On October 22, the pandemic peaked in New Jersey. On that day, there were 7,449 new cases and 366 deaths. The situation slowly improved after the third week of October.
1999-2002	West Nile Virus Outbreak	Statewide	WNV was identified in New York City in 1999, and spread rapidly across the United States, with human disease documented in 39 states and the District of Columbia. In 2002, WNV spread westward and activity was reported in all but six states (Arizona, Utah, Nevada, Oregon, Alaska, and Hawaii) and triggered the largest human arboviral encephalitis epidemic in U.S. history. From June 10 to December 31, 2002, there were 4,156 cases of WNV (including 284 deaths) reported in 39 states and the District of Columbia.
2002-2003	SARS coronavirus (SARS-CoV)	Statewide	SARS coronavirus (SARS-CoV) – virus identified in 2003. SARS-CoV is thought to be an animal virus from an as-yet-uncertain animal reservoir, perhaps bats, that spread to other animals (civet cats) and first infected humans in the Guangdong province of southern China in 2002. SARS affected 26 countries and resulted in more than 8,000 cases in 2003. Since then, a small number of cases have occurred as a result of laboratory accidents or, possibly, through animal-to-human transmission (WHO, 2020)
04/15/2009	Global H1N1 Pandemic	Statewide	The first novel H1N1 patient in the United States was confirmed April 15, 2009. The second patient was confirmed on April 17, 2009. On April 22, the CDC activated its Emergency Operations Center to better coordinate the public health response. On April 26, 2009, the U.S. government declared a public health emergency and began actively and aggressively implementing the country's pandemic response plan. By June 19, 2009, all 50 states in the United States reported novel H1N1 infection. On June 11, 2009, the WHO signaled that a global pandemic of H1N1 was underway by raising the worldwide pandemic alert level to Phase 6. At the time, more than 70 countries had reported cases of novel influenza A (H1N1) infection. In total there were 18,306 lab-confirmed deaths as a result of H1N1 worldwide. In the United States between April 2009 and August 2009 there were 9,079 cases that required hospitalization and 593 deaths. In New Jersey, cases were widespread in July 2009, with 1,414 confirmed cases and 15 deaths.

Date(s) of Event	Event Type	Area Affected	Description
January – 2/1/2011	Escherichia coli O157:H7	N/A	Between January 10 and February 15, 2011, a total of 14 persons were infected with the outbreak strain of Escherichia coli O157:H7 were reported in five states, including two reports in New Jersey. Three of the 14 were hospitalized; no deaths occurred. The outbreak was associated with Lebanon bologna.
February – September 2011	Salmonella Heidelberg	N/A	Between February 27 and September 13, 2011, a total of 136 persons infected with the outbreak strain of Salmonella Heidelberg were reported from 34 states, including one report in New Jersey. Ill persons ranged in age from less than one year old to 90years old. Thirty-seven people were hospitalized; one death was
April – November 2011	Salmonella Heidelberg	N/A	Between April 1 and November 17, 2011, a total of 190 illnesses occurred due to Salmonella Heidelberg that was linked to kosher broiled chicken livers. Sixty-two of those illnesses were reported in New Jersey. Ill person's ages ranged from less than 1 year old to 97 years old. Thirty of the infected people were hospitalized.
8/1/2011	Salmonella Enteritidis	N/A	A total of 43 individuals infected with the outbreak strain of Salmonella Enteritidis were reported from five states, including two cases in New Jersey. Ill persons ranged in age from less than one year old to 94 years old. Two patients were hospitalized; no deaths occurred. The outbreak was linked to Turkish pine nuts purchased from bulk bins at Wegmans grocery stores.
January – June 2012	Salmonella Infantis	N/A	Between January 4 and June 26, 2012, a total of 49 individuals (human) were infected with the outbreak strain of Salmonella Infantis linked to multiple brands of dry dog food produced by Diamond Pet Foods produced at a facility in Gaston, South Carolina. Ten people were hospitalized; there were no deaths. Twenty states reported an outbreak, including two cases in New Jersey. Ill persons ranged in age from less than 1 year old to 82 years old.
January – July 2012	Salmonella Bareilly and Salmonella Nchanga	N/A	Between January 1 and July 7, 2012, a total of 425 individuals were infected with the outbreak strain of Salmonella Bareillyand Salmonella Nchanga. Twenty-eight states reported outbreaks, included 46 cases in New Jersey. The outbreaks were associated with an imported frozen raw yellowfin tuna product, known as Nakaochi Scrape, from Moon Marine USA Corporation. Ill persons
March-September 2012	Salmonella Infantis, *Salmonella* Newport, and *Salmonella* Lille	N/A	Between March 1, 2012 and September 24, 2012, a total of 195 individuals were infected with the outbreak strain of Salmonella Infantis, Salmonella Newport, and Salmonella Lille. Twenty-seven states reported an outbreak, including five cases in New Jersey. The outbreak was linked to chicks, ducklings, and other live poultry from Mt. Healthy Hatchery in Ohio. Ill persons ranged in age from less than 1 year old to 100 years old.
March-October 2012	Listeria monocytogenes Outbreak	N/A	Between March 28, and October 6, 2012, a total of 22 individuals were infected with the outbreak strain of Listeria monocytogenes. Ricotta salata cheese was the likely source of this outbreak. Thirteen states reported an outbreak, including three cases in New Jersey. Twenty of the persons infected were hospitalized, nine were related to pregnancy, and three were diagnosed in newborns. The others ranged from 30 years old to 87 years old.

Date(s) of Event	Event Type	Area Affected	Description
June-September 2012	Salmonella Bredeney	N/A	Between June 14 and September 21, 2012, a total of 42 individuals were infected with the outbreak strain of Salmonella Bredeney. The outbreak was linked to Trader Joe's Valencia Peanut Butter. Twenty states reported an outbreak, including two cases in New Jersey. Ill persons ranged in age from less than 1 year old to 79 years old, with a median age of 7 years old.
July-September 2012	Salmonella Braenderup, *Salmonella* Typhimurium and Newport	N/A	Between July 3and September 1, 2012, a total of 127 individuals were infected with the outbreak of Salmonella Braenderup linked to mangoes originating from Agricola Daniella of Sinaloa, Mexico. Fifteen states reported an outbreak, including one case in New Jersey. Ill persons ranged in age from less than 1 year old to 86 years old. Between July 6 and September 16, 2012, a total of 261 individuals were infected with the outbreak of Salmonella Typhimurium and Newport linked to cantaloupe originating from Chamberlain Farms Produce in Owensville, Indiana. Twenty-four states reported an outbreak, including two cases in New Jersey. Ill persons ranged from less than one year old to 100 years old.
2012	West Nile Virus Outbreak	Statewide	During the summer-fall months of 2012, the worst WNV outbreak in the United States occurred. As of December 11, 2012, 48 states reported WNV infections in people, birds, or mosquitoes. A total of 5,387 cases of WNV in people, including 243 deaths, have been reported to CDC. Of these, 2,734 (51%) were classified as neuroinvasive disease (such as meningitis or encephalitis) and 2,653 (49%) were classified as non-neuroinvasive disease. In New Jersey, there were 46 positive test results.
2012	Middle East Respiratory Syndrome (MERS)	Statewide	Health officials first reported the disease in Saudi Arabia in September 2012. Through retrospective (backward-looking) investigations, they later identified that the first known cases of MERS occurred in Jordan in April 2012. So far, all cases of MERS have been linked through travel to, or residence in, countries in and near the Arabian Peninsula. The largest known outbreak of MERS outside the Arabian Peninsula occurred in the Republic of Korea in 2015. The outbreak was associated with a traveler returning from the Arabian Peninsula (CDC, 2020).
July-October 2016	Zika Outbreak	Statewide	In August 2016 the number of Zika cases reported in New Jersey reached over 100. Two counties - Bergen and Passaic - accounted for more than a third of the cases statewide.
2019 Measles Outbreak	2019 Pacific Northwest measles outbreak	Statewide	The New Jersey Department of Health (NJDOH) and local health officials identified 33 cases of measles (30 confirmed cases in Ocean County and 3 connected cases in a Passaic County household) in an outbreak investigation lasting from October 2018 to January 2019 . NJDOH and local officials then identified 12 cases of measles in Ocean and Monmouth counties in an investigation lasting from March 2019 to May 2019. Eight cases were confirmed in Ocean County and four cases were confirmed in one household in Monmouth County connected to the Ocean cases. All individuals involved in the more recent outbreak were unvaccinated or had no documentation of vaccination against measles .

Date(s) of Event	Event Type	Area Affected	Description
2019-2020	Coronavirus Disease 2019 (COVID-19)	Statewide	The disease was first identified in 2019 in Wuhan, China, and has since spread globally, resulting in the 2019–20 coronavirus pandemic. At the time of this HMP update, there were eight cases of COVID-19 in Monmouth County, however that number is expected to increase significantly.

SOURCES: BILLINGS 1997; DHHS 2013; CDC 2008; CDC 2009; WHO 2010; CDC 2011; LADAY, 2012; JASLOW, 2012; ROCHABRUN, 2012; ROCHABRUN, NJ.COM, 2016; 2012; CDC, 2018

Table 4.13-2 Communicable Disease Incidence in Monmouth County depicts the number of Reportable Diseases along with the Number of Cases by Year from 2015-2017, as reported by the New Jersey Department of Health (NJDOH). Campylobacteriosis (food-borne disease), Chronic Hepatitis C, Influenza-Type A, Influenza-Type B, Lyme Disease, Non-Typhoid Salmonellosis (food-borne disease), Shiga Toxin-Producing E.Coli (STEC) - Non O157:H7 (food-borne disease), and Shigellosis (food-borne disease) had a number of cases in the double- and triple-digits. Negating influenza, which may be seasonal, food-borne illnesses, Hepatitis C, and Lyme disease are prevalent in Monmouth County. The table and chart depict counts of communicable diseases in Monmouth County through the years of 2015-2017.

Table 4.13 - 2 Communicable Disease Incidence in Monmouth County, 2015-2017

Reportable Disease	2015	2016	2017	3-Year Total
Amoebiasis	6	8	7	21
Babesiosis	46	24	14	84
Botulism - Infant	0	0	2	2
Campylobacteriosis	139	136	111	386
Chikungunya	2		0	2
Creutzfeldt-Jakob Disease	0	2	0	2
Creutzfeldt-Jakob Disease - Sporadic	0	1	0	1
Cryptosporidiosis	8	14	4	26
Cyclosporiasis	1	3	5	9
Dengue Fever	7	0	0	7
Dengue Fever - Dengue	0	1	1	2
Ehrlichiosis/Anaplasmosis Anaplasma Phagocytophilum (Previously HGE)	4	10	7	21
Ehrlichiosis/Anaplasmosis - Ehrlichia Chaffeensis (Previously HME)	6	6	13	25
Ehrlichiosis/Anaplasmosis - Undetermined	0	1	0	1
Foodborne Intoxications - Mushroom Poisoning	0	0	1	1
Foodborne Intoxications - Scombroid	2	0	1	3
Giardiasis	21	52	25	98
Haemophilus Influenzae	16	18	18	52
Hepatitis A	3	1	4	8
Hepatitis B - Acute	5	3	4	12
Hepatitis B - Chronic	15	8	6	29
Hepatitis C - Acute	13	18	9	40

Reportable Disease	2015	2016	2017	3-Year Total
Hepatitis C - Chronic	502	463	385	1350
Hepatitis C - Perinatal	0		2	2
Influenza, Human Isolates - Type 2009 H1N1	0	9	0	9
Influenza, Human Isolates - Type A (Subtyping Not Done)	701	544	895	2140
Influenza, Human Isolates - Type A H3	9	8	22	39
Influenza, Human Isolates - Type B	102	244	373	719
Legionellosis	12	5	15	32
Listeriosis	1	3	2	6
Lyme Disease	530	492	550	1572
Malaria	3	1	4	8
Meningococcal Disease (Neisseria Meningitidis)	1	1	0	2
Mumps	5	6	2	13
Pertussis	42	30	15	87
Salmonellosis - Non-Typhoid	109	83	94	286
Shiga Toxin-Producing E.Coli (STEC) - Non O157:H7	10	12	8	30
Shiga Toxin-Producing E.Coli (STEC) - O157:H7	3	2	2	7
Shigellosis	37	16	15	68
Spotted Fever Group Rickettsiosis	8	6	16	30
Streptococcus Agalactiae (GBS)	1	2	1	4
Streptococcus Pneumoniae	47	56	46	149
Streptococcus Pyogenes (GAS) - With Toxic Shock Syndrome	1	0	1	2
Streptococcus Pyogenes (GAS) - Without Toxic Shock Syndrome	14	20	19	53
Tularemia	0	1	0	1
Typhoid Fever	4	1	2	7
Vancomycin-Intermediate Staphylococcus Aureus (VISA)	0	1	0	1
Varicella	19	15	15	49
Vibrio Infections (Other Than V.Cholerae Spp.)	4	3	4	11
West Nile Virus (WNV)	3	1	1	5
Yersiniosis	4	1	0	5
Zika Virus - Disease, Non-Congenital	0	10	0	10
Zika Virus - Infection, Non-Congenital	0	2	2	4
Totals	2,466	2,344	2,723	7,533

SOURCE: COMMUNICABLE DISEASE REPORTING AND SURVEILLANCE SYSTEM, NEW JERSEY DEPARTMENT OF HEALTH

4.13.5 PROBABILITY OF FUTURE OCCURRENCES

It is difficult to predict when the next pandemic will occur and how severe it will be because viruses are always changing. The United States and other countries are constantly preparing to respond to pandemic. The Department of Health and Human Services and others are developing supplies of vaccines and medicines. In addition, the United States has been working with the WHO and other countries to strengthen detection of disease and response to outbreaks. Preparedness efforts are ongoing at the national, state, and local level (Barry-Eaton District Health Department, 2013).

In New Jersey, the probability for a future pandemic event is dependent on several factors. One factor that influences the spread of disease is population density. Populations that live close to one another are more likely to spread diseases. As population density increases in the State, so too will the probability of a pandemic event occurring. As seen in the COVID-19 pandemic, the State advised people to practice social distancing of at least six feet from other people to minimize the spread of the virus.

As previously shown, Monmouth County has a high percentage of unvaccinated school-aged children relative to the rest of the State and saw an increase from the 2016-2017 school year to the 2017-2018 school year. Further, the 2019 Measles Outbreak demonstrates how communicable diseases can spread across neighboring counties. Monmouth County should be advised that a growing unvaccinated community could decrease the county's herd immunity and increase the probability of an outbreak.

4.13.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

Climate change has the potential to increase the probability of pandemic occurring. While the relationship between climate change and increase in virus susceptibility is difficult to predict with certainty, there are scientific linkages between the two. As warm habitats that host insects such as mosquitoes increase, more of the population becomes exposed to potential virus threats (The Washington Post, 2017). The notion that rising temperatures will increase the number of mosquitoes that can transmit diseases such as West Nile Virus and Zika among humans (rather than just shift their range) has been the subject of debate over the past decade. Milder winters can also lead to increasing tick populations and increase in risk of contracting Lyme disease. Some believe that climate change may affect the spread of disease, while others are not convinced. However, many researchers point out that climate is not the only force at work in increasing the spread of infectious diseases into the future.

4.13.7 VULNERABILITY ASSESSMENT

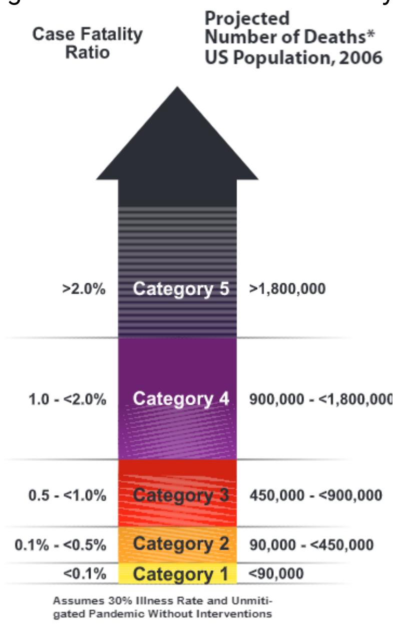
Impacts

The severity of a pandemic or infectious disease threat in New Jersey will range significantly depending on the aggressiveness of the virus in question and the ease of transmission. Pandemics around the nation have the potential to affect New Jersey's populated areas.

The CDC and Prevention Community Strategy for Pandemic Influenza Mitigation guidance introduced a Pandemic Severity Index (PSI), which uses the case fatality ratio as the critical driver for categorizing the severity of a pandemic. The index is designed to estimate the severity of a pandemic on a population to allow better forecasting of the impact of a pandemic, and to enable recommendations on the use of mitigation interventions that are matched to the severity of influenza pandemic.

The severity and length of the next pandemic cannot be predicted; however, experts expect that its effect on the United States could be severe. Based on previous pandemics and without medications or vaccines available, it is estimated that a severe pandemic could cause almost 2 million deaths in the United States, more than nine million hospitalizations, and more than 90 million people ill (NJDOH, 2012). Pandemics are assigned to one of five discrete categories of increasing severity (Category 1 to Category 5) (NJDOH, 2017). Figure 4.13 – 1 Pandemic Severity Index illustrates the five categories of the PSI.

Figure 4.13 - 1 Pandemic Severity Index



SOURCE: NJDOH, 2012

The H1N1 outbreak of 2009 is one case where the severity of a virus outbreak can easily be measured. The severity of illness from the 2009 H1N1 influenza flu virus has varied, with the gravest cases occurring mainly among those populations considered be at highest risk including children, the elderly, pregnant women, and patients with chronic diseases and reduced immune system capacity. While most people infected with H1N1 in 2009 have recovered without needing medical treatment, the virus resulted in some deaths. According to the CDC, about 70% of those who have been hospitalized with the 2009 H1N1 flu virus in the United States belonged to a high-risk population group (CDC, 2009).

Severity of the threat of pandemic is likely to increase. Factors, such as expanded rapid travel and evolution of resistance to medical treatments, are already changing the ways pathogens infect people, plants, and animals. Climate change accelerates may likely to work synergistically with many of these factors, especially in populations increasingly subject to massive migration and malnutrition (Harmon, 2010).

Pandemics are inevitable and arrive with very little warning. Air travel could hasten the spread of a new virus and decrease the time available for implementing interventions. Outbreaks are expected to occur simultaneously throughout much of the United States, preventing shifts in human and material resources. Warning time for any pandemic will depend the origin of the virus and the amount of time needed to identify the virus.

Exposure and Damages

The entire county's population is vulnerable to the effects of a pandemic. Areas with higher population density are more prone to being exposed to a virus. Additionally, vulnerable populations such as the young and elderly are considered at higher risk. The most significant impact on critical facilities would be the increase in hospitalization and emergency room visits that would take place as a result of the outbreak. This would create a greater demand on these critical facilities, their staff, and resources. CDC's model estimates an increase of more than 25% in the demand for hospitalization and intensive care unit services, even in a 'moderate pandemic' (United States Department of Health and Human Services, 2005). In addition to higher demand of critical facility use, it could be anticipated that there would be less employees available to run facilities. Employees who are unable to come to work would result in a loss of service, impacting the function of critical facilities.

As the COVID-19 pandemic continues to affect Monmouth County, local impacts are significantly disrupting everyday activities. In attempt to slow down the spread of the virus, the State and local governments are either closing their offices or requiring their staff work from home, as are private companies. The State closed malls and amusement parks while local municipalities, such as Asbury Park, closed all restaurants and bars for the foreseeable future. Several churches, parks, doctor offices, and schools are also closed for at least two weeks. Large events are cancelled or postponed and national sporting leagues are suspended. Airlines are constantly cancelling flights. Grocery stores are constantly out of food and supplies. On March 9, 2020, the stock market dropped the most since the crash of 1987. The social and economic impacts and damage created by the COVID-19 pandemic are unknown the time of this report, however are already proving to be catastrophic.

4.14 POWER FAILURE

4.14.1 HAZARD DESCRIPTION

Power failure is defined as any interruption or loss of electrical service caused by disruption of power transmission caused by accident, sabotage, natural hazards, or equipment failure (also referred to as a loss of power or power outage). A significant power failure is defined as any incident of a long duration which would require the involvement of the local and/or State emergency management organizations to coordinate provision of food, water, heating, cooling, and shelter.

4.14.2 LOCATION

Power failures in New Jersey are usually localized and are usually the result of a natural hazard event involving high winds or ice storms. New Jersey's power systems are overseen by the State of New Jersey Board of Public Utilities. Under New Jersey law, consumers can shop for electric suppliers through a variety of third-party vendors. While the supply portion of energy is open to competition, the delivery of electricity is limited geographically to the following service providers: Atlantic City Electric, Jersey Central Power and Light (JCP&L), Rockland Electric Company, and Public Service Electric and Gas (PSE&G). In Monmouth County, JCP&L is responsible for maintaining power in most of the county, although a small portion is covered by PSE&G.

Power systems across the State are supported by a vast network of delivery systems, which bridge the gap between supplier and customer.

Power failure is particularly problematic for homes that are heated with electricity. Widespread power outages during the winter months can directly impact vulnerable populations such as the elderly and medically frail. According to the 2007 – 2011 American Community Survey, 27,972 homes across Monmouth County are heated with electricity. This represents 10.8% of the total homes in the county (American Community Survey 5-Year Estimates, 2015).

Aside from the importance of power to heat homes, power is vital to maintain out-of-hospital lifesaving systems for patients such as oxygen concentrators and ventilation machines. Without power, these individuals will require shelter at a medical-needs shelter or admission to a hospital.

4.14.3 EXTENT

Power failures can range in duration from a few minutes to multiple days and also in the extent of impacts, from minor loss of communication systems at a facility to catastrophic loss of lifelines such as water and electricity. Utility interruptions usually occur because of, or in combination with, other emergency or disaster incidents, such as severe weather and flooding, and can exacerbate such emergencies.

Power failures often result from damage to or electrical hazards within an electric power system. System components include power generation plants, substations, circuits, switches, transformers, power lines, and power poles. Due to the varied nature of power outage causes ranging from vehicle accidents to severe weather, utility interruptions can happen at any time.

Power disruption can lead to significant consequences, including service disruption, disruption to infrastructure operations, and loss of heat or cooling that can cause further disturbance or injury.

4.14.4 PREVIOUS OCCURRENCES AND LOSSES

Monmouth County has experienced several widespread power outage incidents. These incidents have been caused by both natural and non-natural hazards. Recent and significant power outages are summarized in Table 4.14-1 Historical Power Loss Events. It is worth noting that power failure incidents occur frequently, often on smaller scales associated with high winds, ice storms, and power grid issues. Data were not readily available on the frequency of smaller power outages across the State.

Table 4.14 - 1 Historical Power Loss Events

Date(s) of Event	Event Type	Description
11/9/1965	Northeast Blackout of 1965	The Northeast Blackout of 1965 was a significant disruption in the supply of electricity, affecting parts of Ontario in Canada and Connecticut, Massachusetts, New Hampshire, Rhode Island, Vermont, New York, and New Jersey in the United States. Over 30 million people and 80,000 square miles (207,000 square kilometers) were left without electricity for up to 12 hours. The cause of the failure was human error that happened days before the blackout.
7/14/1977	New York City Blackout 1977	On July 14, 1977, lightning hit two Con Edison transmission lines north of New York City, tripping relays that soon shut down power plants in the New York metropolitan area. Parts of the City were dark for more than 25 hours, and there was widespread looting.
9/27/1985	Hurricane Gloria	The storm knocked out power and forced people to be evacuated from homes along the Jersey Shore, including Monmouth County. Gloria downed thousands of trees and caused extensive power outages across the state.
10/10/1992 – 10/12/1992	Nor'easter	The December 1992 Nor'easter produced record-high tides and snowfall across the northeastern United States. Throughout New Jersey, the Nor'easter damaged about 3,200 homes and caused an estimated $750 million in damage. Additionally, the storm left 102,000 customers of Jersey Central Power and Light without power. Damage to short circuits caused house fires in Monmouth County. The Borough of Fair Haven indicated that power outages lasted up to six days during the 1992 event.
7/16/1999	Tropical Storm Floyd	Wind gusts rarely exceeded 50 mph, but all the flooding rains made it easier for trees to be knocked over. The strongest winds occurred during the evening and blew down transformers, wires, tree limbs and several trees throughout the county.
2/16/2003 – 2/17/2003	President's Day Storm (Winter Storm)	The strong winds caused about 11,000 homes and businesses to lose power. Monmouth Beach was hit the hardest by power outages, waiting two days for power to be restored.
9/18/03 – 9/19/03	Tropical Storm Isabel	Peak wind gusts included 52 mph in Keansburg, and downed trees, tree limbs and power lines.

Date(s) of Event	Event Type	Description
2/14/2007	Valentine's Day Storm (Winter Storm)	Numerous trees were downed and extensive power outages plagued the area. The Borough of Fair Haven reported that the Valentine's Day Storm of 2007 caused power outages that lasted for several days. The Borough of Shrewsbury was heavily affected by the ice storm of February 2007, which caused three days of power outage for 90 percent of the area's homes and businesses, and up to seven days for several dozen homes.
6/15/2007 – 06/17/2007	Nor'easter	High winds caused a few scattered power outages
3/5/2008	Thunderstorm Wind	Power outages because of downed wires occurred in Bradley Beach, Eatontown, Farmingdale, Howell and Neptune. Outages because of downed trees and limbs occurred in Colts Neck, Englishtown, Freehold, Hazlet, Middletown, Neptune, Oceanport and Union Beach.
9/6/2008	Tropical Storm Hanna	About 2,600 homes and businesses lost power in Monmouth and Ocean Counties. All power was restored by the 7th.
3/14/2010	Severe Windstorm	A severe windstorm knocked out power to hundreds of thousands of customers primarily in southwestern Connecticut as well as parts of Westchester County and Long Island, in New York State, and New Jersey. The outage lasted as long as six days for some customers in the hardest-hit communities.
8/23/2011	Earthquake	There were minor scattered power outages reported throughout the state.
08/27/2011 – 08/28/11	Hurricane Irene	Hurricane Irene caused a power outage to over five million customers throughout the mid-Atlantic and northeast regions of the United States. Approximately 1.9 million New Jersey residents were without power as a result of this storm. High winds downed trees and power lines and caused reported power outages at 121,000 homes across Monmouth County.
10/28/2011 – 10/30/2011	2011 Halloween Nor'easter	The 2011 Halloween Nor'easter started as a large low-pressure area that produced unusually early snowfall across the northeastern United States. Snow fell on trees that were often still in leaf, adding extra weight. Trees and branches that disruptiond under the weight of the snow caused considerable damage, particularly to power lines. In New Jersey, 700,000 customers were without power as a result of the storm.
10/29/2012	Superstorm Sandy	One of the most significant power failure incidents in New Jersey occurred as a result of Superstorm Sandy in 2012. In total, the incident caused approximately 2.5 million power customers across the State to lose power for an extended period of time, forcing many shelters to remain open several weeks (United States Department of Energy, 2012). Power crews from across the country converged in the region to assist with power restoration efforts. Restoration efforts were hampered by the extent of the outages, and the sheer number of customers without power. For example, approximately 90% of JCP&L's customers were without power following the storm (Rose, 2012). In many cases it took weeks to fully restore power to the entire State. Monmouth County had the greatest number of sustained outages of any county in the state. The utility had to cut through approximately 45,000 fallen trees. It was unable to restore power to about 30,000 of its shore and barrier island customers because of massive infrastructure damage to those homes and businesses. To date, Superstorm Sandy remains as the most devastating natural

Date(s) of Event	Event Type	Description
		disaster to impact the State, and the most extensive power failure incident.
11/7/2012	Winter Storm Athena	A winter storm left thousands across the east coast of the United States without power, adding to the blackouts after Superstorm Sandy. An estimated 60,000 people lost electricity as the Nor'easter moved through New Jersey, New York, and Connecticut. As of December 3, 2012, all customers who were able to receive electricity had power restored due to Superstorm Sandy and the subsequent Nor'easter.
1/31/2013	High Wind	Strong to high winds occurred across New Jersey from the middle of the evening on the 30th into the early afternoon of the 31st in New Jersey. Peak wind gusts reached between 45 mph and 65 mph and downed weak trees, tree limbs and power lines and caused power outages. Approximately 20,000 homes and businesses lost power. The wind damage was exacerbated by isolated severe thunderstorms that moved through the central part of the state during the early morning on the 31st. PSE&G reported about 11,000 outages across New Jersey, 3,400 of them in Burlington County. Power was expected to be fully restored later in the day on the 31st.
2/8/2013 – 2/9/2013	Winter Weather	scattered power outages were reported, mainly in the northern portion of the state, with service restored by Saturday afternoon.
2/5/2014	Winter Weather	A major winter storm brought heavy snow and sleet to northwest New Jersey and a wintry mix which included a significant accumulation of ice to the central third of New Jersey. Snowfall reached one foot in Sussex County and ice accumulations were as high as half an inch. The snow that was still on the trees from the just concluded winter storm was a major contributing factor to the power outages. The weight of the snow, then sleet and freezing rain on limbs all collaborated to cause more tree damage then would have occurred if trees were bare at the start of the event. It was the worst ice related outages in the Public Service Electric and Gas's service area since 1999. Public Service Electric and Gas reported about 110,000 of its customers lost power with Mercer, Burlington and Middlesex Counties most affected. Power was fully restored late in the day on the 7th. Jersey Central Power and Light reported about 44,000 of its customers lost power with Middlesex and Monmouth Counties most affected. Power was fully restored on the afternoon of the 6th. One of the hardest hit municipalities with outages was Lambertville as 40 percent of the city lost power. Atlantic City Electric reported about 2,000 of its customers lost power.

Date(s) of Event	Event Type	Description
7/08/2014 - 7/10/2014	Thunderstorm Wind	A hot and humid air mass and a lee side trough helped trigger a squall line of strong to severe thunderstorms that moved through New Jersey during the evening of the 8th. The worst wind damage occurred across the central third of the state. About 80,000 homes and businesses lost power in the state. Hardest hit counties were Burlington, Gloucester and Monmouth. About 15,200 homes and businesses were without power on the morning of the 9th and 5,500 overnight on the 9th. Power was fully restored on the 10th.
2/2/2015	Strong Wind	Strong, gusty northwest winds occurred in the wake of a departing and intensifying low pressure system during the late afternoon into the middle of the evening on the 2nd in New Jersey. Peak wind gusts average around 50 mph and knocked down weak trees, tree limbs and wires. Scattered power outages occurred.
3/1/2015	Winter Weather	Ice accumulations on exposed surfaces reached as high as around one-third of an inch in the southern half of the state and caused scattered power outages
3/17/2015	Strong Wind	Gusty northwest winds following a cold frontal passage affected locations near and along Raritan Bay in New Jersey during the late afternoon and early evening on the 17th. Peak wind gusts averaged 45 to 50 mph and knocked down weak tree limbs and wires and caused isolated power outages.
3/20/2015	Winter Weather	The heaviest snow fell in the central third of the state. It was a heavy, wet snow and the snow did knock down some weak trees and tree limbs and caused isolated power outages in central New Jersey, primarily in Burlington County. About 100 homes and businesses were still without power on the morning of the 21st.
10/02/2015 – 10/03/2015	High Wind	In Pennsville (Salem County), a large falling tree limb was the cause of a major power outage that left more than 3,300 Atlantic City Electric customers in the dark for a couple of hours the evening of the 2nd. Other scattered power outages also occurred across portions of southern to central New Jersey during the height of the storm on the 2nd and 3rd.
7/22/19	Severe Weather	A heat wave gave way to powerful thunderstorms with 60-70 mph winds leaving more than 45% of the County without electricity. Heaviest hit areas were Wall, Howell, and Freehold Townships.
10/16/19	Nor'easter	A nor'easter, now labeled "bomb cyclone", with winds between 30 to 50 mph created countywide power outages, with more than 330 residents without power in Middletown Township.

4.14.5 PROBABILITY OF FUTURE OCCURRENCES

While the probability of future power failure incidents in Monmouth County is difficult to predict, the historic record indicates that significant power failures have occurred as a result of high winds, lightning, winter weather, and technological failures. As shown in the table above, it can be anticipated that multiple power outage events caused by natural hazards can happen in a year. It is more difficult to predict the probability of power outages caused by technical error. The potential for another major power failure that disrupts power for many Monmouth County residents is always possible yet are expected to occur less frequently than smaller incidents.

4.14.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

Future changes in climate may also impact the frequency and probability of future power failure occurrences. Extreme temperatures, which are becoming more common occurrences due to Climate Change, place a burden on existing conveyance systems as electrical usage increases during more extreme hot weather events.

4.14.7 VULNERABILITY ASSESSMENT

Impacts

Regional or widespread power outages are the most severe type of power failures. The severity of power failures can be linked to severe weather events, such as winter storms and hurricanes. Power failures lead to the inability to use electric-powered equipment, such as: lighting; heating, ventilation, and air conditioning (HVAC) and necessary equipment; communication equipment (telephones, computers, etc.); fire and security systems; small appliances such as refrigerators, sterilizers, etc.; and life dependent medical equipment. This all can lead to food spoilage, loss of heating and cooling, basement flooding due to sump pump failure, and loss of water due to well pump failure.

Widespread power outages can occur without warning or as a result of a natural disaster. Generally warning times will be short in the case of technological failure, such as a fire at a sub-station, traffic accident, human error or terrorist attack. In cases where a power failure is caused by natural hazards, greater warning time is possible. For example, high wind events such as tornados and hurricanes often cause widespread power failure and are often forecasted before they affect a community. Additionally, severe winter weather conditions such as ice storms, blizzards, and snowstorms often cause power failure. Incidents such as these often have plenty of warning time, thus power response crews can stage resources to prepare for power failure.

Power failures can cause secondary hazards and have an effect on the health of residents. One potential secondary hazard is chemical accidents that occur after power is restored to industrial facilities. Power interruptions at chemical handling plants are of particular concern because of the potential for a chemical spill during restart (EPA, 2001). Chemical spills in turn can have significant health and environmental impacts.

Another secondary hazard that can result from power failure is a loss of communications capability by first responders, which may in turn have negative impacts on public safety. Backup systems such as amateur radio operators may be required during disaster to augment communications capabilities. Power outages can also lead to instances of civil disturbance, including looting.

Wastewater and potable water utility interruption may occur as a result of a power failure. These critical utilities are essential to community continuity and recovery. Their interruption of service may have cascading economic and environmental impacts.

Because of a lack of power, retail and wholesale gas suppliers cannot access gas in underground tanks or have the electricity to pump it into the tanker trucks for delivery. According to the American Automobile Association, on November 2, 2012, about 60% of the gas stations in New Jersey were closed post Superstorm Sandy due to both power failure and lack of fuel supply (United States Energy Information Administration, 2012). Currently, all 22 gas stations located on the Garden State Parkway, the New Jersey Turnpike, and the Atlantic City Expressway are equipped with back-up power in the case of an outage.

Power failure can have vast secondary impacts on the health of the community. During periods of extreme heat or extreme cold, vulnerable populations such as the elderly and medically frail can be affected and are susceptible to hypothermia or heat stroke. Additionally, power failure can lead to food spoilage, which has negative impacts on public health.

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 (New Jersey Department of Community Affairs, 2012).

Power failure may also lead to an increase in traffic accidents. Traffic accidents may increase because of the lack of traffic control devices such as stoplights and railroad crossing advisory signals. Power outages lasting a long duration will force law enforcement officials to man traffic control points to prevent accidents.

Power failures are particularly critical at locations where the environment and public safety are at risk. Facilities such as hospitals, sewage treatment plans, mines, etc. typically have backup power; however, even backup power can fail due to equipment malfunction or lack of fuel supply. Distributed generation and cogeneration plants are additional backup power options with the capability to 'island' and generate energy off the power grid. There are environmental benefits to distributed generation such as reduction in greenhouse gas emissions and reduced carbon footprint. Typically, power failure events are not generally threating to the environment, unless there are major secondary incidents such as a hazardous substance release.

Exposure and Damages

Overall, the entire State is vulnerable to the power failure hazard. Loss of power can have serious impacts on the health and welfare of residents, continuity of business, and the ability of public safety agencies to respond to emergencies.

Individuals with medical needs are vulnerable to power failures, because medical equipment such as oxygen concentrators requires electricity to operate. The elderly are also vulnerable to the effects of power failure, as power failure has the potential to expose them to extreme heat or extreme cold.

During power failure events, water purification systems may not be functioning. Further, populations on private wells will not have access to potable water. Many power outage events are caused by storm events that can lead to flooding. Without electricity, residents would be unable to pump water from their basements potentially causing structural and content damage to their homes. Section 4.3 Hurricane, Tropical Storm and Nor'easter includes a more detailed discussion on Monmouth County's vulnerability to the flood hazard.

As discussed, power interruptions can cause economic impacts stemming from lost income, spoiled food and other goods, costs to the owners/operators of the utility facilities, and costs to government and community service groups. FEMA's benefit-cost analysis methodology measures the loss of electrical service on a per- person-per-day-of-lost-service basis for the service area affected. For the electrical utility, the standard value is $131 per person per day (BCA module version 5.2.1).

Deaths caused by carbon monoxide poisoning are a concern during extended power outages. According to the New Jersey Department of Health website, there were five deaths in New Jersey caused by carbon monoxide poisoning from the improper use of generators after Superstorm Sandy. In the 2 weeks following Superstorm Sandy, 398 people were treated for carbon monoxide exposure in hospital emergency rooms. In addition, power outages can also create an increased risk of fire because of the use of alternative light and fuel sources such as candles, wood, and kerosene.

A prolonged power failure in Monmouth County could impact the county's economy. New Jersey hosts the busiest commuter rail network in the country, which operates primarily on electricity. Disruption in the rail network would mean that thousands of workers would not be able to travel to their jobs. For example, the 2003 Northeast Blackout cost states in the northeast an estimated $4 to $10 billion in losses collectively. A widespread power failure in New Jersey could have a similar effect on the State. Other factors include New Jersey's chemical industry and pharmaceutical industry, which rely heavily on power for manufacturing purposes.

All critical facilities and infrastructure without backup power systems or islanding capabilities with distributed generation are exposed to power failure events. It is imperative that facilities that protect life and property and support emergency response, government, sheltering functions and recovery efforts remain operational during times of need. Examples of critical infrastructure includes sewer and stormwater pump stations, water treatment plants, traffic signals, and communication towers.

Critical facilities rely on power to conduct daily activities that support Monmouth County residents. Of particular concern are those facilities that rely on power to conduct life-saving operations, such as fire, police, and emergency medical services, which may be unable to respond to calls if their stations are not operational. Also important are 9-1-1 communications systems that rely on power to transmit emergency calls to first responders. Without a consistent power source, responders may be unable to charge equipment or operate critical systems, such as computer networks or communications devices. Response efforts could be hampered by the traffic delays caused by inoperable signals. Although many of these facilities typically have backup power, a prolonged power failure would pose challenges related to refueling backup systems. Also, backup power systems may malfunction if they are not regularly maintained, forcing the closure of the facility.

In the event of a power outage, transformers and substations can be damaged. A power failure in one area can cause a cascading effect, damaging components in other parts of the electrical grid. Other utilities may also be impacted as a result of a power failure including potable water and wastewater plants.

All critical facilities and infrastructure are exposed and vulnerable to a power failure event. Monmouth County may potentially experience losses because of an interruption of critical services. Further increased costs such as providing shelters, and costs related to cooling and heating centers may be incurred. Extended power outages will require officials to shelter victims who require heat and power for activities of daily living. This hazard is difficult to quantify in terms of loss of government services.

4.15 TERRORISM

4.15.1 HAZARD DESCRIPTION

Terrorism is the use of force or violence against persons or property with the intent to intimidate or coerce. Acts of terrorism include threats of terrorism; assassinations; kidnappings; hijackings; bomb scares and explosive attacks; cyber-attacks (computer-based attacks); and the use of chemical, biological, nuclear, and radiological weapons (FEMA, 2009). Various types of terrorism are discussed in the sections below.

Armed Attacks and Assassinations

Armed attacks include raids and ambushes. Assassinations are the killing of a selected victim, usually by bombings or small arms. Drive-by shootings is a common technique employed by unsophisticated or loosely organized terrorist groups. Historically, terrorists have assassinated specific individuals for psychological effect.

Arson and Firebombing

Incendiary devices are inexpensive and easy to hide. Arson and firebombings are easily conducted by terrorist groups that may not be as well organized, equipped, or trained as a major terrorist organization. An act of arson or firebombing against a utility, hotel, government building, or industrial center portrays an image to the public that the ruling government is incapable of maintaining order.

Bioterrorism

Bioterrorism refers to the intentional release of toxic biological agents to harm and terrorize civilians, in the name of a political or other cause. The United States Centers for Disease Control and Prevention (CDC) has classified the viruses, bacteria, and toxins that could be used in an attack. Category A Biological Diseases are those most likely to do the most damage. They include:

- Anthrax (Bacillus anthracis)
- Botulism (Clostridium botulinum toxin)
- The Plague (Yersinia pestis)
- Smallpox (Variola major)
- Tularemia (Francisella tularensis)
- Hemorrahagic fever, due to Ebola Virus or Marburg Virus

Explosive Attacks

Explosive Attack can be defined as an attack in which a bomb and or destructive device is used to destroy, incapacitate, harass, or distract. These devises are used by criminals, vandals, terrorists, suicide bombers and insurgents. Explosive devices used in an explosive attack can come in many forms ranging from a pipe bomb to a sophisticated device capable of causing massive damage and loss of life (The National Academies and Homeland Security). Bombings are the most common type of terrorist act. Typically, improvised explosive devices are inexpensive and easy to make. Modern devices are smaller and harder to detect and contain very destructive capabilities.

Cyber Terrorism

Cyber terrorists use information technology to attack civilians and draw attention to the terrorists' cause. This may mean that they use information technology, such as computer systems or telecommunications, as a tool to orchestrate a traditional attack. More often, cyber terrorism refers to an attack on information technology itself in a way that would radically disrupt networked services. For example, cyber terrorists could disable networked emergency systems or hack into networks housing critical financial information. A full discussion of cyber terrorism is presented in Section 5.16 Cyber Attack.

Domestic Terrorism

Domestic terrorism encompasses criminal acts dangerous to people or property, with the intent of inflicting malice. This manner of terrorism may include coercion, intimidation, kidnapping, assassination, or mass destruction, as defined by the Patriot Act. The most common form of domestic terrorism is the targeting of public masses, which often seeks to harm specific educational, religious, ethnic, or racial groups. Infrastructure, such as public spaces or utilities, may also be subject to domestic terrorism, as it causes an interruption in the function of a community. In response to this threat, Monmouth County municipalities are implementing measures such as security screening or infrastructure (e.g., bollards, surveillance cameras, checkpoints), and those that have not have listed them as mitigation action to implement in the future.

Ecoterrorism

Ecoterrorism is a recently coined term describing violence in the interests of environmentalism. In general, environmental extremists sabotage property to inflict economic damage on industries, businesses, or persons perceived as harming animals or the natural environment. Targets of ecoterrorist attacks have included fur companies, logging companies, and animal research laboratories.

Hijackings and Skyjackings

Hijacking is the seizure by force of a surface vehicle, its passengers, and/or its cargo. Skyjacking is the taking of an aircraft, which creates a mobile, hostage barricade situation; provides terrorists with hostages from many nations; and draws heavy media attention. Skyjacking also provides mobility for the terrorists to relocate the aircraft to a country that supports their cause and provides them with a human shield, making retaliation difficult.

Kidnappings and Hostage-Takings

Terrorists use kidnapping and hostage-taking to establish a bargaining position and to elicit publicity. Kidnapping is one of the most difficult acts for a terrorist group to accomplish, but, if a kidnapping is successful, it can gain terrorists money, release of jailed comrades, and publicity for an extended period. Hostage-taking involves the seizure of a facility or location and the taking of hostages present in that facility. Unlike a kidnapping, hostage-taking provokes a confrontation with authorities. It forces authorities to either make dramatic decisions or to comply with the terrorist's demands. It is overt and designed to attract and hold media attention. The terrorists' intended target is the audience affected by the hostage's confinement, not the hostage.

Nuclear Terrorism

Nuclear terrorism refers to a number of different ways nuclear materials might be exploited as a terrorist tactic. These include attacking nuclear facilities, purchasing nuclear weapons, or building nuclear weapons or otherwise finding ways to disperse radioactive materials. Nuclear attack can be defined as an attack in which nuclear weaponry is used to inflict crippling damage on a place and the people living there. Nuclear weapons are weapons of mass destruction, which means they can produce far ranging destruction in very short timeframe, while also having lasting impacts (Birks and Sherry, 1986).

4.15.2 LOCATION

Terrorist attacks can occur anywhere. However, the State of New Jersey is a particularly attractive target of a potential terrorist activity because of its dense population and location relative to major urban areas. The State also houses the busiest commuter rail system in the United States, as well as the headquarters of major corporations in economically vital sectors such as the financial and pharmaceutical industries.

Additional targets in Monmouth County include the county's critical infrastructure such as utilities, roadways, bridges, tunnels, hospitals, schools, civic centers, and other high-profile venues. The link between New Jersey Transit and New York City also makes this transportation system a target for terrorists. Locations with a high population density will be attractive targets for terror attacks.

Naval Weapon Station (NWS) Earle, the largest Weapons Station on the East Coast, is located in Monmouth County and could potentially be targeted for a terrorist attack[39].

4.15.3 EXTENT

Any acts of terrorism can occur anywhere at any time of day. The National Terrorism Advisory System (NTAS) communicates information about terrorist threats by providing detailed information to the public, government agencies, first responders, airports and other transportation hubs, and the private sector. When there is a threat, an NTAS Alert will be announced by the Secretary of Homeland Security and will be shared with the public. It may include specific information about the nature of the threat, including the geographic region, mode of transportation, or critical infrastructure potentially affected, as well as steps that individuals and communities can take to protect themselves and help prevent, mitigate or respond to the threat. The alert indicates whether the threat is elevated or imminent. Elevated threats are when there is no specific information about the timing or location. Imminent threats are when it is believed the threat is impending or very soon. The alerts will be posted online and released to the news media for distribution. The United States Department of Homeland Security (USDHS) will also distribute alerts through its social media channels (USDHS, 2013).

In New Jersey, the NJOEM, New Jersey Office of Homeland Security and Preparedness (OHSP), and the Regional Operations Intelligence Center (ROIC) have introduced NJ Alert, a mass text and email emergency notification system. During an emergency, NJ Alert assists these agencies in delivering emergency messages to the public through their handheld devices or computers, in addition to the Emergency Alert Systems and Amber Alert (NJEOM, 2009).

4.15.4 PREVIOUS OCCURRENCES AND LOSSES

Now known as 9-11, the most significant terrorist incident to occur in the United States occurred on September 11, 2001 adjacent to New Jersey in Lower Manhattan, New York, when an extreme terrorist group hijacked two commercial airplanes and flew them into the Towers 1 and 2 of the World Trade Center. Additionally, a simultaneous attack occurred in the Washington D.C. area where a plane was

39 http://co.monmouth.nj.us/documents/24/NWS%20Earle%20JLUS%20Study%20fact%20sheet.pdf

crashed into the Pentagon. New Jersey was directly affected as many of the victims and evacuees were ferried across the Hudson River to New Jersey. The incident required a joint response between regional entities, and affected New Jersey significantly. Seven days after 9-11, anonymous letters laced with deadly anthrax spores began arriving at media companies and congressional offices resulting in four deaths and 17 others infected.

The 2013 Boston Marathon Bombers made pressure cooker that killed three people and injured several hundred people at the finish line of the race. On September 17, 2016, three bombs exploded, and several unexploded ones were found in the New York/New Jersey metropolitan area, including Seaside Heights in Ocean County. The bombings left 31 people wounded, but no fatalities or life-threatening injuries were reported. Terrorists such as those responsible for this bombing can use materials that are readily available to the average consumer to construct a bomb.

4.15.5 PROBABILITY OF FUTURE OCCURRENCES

While the potential for future terrorism incidents in Monmouth County is difficult to predict, the combination of past incidents and potential terrorist targets make a terrorism incident possible. Efforts from local, state, and federal officials must be coordinated to prevent future terrorist incidents from occurring. However, despite the best efforts of these entities, the reality is that a terrorist attack may occur in Monmouth County or the surrounding areas.

Figure 4.15-1 New Jersey's Assessed Threat Level in 2019 is taken from the New Jersey Office of Homeland Security and Preparedness' 2019 Terrorism Threat Assessment, which visualizes the Assessed Threat Level of various terrorist organizations and extremists in New Jersey.

Figure 4.15 - 1 New Jersey's Assessed Threat Level in 2019 (NJOHSP)

High	Homegrown Violent Extremists
Moderate	Anarchist Extremists
	ISIS
	Militia Extremists
	Sovereign Citizen Extremists
	White Supremacist Extremists
Low	Al-Qa'ida
	Al-Qa'ida in the Arabian Peninsula
	Al-Qa'ida in the Indian Subcontinent
	Al-Qa'ida in the Islamic Maghreb
	Al-Shabaab
	Animal Rights Extremists
	Anti-Abortion Extremists
	Black Separatist Extremists
	Boko Haram
	Environmental Extremists
	HAMAS
	Hizballah
	Lashkar-e-Tayyiba
	Nusrah Front
	Tehrik-e-Taliban Pakistan

Change from 2018

Al-Qa'ida in the Arabian Peninsula (AQAP)

The threat from AQAP decreased from moderate to low in 2019. AQAP continues to focus on local issues within Yemen, and drone strikes have nearly decimated much of the group's command staff. Propaganda output has declined to nearly half of what it produced last year. AQAP has not successfully executed an attack in the West since the operation in January 2015 against the offices of the satirical newspaper Charlie Hebdo in Paris.

4.15.6 POTENTIAL EFFECTS OF CLIMATE CHANGE

This plan does not recognize a link between climate change and terrorism.

4.15.7 VULNERABILITY ASSESSMENT

Impacts

The effect of a terrorism event can vary depending on the type of attack and the magnitude of the event or events. A terrorism event can cause public fear regarding the use of mass transportation or leaving their homes in the event of a biological or nuclear attack. Communication systems, both public and private, can fail because of an overwhelming amount of usage or damage to its infrastructure. Healthcare facilities can become quickly inundated and must be prepared to triage injured patients, handle mass casualties, and conduct decontamination operations.

There is often very little if any warning time that a terrorist attack is about to occur. It is possible, however, to thwart terrorist attacks through aggressive intelligence monitoring and monitoring of individuals who exhibit radical tendencies. Some terrorist attacks may show warning signs that an incident may occur, such as a suspicious package left unattended. Local, state, and federal officials as well as the general public are responsible for recognizing the warning signs of terrorism incidents and for taking appropriate actions to mitigate against possible attacks. In New Jersey, the coordination, direction, and control of all law enforcement personnel and resources fall under the purview of the Attorney General. Additionally, the New Jersey OHS administers, coordinates, leads, and supervises New Jersey's counter-terrorism efforts.

The secondary hazards resulting from a terrorist attack depend on the size and scope of the incident. Some possible secondary hazards include widespread health effects such as epidemics or pandemics, flooding (if a dam was destroyed), and environmental contamination.

Depending on the type and location of an act of terrorism, it can impact the environment and result in loss of life for humans and animals. A radiological device or an improvised nuclear device would have a long-term impact that could cost billions of dollars to remediate. Additionally, an attack on waste treatment, natural gas, petroleum, or chemical facilities could also have long term environmental impacts.

Exposure and Damages

The entire population of New Jersey is exposed to the effects of terrorism and terrorist incidents. However, because terrorists typically prefer to impact the greatest number of individuals in a given location, it can be inferred that individuals living in highly populated areas will have a greater exposure to terrorist incidents than those living in rural areas.

Because terrorist attacks are designed to take victims by surprise, predicting the location and nature of potential attacks is extremely difficult, as is assessing the population's vulnerability. Aside from population density, other indicators of vulnerable populations may be commuters using public transportation on a regular basis (as mass transit systems have been the targets of past terrorist attacks outside New Jersey), locations in and around military bases or government facilities (as was planned for Fort Dix in New Jersey in 2007), as well as high-profile gatherings of a large number of people (such as the attacks that occurred at the Boston Marathon in 2013).

Measuring the economic impact of a terrorist attack on the State is a difficult task. The initial impact can be measured in immediate costs such as costs related to responding to the event, and those associated with the immediate loss of productivity due to closed businesses. The fuller economic impact includes long-term costs such as terrorism mitigation activities.

The direct cost of the attacks on September 11, 2001 has been estimated at somewhat over $20 billion. Paul Krugman cites a property loss estimate by the Comptroller of the City of New York of $21.8 billion, which he has said is about 0.2 % of the GDP for one year (Krugman, 2004). Similarly, the Organization for Economic Cooperation and Development (OECD) estimated that the attack cost the private sector $14 billion and the federal government $0.7 billion, while clean-up was estimated at $11 billion. According to R. Barry Johnston and Oana M. Nedelscu, these numbers are equal to about one- quarter of one percent of the United States annual GDP—approximately the same result arrived at by Krugman (Johnston and Nedelscu, 2004).

In New Jersey, the impact of a large-scale terrorist attack would be significant. Of particular concern would be the State's top industries. Also, if an attack would occur along the Jersey Shore, the impact of lost tourism dollars would be significant.

Critical facilities are exposed to terrorist attacks, particularly because of the impact that an attack has on these types of facilities. Dams, power stations, and tunnels are all examples of critical infrastructure and facilities that are vulnerable. Additionally, communications systems, first-responder stations, and emergency operations centers are all vulnerable to terrorist attacks. Disrupting one of these facilities or destroying critical infrastructure would have devastating, cascading impacts on New Jersey. The potential losses to state facilities are difficult to quantify because of the unpredictability of terrorist events. The replacement cost value for state facilities provides a total risk exposure quantity.

4.16 CONCLUSIONS ON HAZARD RISK

- The results of this vulnerability assessment are useful in at least three ways:
- Improving our understanding of the risk associated with the natural hazards in Monmouth County through better understanding of the complexities and dynamics of risk, how levels of risk can be measured and compared, and the myriad of factors that influence risk. An understanding of these relationships is critical in making balanced and informed decisions on managing the risk.
- Providing a baseline for policy development and comparison of mitigation alternatives. The data used for this analysis presents a current picture of risk in Monmouth County. Updating this risk "snapshot" with future data will enable comparison of the changes in risk with time. Baselines of this type can support the objective analysis of policy and program options for risk reduction in the region.
- Comparing the risk among the natural hazards addressed. The ability to quantify the risk to all these hazards relative to one another helps in a balanced, multi-hazard approach to risk management at each level of governing authority. This ranking provides a systematic framework to compare and prioritize the very disparate natural hazards that are present in Monmouth County. This final step in the risk assessment provides the necessary information for local officials to craft a mitigation strategy to focus resources on only those hazards that pose the most threat to the county.

Exposure to hazards can be an indicator of vulnerability. Economic exposure can be identified through locally assessed values for improvements (buildings), and social exposure can be identified by estimating the population exposed to each hazard. This information is especially important for decision-makers to use in planning for evacuation or other public safety related needs. A summary of the value of buildings at-risk (exposed) to each hazard is presented in Table 4.16 - 1 Assessed Building Value At-Risk by Hazard by Jurisdiction, and a summary of population exposure is presented in Table 4.16 - 2 Population Exposure by Hazard by Jurisdiction. Using the previously described methodology, economic results were estimated for the different hazards profiled earlier in this section. The economic loss results are summarized in Table 4.17- 3 Annualized Building Losses by Hazard by Jurisdiction using Annualized Loss (AL), which is the estimated long-term value of losses to the general building stock in any single year in a specified geographic area (i.e., jurisdiction). The estimated AL addresses the two key components of risk: the probability of the hazard occurring in the jurisdiction and the consequences of the hazard, largely a function of building construction type and quality, and of the intensity of the hazard event. By annualizing estimated losses, the AL factors in historic patterns of frequent smaller events with infrequent but larger events to provide a balanced presentation of the risk.

A summary of the annualized loss ratio (ALR) results is presented in **Table 4.16 - 4 Annualized Loss Ratios by Hazard by Jurisdiction**. The ALR represents the AL as a fraction of the local assessed value of improvements (calculated as annualized losses divided by the total exposure at risk). The annualized loss ratio gauges the relationship between average annualized loss and assessed value. This ratio can be used as a measure of vulnerability in the areas and, since it is normalized by assessed value, it can be directly compared across different jurisdictions.

In order to illustrate composite vulnerability, several hazards were mapped for the county and each jurisdiction using overlays to show areas which are vulnerable (indicated by shading scaled so that darker tones indicate vulnerability to multiple hazards). It should be noted that some jurisdictions may not be exposed to all four hazards. **Figure 4.16-1 Assessed Building Value At-Risk by Hazard by Jurisdiction** shows Monmouth County's composite vulnerability.

Delineable hazards include coastal erosion, flood, surge, wave action, landslide, and wildfire. Wave action is included within the VE portion of the flood layer. Coastal erosion is not mapped at this scale because it is assumed that beach nourishment will be ongoing to prevent long term erosion of 200 feet and short term remains on shoreline.

Table 4.16 - 1 Assessed Building Value At-Risk by Hazard by Jurisdiction

Jurisdiction	Extreme Temps, Tornado, Hurricane, Extreme Wind, Lightning, Nor'easter, Earthquake, and Winter Storm	Coastal Erosion	Dam Failure	Drought** (Value of Crops at Risk)	Flood	Storm Surge	Wave Action	Wildfire
Aberdeen, Township of	$1,191,378,710	$904,087	$0	N/A	$49,670,275	$42,530,763	$3,205,481	$129,530,245
Allenhurst, Borough of	$184,273,506	$6,781,991	$0	$0	$1,673,162	$104,392,891	$156,990	$6,157,580
Allentown, Borough of	$144,986,655	$0	$0	N/A	$5,298,388	$0	$0	$13,890,802
Asbury Park, City of	$926,436,309	$1,883,331	$0	$0	$26,163,424	$583,563,435	$2,991,996	$4,571,794
Atlantic Highlands, Borough of	$283,605,536	$8,179,671	$0	$0	$25,952,689	$81,800,609	$2,456,740	$24,102,505
Avon-By-The-Sea, Borough of	$389,654,562	$1,777,553	$0	$0	$97,157,637	$383,429,812	$959,595	$2,017,036
Belmar, Borough of	$571,363,121	$3,354,414	$0	$0	$116,435,795	$566,789,888	$4,309,244	$6,397,451
Bradley Beach, Borough of	$453,814,625	$153,774	$0	$0	$12,942,404	$400,929,137	$0	$267,281
Brielle, Borough of	$552,314,872	$1,709,430	$0	$0	$94,954,192	$254,268,555	$3,862,182	$48,440,239
Colts Neck, Township of	$1,890,977,157	$0	$0	N/A	$65,252,437	$0	$0	$1,474,128,197
Deal, Borough of	$576,102,800	$29,171,805	$0	$0	$22,789,640	$122,446,063	$6,976,995	$175,092,174
Eatontown, Borough of	$1,304,537,650	$0	$0	N/A	$25,106,453	$188,374,201	$0	$183,975,430
Englishtown, Borough of	$141,599,834	$0	$0	N/A	$10,622,687	$0	$0	$16,186,059

Jurisdiction	Extreme Temps, Tornado, Hurricane, Extreme Wind, Lightning, Nor'easter, Earthquake, and Winter Storm	Coastal Erosion	Dam Failure	Drought** (Value of Crops at Risk)	Flood	Storm Surge	Wave Action	Wildfire
Fair Haven, Borough of	$664,020,499	$2,140,748	$0	$0	$18,453,091	$113,983,854	$12,486,679	$81,941,545
Farmingdale, Borough of	$126,803,073	$0	$0	N/A	$13,375,616	$0	$0	$9,460,258
Freehold, Borough of	$716,416,050	$0	$0	N/A	$50,603	$0	$0	$44,203,739
Freehold, Township of	$4,442,053,178	$0	$0	N/A	$41,058,883	$0	$0	$942,807,853
Hazlet, Township of	$1,364,990,949	$0	$0	N/A	$115,104,018	$369,369,674	$0	$96,897,457
Highlands, Borough of	$316,247,035	$20,878,514	$0	$0	$161,437,092	$178,112,497	$2,201,971	$21,881,291
Holmdel, Township of	$2,349,627,973	$0	$0	N/A	$20,973,887	$4,930,564	$0	$1,024,338,601
Howell, Township of	$3,583,728,444	$0	$15,709,065	N/A	$58,630,432	$222,755	$0	$889,177,338
Interlaken, Borough of	$103,253,102	$0	$0	$0	$5,363,153	$78,362,097	$0	$7,900,841
Keansburg, Borough of	$393,782,623	$25,532	$0	$0	$335,965,082	$393,782,623	$3,213,537	$11,603,805
Keyport, Borough of	$475,718,484	$3,247,786	$0	$0	$44,138,233	$183,425,844	$6,795,237	$18,939,470
Lake Como, Borough of	$175,353,286	$0	$0	$0	$12,329,648	$163,293,100	$0	$658,368
Little Silver, Borough of	$842,175,677	$39,926,563	$0	N/A	$123,307,184	$449,644,784	$0	$208,186,120
Loch Arbour, Village of	$43,964,818	$423,565	$0	$0	$15,339,574	$43,964,818	$281,258	$3,062
Long Branch, City of	$2,641,334,898	$77,733,622	$0	$0	$166,032,379	$1,527,802,728	$7,011,919	$168,406,859
Manalapan, Township of	$4,272,188,920	$0	$0	N/A	$73,755,432	$0	$0	$1,030,336,783
Manasquan, Borough of	$814,952,277	$3,879,813	$0	$0	$421,244,806	$711,352,880	$50,372,041	$19,898,548
Marlboro, Township of	$4,445,129,741	$0	$0	N/A	$74,433,230	$0	$0	$1,107,174,878
Matawan, Borough of	$565,160,331	$0	$0	$0	$10,778,158	$7,128,608	$0	$52,726,509
Middletown, Township of	$5,608,683,680	$67,603,389	$6,394,012	N/A	$497,493,915	$956,929,375	$20,815,231	$1,263,019,436
Millstone, Township of	$1,119,995,483	$0	$0	N/A	$18,935,228	$0	$0	$900,339,529
Monmouth Beach, Borough of	$509,731,405	$53,464,884	$0	$0	$327,233,261	$509,731,405	$284,668	$33,864,852
Neptune City, Borough of	$270,381,912	$3,504,491	$0	$0	$12,040,556	$140,452,387	$1,016,835	$7,555,562
Neptune, Township of	$1,715,132,526	$7,165,600	$12,793,205	N/A	$95,114,294	$636,714,664	$2,994,974	$113,361,777
Ocean, Township of	$2,349,862,610	$0	$0	N/A	$82,112,922	$99,458,836	$0	$339,842,424
Oceanport, Borough of	$584,044,723	$29,605,147	$0	N/A	$163,073,648	$499,778,269	$0	$141,549,273
Red Bank, Borough of	$1,335,760,921	$4,040,661	$0	$0	$61,082,868	$69,189,167	$17,494,834	$35,192,517
Roosevelt, Borough of	$45,760,596	$0	$0	N/A	$41,379	$0	$0	$10,993,677
Rumson, Borough of	$1,590,045,162	$93,323,187	$0	N/A	$311,251,487	$885,822,692	$10,712,125	$1,053,582,311
Sea Bright, Borough of	$268,030,710	$65,305,039	$0	$0	$207,695,707	$268,030,710	$6,123,371	$10,749,290

Jurisdiction	Extreme Temps, Tornado, Hurricane, Extreme Wind, Lightning, Nor'easter, Earthquake, and Winter Storm	Coastal Erosion	Dam Failure	Drought** (Value of Crops at Risk)	Flood	Storm Surge	Wave Action	Wildfire
Sea Girt, Borough of	$528,262,182	$16,173,987	$0	$0	$51,786,985	$483,183,139	$8,398,641	$17,907,699
Shrewsbury, Borough of	$552,323,431	$1,235,115	$0	N/A	$9,332,215	$102,521,547	$0	$114,901,606
Shrewsbury, Township of	$30,284,084	$0	$0	$0	$0	$0	$0	$37,474
Spring Lake, Borough of	$1,179,693,874	$4,194,768	$0	$0	$123,616,260	$862,005,595	$1,011,588	$22,789,793
Spring Lake Heights, Borough of	$511,441,370	$0	$0	$0	$24,293,550	$141,598,370	$0	$13,217,737
Tinton Falls, Borough of	$2,269,023,237	$0	$6,046,704	N/A	$90,040,992	$13,953,265	$0	$544,347,862
Union Beach, Borough of	$288,161,877	$7,605,567	$0	$0	$227,332,133	$288,161,877	$10,892,606	$32,375,198
Upper Freehold, Township of	$913,190,916	$0	$0	N/A	$24,716,431	$0	$0	$502,053,182
Wall, Township of	$2,593,454,301	$16,758,863	$3,896,860	N/A	$79,514,941	$86,795,703	$3,025,815	$690,896,526
West Long Branch, Borough of	$885,131,566	$0	$0	N/A	$15,629,909	$151,608,715	$0	$98,895,464
Monmouth County	$62,096,343,261	$572,152,900	$44,839,846	$0	$4,688,128,366	$13,144,104,601	$190,052,551	$13,768,773,307
Percent of Total Exposure	$0	$0	$0	$1	$0	$0	$0	$0

Table 4.16 - 2 Population Exposure by Natural Hazard, by Jurisdiction

Jurisdiction	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter						Winter Storm	Dam Failure	Drought	Earthquake	Wildfire
	Extreme Temps	Extreme Wind	Lightning	Tornado	Hurricane & Trop. Storm	Nor'easter	Flood	Storm Surge	Wave Action	Coastal Erosion					
Aberdeen, Township of	18,210	18,210	18,210	18,210	18,210	18,210	1,429	2,044	420	33	18,210	0	18,210	18,210	4,807
Allenhurst, Borough of	496	496	496	496	496	496	13	403	3	10	496	0	496	496	41
Allentown, Borough of	1,828	1,828	1,828	1,828	1,828	1,828	163	0	0	0	1,828	0	1,828	1,828	331
Asbury Park, City of	16,116	16,116	16,116	16,116	16,116	16,116	869	11,274	0	0	16,116	0	16,116	16,116	50
Atlantic Highlands, Borough of	4,385	4,385	4,385	4,385	4,385	4,385	410	1,236	55	92	4,385	0	4,385	4,385	530
Avon-By-The-Sea, Borough of	1,901	1,901	1,901	1,901	1,901	1,901	507	1,829	0	7	1,901	0	1,901	1,901	33

Jurisdiction	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter						Winter Storm	Dam Failure	Drought	Earthquake	Wildfire
	Extreme Temps	Extreme Wind	Lightning	Tornado	Hurricane & Trop. Storm	Nor'easter	Flood	Storm Surge	Wave Action	Coastal Erosion					
Belmar, Borough of	5,794	5,794	5,794	5,794	5,794	5,794	1,246	5,750	59	42	5,794	0	5,794	5,794	162
Bradley Beach, Borough of	4,298	4,298	4,298	4,298	4,298	4,298	185	3,788	0	10	4,298	0	4,298	4,298	73
Brielle, Borough of	4,774	4,774	4,774	4,774	4,774	4,774	611	2,181	2	12	4,774	0	4,774	4,774	569
Colts Neck, Township of	10,142	10,142	10,142	10,142	10,142	10,142	732	0	0	0	10,142	1	10,142	10,142	7,132
Deal, Borough of	750	750	750	750	750	750	38	136	12	29	750	0	750	750	172
Eatontown, Borough of	12,709	12,709	12,709	12,709	12,709	12,709	234	1,223	0	0	12,709	0	12,709	12,709	2,627
Englishtown, Borough of	1,847	1,847	1,847	1,847	1,847	1,847	311	0	0	0	1,847	0	1,847	1,847	373
Fair Haven, Borough of	6,121	6,121	6,121	6,121	6,121	6,121	154	1,011	92	11	6,121	0	6,121	6,121	963
Farmingdale , Borough of	1,329	1,329	1,329	1,329	1,329	1,329	317	0	0	0	1,329	0	1,329	1,329	241
Freehold, Borough of	12,052	12,052	12,052	12,052	12,052	12,052	1	0	0	0	12,052	0	12,052	12,052	970
Freehold, Township of	36,184	36,184	36,184	36,184	36,184	36,184	1,073	0	0	0	36,184	0	36,184	36,184	10,122
Hazlet, Township of	20,334	20,334	20,334	20,334	20,334	20,334	2,650	6,736	0	0	20,334	0	20,334	20,334	2,744
Highlands, Borough of	5,005	5,005	5,005	5,005	5,005	5,005	2,641	2,779	96	326	5,005	0	5,005	5,005	893
Holmdel, Township of	16,773	16,773	16,773	16,773	16,773	16,773	445	315	0	0	16,773	0	16,773	16,773	8,373
Howell, Township of	51,075	51,075	51,075	51,075	51,075	51,075	3,390	473	0	0	51,075	104	51,075	51,075	24,032
Interlaken, Borough of	820	820	820	820	820	820	33	649	0	0	820	0	820	820	78
Keansburg, Borough of	10,105	10,105	10,105	10,105	10,105	10,105	8,946	10,105	65	12	10,105	0	10,105	10,105	506
Keyport, Borough of	7,240	7,240	7,240	7,240	7,240	7,240	1,027	3,548	185	80	7,240	0	7,240	7,240	764
Lake Como, Borough of	1,759	1,759	1,759	1,759	1,759	1,759	95	1,609	0	0	1,759	0	1,759	1,759	20
Little Silver, Borough of	5,950	5,950	5,950	5,950	5,950	5,950	784	3,090	0	176	5,950	0	5,950	5,950	1,637
Loch Arbour, Village of	194	194	194	194	194	194	75	194	0	0	194	0	194	194	0
Long Branch, City of	30,719	30,719	30,719	30,719	30,719	30,719	3,301	18,701	119	528	30,719	0	30,719	30,719	1,939

Jurisdiction	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter						Winter Storm	Dam Failure	Drought	Earthquake	Wildfire
	Extreme Temps	Extreme Wind	Lightning	Tornado	Hurricane & Trop. Storm	Nor'easter	Flood	Storm Surge	Wave Action	Coastal Erosion					
Manalapan, Township of	38,872	38,872	38,872	38,872	38,872	38,872	1,881	0	0	0	38,872	0	38,872	38,872	12,752
Manasquan, Borough of	5,897	5,897	5,897	5,897	5,897	5,897	2,440	4,862	142	32	5,897	0	5,897	5,897	347
Marlboro, Township of	40,191	40,191	40,191	40,191	40,191	40,191	1,100	0	0	0	40,191	0	40,191	40,191	15,752
Matawan, Borough of	8,810	8,810	8,810	8,810	8,810	8,810	500	484	0	0	8,810	0	8,810	8,810	1,929
Middletown, Township of	66,522	66,522	66,522	66,522	66,522	66,522	10,246	17,876	234	316	66,522	214	66,522	66,522	16,794
Millstone, Township of	10,566	10,566	10,566	10,566	10,566	10,566	377	0	0	0	10,566	0	10,566	10,566	8,419
Monmouth Beach, Borough of	3,279	3,279	3,279	3,279	3,279	3,279	2,132	3,279	1	325	3,279	0	3,279	3,279	392
Neptune City, Borough of	4,869	4,869	4,869	4,869	4,869	4,869	273	2,649	16	91	4,869	0	4,869	4,869	351
Neptune, Township of	27,935	27,935	27,935	27,935	27,935	27,935	1,627	9,413	157	229	27,935	288	27,935	27,935	3,505
Ocean, Township of	27,291	27,291	27,291	27,291	27,291	27,291	1,972	1,686	0	0	27,291	0	27,291	27,291	4,995
Oceanport, Borough of	5,832	5,832	5,832	5,832	5,832	5,832	1,499	4,721	0	209	5,832	0	5,832	5,832	1,084
Red Bank, Borough of	12,206	12,206	12,206	12,206	12,206	12,206	663	858	18	57	12,206	0	12,206	12,206	788
Roosevelt, Borough of	882	882	882	882	882	882	17	0	0	0	882	0	882	882	499
Rumson, Borough of	7,122	7,122	7,122	7,122	7,122	7,122	1,360	3,970	54	253	7,122	0	7,122	7,122	3,501
Sea Bright, Borough of	1,412	1,412	1,412	1,412	1,412	1,412	1,254	1,414	37	300	1,412	0	1,412	1,412	174
Sea Girt, Borough of	1,828	1,828	1,828	1,828	1,828	1,828	125	1,520	4	12	1,828	0	1,828	1,828	66
Shrewsbury, Borough of	3,809	3,809	3,809	3,809	3,809	3,809	99	891	0	18	3,809	0	3,809	3,809	1,113
Shrewsbury, Township of	1,141	1,141	1,141	1,141	1,141	1,141	0	0	0	0	1,141	0	1,141	1,141	65
Spring Lake, Borough of	2,993	2,993	2,993	2,993	2,993	2,993	360	2,060	0	2	2,993	0	2,993	2,993	93
Spring Lake Heights., Borough of	4,713	4,713	4,713	4,713	4,713	4,713	325	1,474	0	0	4,713	0	4,713	4,713	569
Tinton Falls, Borough of	17,892	17,892	17,892	17,892	17,892	17,892	736	430	0	0	17,892	464	17,892	17,892	6,207

Jurisdiction	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter						Winter Storm	Dam Failure	Drought	Earthquake	Wildfire
	Extreme Temps	Extreme Wind	Lightning	Tornado	Hurricane & Trop. Storm	Nor'easter	Flood	Storm Surge	Wave Action	Coastal Erosion					
Union Beach, Borough of	6,245	6,245	6,245	6,245	6,245	6,245	4,991	6,245	519	129	6,245	0	6,245	6,245	931
Upper Freehold, Township of	6,902	6,902	6,902	6,902	6,902	6,902	315	0	0	0	6,902	0	6,902	6,902	4,521
Wall, Township of	26,164	26,164	26,164	26,164	26,164	26,164	1,170	1,646	40	146	26,164	120	26,164	26,164	7,295
West Long Branch, Borough of	8,097	8,097	8,097	8,097	8,097	8,097	107	1,513	0	0	8,097	0	8,097	8,097	979
Monmouth County	630,380	630,380	630,380	630,380	630,380	630,380	67,249	142,143	2,330	3,487	630,380	1,173	630,380	630,380	163,328
Percent of Total Population	100%	100%	100%	100%	100%	100%	10.70%	22.60%	0.40%	0.60%	100%	0.20%	100%	100%	25.90%

Table 4.16 - 3 Population Exposure by Hazard by Human-based, by Jurisdiction

	Human Based Hazards					
Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Aberdeen, Township of	18,372	18,372	18,372	18,372	18,372	18,372
Allenhurst, Borough of	506	506	506	506	506	506
Allentown, Borough of	1,890	1,890	1,890	1,890	1,890	1,890
Asbury Park, City of	15,830	15,830	15,830	15,830	15,830	15,830
Atlantic Highlands, Borough of	4,322	4,322	4,322	4,322	4,322	4,322
Avon-By-The-Sea, Borough of	1,814	1,814	1,814	1,814	1,814	1,814
Belmar, Borough of	5,719	5,719	5,719	5,719	5,719	5,719
Bradley Beach, Borough of	4,262	4,262	4,262	4,262	4,262	4,262
Brielle, Borough of	4,738	4,738	4,738	4,738	4,738	4,738
Colts Neck, Township of	10,018	10,018	10,018	10,018	10,018	10,018
Deal, Borough of	579	579	579	579	579	579
Eatontown, Borough of	12,258	12,258	12,258	12,258	12,258	12,258

Jurisdiction	Human Based Hazards					
	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Englishtown, Borough of	2,131	2,131	2,131	2,131	2,131	2,131
Fair Haven, Borough of	6,015	6,015	6,015	6,015	6,015	6,015
Farmingdale, Borough of	1,470	1,470	1,470	1,470	1,470	1,470
Freehold, Borough of	11,938	11,938	11,938	11,938	11,938	11,938
Freehold, Township of	35,429	35,429	35,429	35,429	35,429	35,429
Hazlet, Township of	20,082	20,082	20,082	20,082	20,082	20,082
Highlands, Borough of	4,880	4,880	4,880	4,880	4,880	4,880
Holmdel, Township of	16,648	16,648	16,648	16,648	16,648	16,648
Howell, Township of	52,076	52,076	52,076	52,076	52,076	52,076
Interlaken, Borough of	825	825	825	825	825	825
Keansburg, Borough of	9,868	9,868	9,868	9,868	9,868	9,868
Keyport, Borough of	7,138	7,138	7,138	7,138	7,138	7,138
Lake Como, Borough of	1,518	1,518	1,518	1,518	1,518	1,518
Little Silver, Borough of	5,917	5,917	5,917	5,917	5,917	5,917
Loch Arbour, Village of	195	195	195	195	195	195
Long Branch, City of	30,751	30,751	30,751	30,751	30,751	30,751
Manalapan, Township of	40,096	40,096	40,096	40,096	40,096	40,096
Manasquan, Borough of	5,824	5,824	5,824	5,824	5,824	5,824
Marlboro, Township of	40,466	40,466	40,466	40,466	40,466	40,466
Matawan, Borough of	8,898	8,898	8,898	8,898	8,898	8,898
Middletown, Township of	65,952	65,952	65,952	65,952	65,952	65,952
Millstone, Township of	10,522	10,522	10,522	10,522	10,522	10,522
Monmouth Beach, Borough of	3,247	3,247	3,247	3,247	3,247	3,247
Neptune City, Borough of	27,728	27,728	27,728	27,728	27,728	27,728
Neptune, Township of	4,749	4,749	4,749	4,749	4,749	4,749

Jurisdiction	Human Based Hazards					
	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Ocean, Township of	27,006	27,006	27,006	27,006	27,006	27,006
Oceanport, Borough of	5,762	5,762	5,762	5,762	5,762	5,762
Red Bank, Borough of	12,220	12,220	12,220	12,220	12,220	12,220
Roosevelt, Borough of	808	808	808	808	808	808
Rumson, Borough of	6,874	6,874	6,874	6,874	6,874	6,874
Sea Bright, Borough of	1,304	1,304	1,304	1,304	1,304	1,304
Sea Girt, Borough of	1,714	1,714	1,714	1,714	1,714	1,714
Shrewsbury, Borough of	4,051	4,051	4,051	4,051	4,051	4,051
Shrewsbury, Township of	1,117	1,117	1,117	1,117	1,117	1,117
Spring Lake, Borough of	2,980	2,980	2,980	2,980	2,980	2,980
Spring Lake Heights, Borough of	4,645	4,645	4,645	4,645	4,645	4,645
Tinton Falls, Borough of	17,902	17,902	17,902	17,902	17,902	17,902
Union Beach, Borough of	5,634	5,634	5,634	5,634	5,634	5,634
Upper Freehold, Township of	6,899	6,899	6,899	6,899	6,899	6,899
Wall, Township of	26,020	26,020	26,020	26,020	26,020	26,020
West Long Branch, Borough of	7,944	7,944	7,944	7,944	7,944	7,944
Monmouth County	627,551	627,551	627,551	627,551	627,551	627,551
Percent of Total Population	100%	100%	100%	100%	100%	100%

Table 4.16 - 4 Annualized Building Losses by Hazard by Jurisdiction

	Severe Weather			Hurricane/ Tropical Storm/ Nor'easter							
Jurisdiction	Extreme Wind	Lightning	Tornado	Hurricane & Tropical Storm *(Hurricane Wind Only)*	Flood (riverine only)	Storm Surge	Wave Action	Coastal Erosion**	Nor'easter (wind only)	Winter Storm	Earthquake
Aberdeen, Township of	$25,893	$581	$111	$216,508	$20,091	$63,796	U	U	$3,374	$5,902	$2,244
Allenhurst, Borough of	$25,893	$581	$111	$64,035	$0	$845,582	U	U	$363	$5,902	$249
Allentown, Borough of	$25,893	$581	$111	$25,866	$56,571	$0	$0	$0	$127	$5,902	$223
Asbury Park, City of	$25,893	$581	$111	$414,465	$0	$1,575,622	U	U	$1,242	$5,902	$1,591
Atlantic Highlands Borough of	$25,893	$581	$111	$75,700	$0	$163,601	U	U	$914	$5,902	$465
Avon-By-The-Sea, Borough of	$25,893	$581	$111	$155,267	$0	$5,252,988	U	U	$435	$5,902	$562
Belmar, Borough of	$38,833	$581	$111	$226,242	$0	$6,631,441	U	U	$698	$5,902	$752
Bradley Beach, Borough of	$25,893	$581	$111	$210,323	$0	$2,004,646	$0	U	$514	$5,902	$724
Brielle, Borough of	$25,893	$581	$111	$237,188	$0	$2,796,954	U	U	$377	$5,902	$689
Colts Neck, Township of	$25,893	$6,930	$111	$408,519	$1,018,943	$0	$0	$0	$4,555	$5,902	$3,279
Deal, Borough of	$25,893	$581	$111	$232,869	$4,738	$453,051	U	U	$1,366	$5,902	$778
Eatontown, Borough of	$25,893	$581	$111	$296,481	$35,382	$18,837	$0	$0	$2,298	$5,902	$2,377
Englishtown, Borough of	$25,893	$581	$111	$17,781	$186,184	$0	$0	$0	$181	$5,902	$226
Fair Haven, Borough of	$25,893	$581	$111	$206,460	$0	$136,780	U	U	$2,150	$5,902	$1,052
Farmingdale, Borough of	$25,893	$581	$111	$24,781	$177,811	$0	$0	$0	$126	$5,902	$231
Freehold, Borough of	$77,667	$581	$111	$153,710	$0	$0	$0	$0	$1,074	$5,902	$1,548
Freehold, Township of	$25,893	$581	$111	$1,000,423	$869,366	$0	$0	$0	$7,493	$5,902	$8,242
Hazlet, Township of	$25,893	$581	$111	$279,141	$224,579	$1,292,794	$0	$0	$4,079	$5,902	$2,935
Highlands, Borough of	$25,893	$581	$908	$110,243	$0	$3,312,893	U	U	$1,293	$5,902	$489
Holmdel, Township of	$25,893	$581	$111	$400,754	$624,566	$0	$0	$0	$5,372	$5,902	$4,583
Howell, Township of	$25,893	$581	$111	$1,072,673	$2,251,491	$0	$0	$0	$3,569	$5,902	$6,738

	Severe Weather			Hurricane/ Tropical Storm/ Nor'easter							
Jurisdiction	Extreme Wind	Lightning	Tornado	Hurricane & Tropical Storm (*Hurricane Wind Only*)	Flood (riverine only)	Storm Surge	Wave Action	Coastal Erosion**	Nor'easter (wind only)	Winter Storm	Earthquake
Interlaken, Borough of	$25,893	$581	$111	$35,418	$709	$517,190	$0	$0	$169	$5,902	$122
Keansburg, Borough of	$25,893	$581	$111	$106,698	$367,864	$17,917,109	U	U	$1,408	$5,902	$874
Keyport, Borough of	$25,893	$581	$111	$99,832	$18,710	$990,499	U	U	$1,454	$5,902	$1,033
Lake Como, Borough of	$25,893	$6,930	$111	$66,013	$0	$963,430	$0	$0	$154	$5,902	$217
Little Silver, Borough of	$25,893	$581	$111	$250,551	$466	$1,393,899	$0	U	$2,561	$5,902	$1,538
Loch Arbour, Village of	$25,893	$581	$1,363	$28,393	$0	$356,115	U	U	$87	$5,902	$105
Long Branch, City of	$25,893	$581	$111	$1,248,692	$173,769	$6,875,112	U	U	$6,678	$5,902	$4,819
Manalapan, Township of	$25,893	$69,302	$18,164	$793,322	$2,751,086	$0	$0	$0	$7,127	$5,902	$8,070
Manasquan, Borough of	$25,893	$581	$111	$369,957	$0	$15,863,169	U	U	$414	$5,902	$1,070
Marlboro, Township of	$77,667	$581	$111	$861,702	$210,177	$0	$0	$0	$8,665	$5,902	$8,927
Matawan, Borough of	$25,893	$581	$111	$92,557	$246,391	$0	$0	$0	$1,457	$5,902	$1,148
Middletown, Township of	$25,893	$15,940	$111	$1,470,866	$1,777,644	$3,349,253	U	U	$17,264	$5,902	$11,766
Millstone, Township of	$25,893	$581	$1,816	$177,288	$828,582	$0	$0	$0	$1,286	$5,902	$1,917
Monmouth Beach, Borough of	$25,893	$581	$111	$340,758	$0	$8,002,783	U	U	$2,033	$5,902	$889
Neptune City, Borough of	$25,893	$581	$111	$108,373	$0	$266,432	U	U	$328	$5,902	$476
Neptune, Township of	$25,893	$581	$111	$616,407	$529,734	$1,846,473	U	U	$2,099	$5,902	$2,865
Ocean, Township of	$25,893	$581	$111	$766,949	$65,373	$59,675	$0	$0	$3,609	$5,902	$4,122
Oceanport, Borough of	$25,893	$6,930	$111	$197,754	$86,894	$2,948,692	$0	U	$1,458	$5,902	$819
Red Bank, Borough of	$25,893	$581	$111	$378,281	$556,642	$242,162	U	U	$3,318	$5,902	$3,005
Roosevelt, Borough of	$25,893	$581	$111	$2,641	$2,086	$0	$0	$0	$47	$5,902	$37
Rumson, Borough of	$25,893	$581	$111	$634,056	$0	$9,832,632	U	U	$5,821	$5,902	$3,003

Jurisdiction	Severe Weather: Extreme Wind	Severe Weather: Lightning	Severe Weather: Tornado	Hurricane/ Tropical Storm/ Nor'easter: Hurricane & Tropical Storm (*Hurricane Wind Only*)	Hurricane/ Tropical Storm/ Nor'easter: Flood (riverine only)	Hurricane/ Tropical Storm/ Nor'easter: Storm Surge	Hurricane/ Tropical Storm/ Nor'easter: Wave Action	Hurricane/ Tropical Storm/ Nor'easter: Coastal Erosion**	Hurricane/ Tropical Storm/ Nor'easter: Nor'easter (wind only)	Winter Storm	Earthquake
Sea Bright, Borough of	$25,893	$581	$111	$254,887	$0	$10,426,395	U	U	$1,704	$5,902	$488
Sea Girt, Borough of	$25,893	$581	$111	$246,662	$32,260	$1,256,276	U	U	$368	$5,902	$688
Shrewsbury, Borough of	$25,893	$581	$111	$104,946	$0	$71,765	$0	U	$1,153	$5,902	$1,029
Shrewsbury, Township of	$25,893	$581	$111	$3,791	$5,913	$0	$0	$0	$97	$5,902	$19
Spring Lake, Borough of	$25,893	$581	$111	$551,202	$109,746	$7,240,847	U	U	$1,063	$5,902	$1,603
Spring Lake Heights., Borough of	$25,893	$581	$111	$209,379	$143,108	$382,315	$0	$0	$503	$5,902	$666
Tinton Falls, Borough of	$25,893	$581	$111	$445,486	$495,370	$0	$0	$0	$4,449	$5,902	$2,900
Union Beach, Borough of	$25,893	$581	$111	$74,904	$0	$13,024,916	U	U	$926	$5,902	$651
Upper Freehold, Township of	$25,893	$34,651	$111	$185,144	$426,263	$0	$0	$0	$616	$5,902	$1,903
Wall, Township of	$25,893	$581	$111	$913,506	$378,478	$69,437	U	U	$1,603	$5,902	$4,758
West Long Branch, Borough of	$25,893	$581	$111	$223,225	$10,867	$0	$0	$0	$1,873	$5,902	$1,251
Monmouth County	$1,488,787	$168,010	$27,705	$17,689,068	$1,569,751	$46,023,644	UTD	UTD	$123,934	$312,823	$112,754

Potential Crop Losses Only; Data allowed for estimate of a county-wide total but not a jurisdiction specific estimate. Communities with USDA reported 0 acres in agriculture were assigned $0 average annual crop losses for planning purposes.U = Unable to Determine presumably negligible (less than $5,000 annual average damage) – For Extreme Temperature, Wildfire, Drought, Dam Failure, Coastal Erosion and Wave Action

Table 4.16 - 5 Annualized Loss Ratios by Hazard by Jurisdiction

Jurisdiction	Severe Weather: Extreme Temperatures	Severe Weather: Extreme Wind	Severe Weather: Lightning	Severe Weather: Tornado	Hurricane/ Tropical Storm/ Nor'easter: Hurricane & Tropical Storm (*Hurricane Wind Only*)	Hurricane/ Tropical Storm/ Nor'easter: Nor'easter (Wind only)	Hurricane/ Tropical Storm/ Nor'easter: Flood (Riverine Only)	Hurricane/ Tropical Storm/ Nor'easter: Storm Surge	Hurricane/ Tropical Storm/ Nor'easter: Wave Action	Hurricane/ Tropical Storm/ Nor'easter: Coastal Erosion	Winter Storm	Dam Failure	Drought* (*Crop Losses Only*)	Earthquake	Wildfire
Aberdeen, Township of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Allenhurst, Borough of	0.00%	0.01%	0.00%	0.00%	0.04%	0.00%	0.00%	0.81%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter										
Jurisdiction	Extreme Temperatures	Extreme Wind	Lightning	Tornado	Hurricane & Tropical Storm *(Hurricane Wind Only)*	Nor'easter (Wind only)	Flood (Riverine Only)	Storm Surge	Wave Action	Coastal Erosion	Winter Storm	Dam Failure	Drought* *(Crop Losses Only)*	Earthquake	Wildfire
Allentown, Borough of	0.00%	0.02%	0.00%	0.00%	0.03%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Asbury Park, City of	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Atlantic Highlands, Borough of	0.00%	0.01%	0.00%	0.00%	0.04%	0.00%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Avon-By-The-Sea, Borough of	0.00%	0.01%	0.00%	0.00%	0.05%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Belmar, Borough of	0.00%	0.01%	0.00%	0.00%	0.04%	0.00%	0.00%	1.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bradley Beach, Borough of	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	0.00%	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Brielle, Borough of	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	1.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Colts Neck, Township of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Deal, Borough of	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.37%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eatontown, Borough of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Englishtown, Borough of	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%	0.13%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fair Haven, Borough of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Farmingdale, Borough of	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%	0.14%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Freehold, Borough of	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Freehold, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hazlet, Township of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Highlands, Borough of	0.00%	0.01%	0.00%	0.00%	0.03%	0.00%	0.00%	1.86%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Jurisdiction	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter						Winter Storm	Dam Failure	Drought* *(Crop Losses Only)*	Earthquake	Wildfire
	Extreme Temperatures	Extreme Wind	Lightning	Tornado	Hurricane & Tropical Storm *(Hurricane Wind Only)*	Nor'easter (Wind only)	Flood (Riverine Only)	Storm Surge	Wave Action	Coastal Erosion					
Holmdel, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Howell, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Interlaken, Borough of	0.00%	0.03%	0.00%	0.00%	0.02%	0.00%	0.00%	0.66%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Keansburg, Borough of	0.00%	0.01%	0.00%	0.00%	0.04%	0.00%	0.09%	4.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Keyport, Borough of	0.00%	0.01%	0.00%	0.00%	0.03%	0.00%	0.00%	0.54%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lake Como, Borough of	0.00%	0.01%	0.00%	0.00%	0.06%	0.00%	0.00%	0.59%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Little Silver, Borough of	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	0.31%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loch Arbour, Village of	0.00%	0.06%	0.00%	0.00%	0.02%	0.00%	0.00%	0.81%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Long Branch, City of	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.01%	0.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Manalapan, Township of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Manasquan, Borough of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	2.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marlboro, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Matawan, Borough of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Middletown, Township of	0.00%	0.00%	0.00%	0.00%	0.07%	0.00%	0.03%	0.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Millstone, Township of	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Monmouth Beach, Borough of	0.00%	0.01%	0.00%	0.00%	0.04%	0.00%	0.00%	1.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter										
Jurisdiction	Extreme Temperatures	Extreme Wind	Lightning	Tornado	Hurricane & Tropical Storm *(Hurricane Wind Only)*	Nor'easter (Wind only)	Flood (Riverine Only)	Storm Surge	Wave Action	Coastal Erosion	Winter Storm	Dam Failure	Drought* *(Crop Losses Only)*	Earthquake	Wildfire
Neptune City, Borough of	0.00%	0.01%	0.00%	0.00%	0.03%	0.00%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Neptune, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.03%	0.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ocean, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Oceanport, Borough of	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.59%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red Bank, Borough of	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.04%	0.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Roosevelt, Borough of	0.00%	0.06%	0.00%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Rumson, Borough of	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	1.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sea Bright, Borough of	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	0.00%	3.89%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sea Girt, Borough of	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.26%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Shrewsbury, Borough of	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	0.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Shrewsbury, Township of	0.00%	0.09%	0.00%	0.00%	0.04%	0.00%	0.02%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%
Spring Lake, Borough of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.01%	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Spring Lake Heights., Borough of	0.00%	0.01%	0.00%	0.00%	0.03%	0.00%	0.03%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tinton Falls, Borough of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Union Beach, Borough of	0.00%	0.01%	0.00%	0.00%	0.04%	0.00%	0.00%	4.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upper Freehold, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Jurisdiction	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter						Winter Storm	Dam Failure	Drought* *(Crop Losses Only)*	Earthquake	Wildfire
	Extreme Temperatures	Extreme Wind	Lightning	Tornado	Hurricane & Tropical Storm *(Hurricane Wind Only)*	Nor'easter (Wind only)	Flood (Riverine Only)	Storm Surge	Wave Action	Coastal Erosion					
Wall, Township of	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.01%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
West Long Branch, Borough of	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Monmouth Countyl	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.98%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 4.16 - 1 Monmouth County Composite Map of Vulnerability

4.16.1 PRIORITY RISK INDEX

The hazard profiles presented in this section were developed using best available data and result in what may be considered principally a qualitative assessment as recommended by FEMA in its guidance document entitled Local Mitigation Planning Handbook. It relies heavily on historical and anecdotal data, stakeholder input, and professional and experienced judgment regarding observed and/or anticipated hazard impacts; and carefully considers the findings in other relevant plans, studies and technical reports.

In order to draw some meaningful planning conclusions on hazard risk for Monmouth County as a whole and each participating jurisdiction, the hazard profiling and risk assessment processes were used to generate hazard classifications according to a "Priority Risk Index" (PRI) - a tool used to measure the degree of risk for identified hazards in a particular planning area. The purpose of the PRI, described further below, is to categorize and prioritize all potential hazards as high, moderate or low risk. The PRI is used to assist the Monmouth County Planning Committee in gaining consensus on the determination of those hazards that pose the most significant threat to Monmouth County based on a variety of factors. The PRI is not scientifically based but is rather meant to be utilized as an objective planning tool for classifying and prioritizing hazard risks in Monmouth County based on standardized criteria. Combined with the asset inventory and quantitative vulnerability assessment provided in the previous sections, the summary hazard classifications generated through the use of the PRI allows for the prioritization of those high hazard risks for mitigation planning purposes, and more specifically, the identification of hazard mitigation opportunities for Monmouth County jurisdictions to consider as part of their proposed mitigation strategies. Each jurisdiction focused on the identification of mitigation actions that will reduce or eliminate their own unique hazard risks.

The application of the PRI results in numerical values that allow identified hazards to be ranked against one another (the higher the PRI value, the greater the hazard risk). PRI values are obtained by assigning varying degrees of risk to five categories for each hazard (probability, impact, spatial extent, warning time and duration). Each degree of risk has been assigned a value (1 to 4) and an agreed upon weighting factor, as summarized in Table 4.16 - 6 Priority Risk Index for Monmouth County. To calculate the PRI value for a given hazard, the assigned risk value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the example equation below. According to the weighting scheme applied for Monmouth County, the highest possible PRI value is 4.0.

PRI VALUE = [(PROBABILITY x .30) + (IMPACT x .30) + (SPATIAL EXTENT x .20) + (WARNING TIME x .10) + (DURATION x .10)]

As part of the 2019 Plan Update, the application of the PRI was redone for every participating jurisdiction. PRI scores and risk rankings were found to change in many communities, as a result of what the planning team feels is a more realistic assessment of the level estimated for each hazard's PRI categories. Prior to being finalized, PRI values for each identified hazard were reviewed and accepted by the members of the CPG.

Table 4.16 - 6 Priority Risk Index for Monmouth County

PRI Category	Degree of Risk			Assigned Weighting Factor
	Level	Criteria	Index Value	
Probability	Unlikely	Less than 1% annual probability	1	30%
	Possible	Between 1 and 10% annual probability	2	
	Likely	Between 10 and 100% annual probability	3	
	Highly Likely	100% annual probability	4	
Impact	Minor	Very few injuries, if any. Only minor property damage and minimal disruption on quality of life. Temporary shutdown of critical facilities.	1	30%
	Limited	Minor injuries only. More than 10% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one day.	2	
	Critical	Multiple deaths/injuries possible. More than 25% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one week.	3	
	Catastrophic	High number of deaths/injuries possible. More than 50% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for 30 days or more.	4	
Spatial Extent	Negligible	Less than 1% of area affected	1	20%
	Small	Between 1 and 10% of area affected	2	
	Moderate	Between 10 and 50% of area affected	3	
	Large	Between 50 and 100% of area affected	4	
Warning Time	More than 24 hours	Self-explanatory	1	10%
	12 to 24 hours	Self-explanatory	2	
	6 to 12 hours	Self-explanatory	3	
	Less than 6 hours	Self-explanatory	4	
Duration	Less than 6 hours	Self-explanatory	1	10%
	Less than 24 hours	Self-explanatory	2	
	Less than one week	Self-explanatory	3	
	More than one week	Self-explanatory	4	

4.16.2 PRI RESULTS

The application of the PRI was done separately for each jurisdiction in Monmouth County, and for the County as a whole. Assigned risk levels were based on the detailed hazard profiles developed for this section, as well as input from the Planning Committee and results of the vulnerability assessment. The results were then used in calculating PRI values and making final determinations for the risk assessment. **Table 4.16 - 7 Summary of PRI Results for Monmouth County** summarizes the degree of risk assigned to each category for all identified hazards based on the application of the PRI for Monmouth County, as a whole.

Table 4.16 - 7 **Summary of PRI Results for Monmouth County**

Hazard		Category/Degree of Risk										
		Probability	Probability Index Value	Impact	Impact Index Value	Spatial Extent	Spatial Index Value	Warning Time	Warning Index Value	Duration	Duration Index Value	PRI Score
Severe Weather	Extreme Temps	Highly Likely	4	Minor	1	Large	4	More than 24 hours	1	Less than one week	3	2.7
Severe Weather	Extreme Wind	Highly Likely	4	Limited	2	Large	4	More than 24 hours	1	Less than 24 hours	2	2.9
Severe Weather	Lightning	Highly Likely	4	Minor	1	Negligible	1	Less than 6 hours	4	Less than 6 hours	1	2.2
Severe Weather	Tornado	Likely	3	Catastrophic	4	Negligible		Less than 6 hours	4	Less than 6 hours	1	2.8
Hurricane/ Tropical Storm/ Nor'easter	Hurricane & Tropical Storm	Likely	3	Catastrophic	4	Large	4	More than 24 hours	1	Less than one week	3	3.3
Hurricane/ Tropical Storm/ Nor'easter	Nor'easter	Highly Likely	4	Limited	2	Large	4	More than 24 hours	1	Less than one week	3	3
Hurricane/ Tropical Storm/ Nor'easter	Flood	Highly Likely	4	Critical	3	Moderate	3	6 to 2 hours	3	Less than one week	3	3.3
Hurricane/ Tropical Storm/ Nor'easter	Storm Surge	Likely	3	Catastrophic	4	Moderate	3	More than 24 hours	1	Less than one week	3	3.1
Hurricane/ Tropical Storm/ Nor'easter	Wave Action	Highly Likely	4	Catastrophic	4	Negligible	1	More than 24 hours	1	Less than one week	3	3
Hurricane/ Tropical Storm/ Nor'easter	Coastal Erosion	Highly Likely	4	Catastrophic	4	Negligible	1	More than 24 hours	1	Less than one week	3	3
Hurricane/ Tropical Storm/ Nor'easter	Tsunami	Unlikely	1	Critical	3	Moderate	3	Less than 6 hours	4	Less than 6 hours	1	2.3
Winter Storm		Highly Likely	4	Minor	1	Large	4	More than 24 hours	1	Less than one week	3	2.7
Dam Failure		Unlikely	1	Catastrophic	4	Negligible	1	Less than 6 hours	4	Less than 6 hours	1	2.2
Drought		Possible	2	Minor	1	Large	4	More than 24 hours	1	More than one week	4	2.2
Earthquake		Unlikely	1	Minor	1	Large	4	Less than 6 hours	4	Less than 6 hours	1	1.9
Landslide		Possible	2	Catastrophic	-	Negligible	-	Less than 6 hours	4	Less than 6 hours	-	2.5
Wildfire		Highly Likely	4	Minor	1	Moderate	3	Less than 6 hours	4	Less than one week	3	2.8
Civil Unrest		Unlikely	1	Limited	3	Moderate	3	Less than 6 hours	4	More than one week	4	2.1
Cyber Attack		Unlikely	1	Critical	2	Moderate	3	Less than 6 hours	4	Less than 24 hours	2	2.6
Economic Disruption		Unlikely	1	Critical	3	Large	4	Less than 6 hours	4	More than one week	4	2.8
Pandemic		Unlikely	1	Catastrophic	4	Large	4	Less than 6 hours	4	More than one week	4	3.1

Hazard	Category/Degree of Risk									
	Probability	Probability Index Value	Impact	Impact Index Value	Spatial Extent	Spatial Index Value	Warning Time	Warning Index Value	Duration	Duration Index Value	PRI Score
Power Failure	Unlikely	1	Minor	1	Large	4	Less than 6 hours	4	Less than one week	3	2.1
Terrorism	Unlikely	1	Critical	3	Large	4	Less than 6 hours	4	Less than 24 hours	2	2.6

Table 4.17 - 8 PRI Results of Natural Hazards, by Jurisdiction presents an overview of the PRI Results for each jurisdiction

Table 4.16 - 8 PRI Results of Natural Hazards, by Jurisdiction

	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter												
Jurisdiction	Extreme Temps.	Extreme Wind	Lightning	Tornado	Hurricane	Nor'easter	Coastal Erosion	Flood	Storm Surge	Wave Action	Tsunami	Winter Storm	Dam Failure	Landslide	Drought	Earthquake	Wildfire
Aberdeen, Township of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Allenhurst, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Allentown, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	2.2	NIA	2.2	1.9	3.1
Asbury Park, City of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Atlantic Highlands, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	3.1	2.2	1.9	1.7
Avon-By-The-Sea, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Belmar, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Bradley Beach, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Brielle, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Colts Neck, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	2.2	NIA	2.2	1.9	2.8
Deal, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Eatontown, Borough of	2.7	2.9	2.2	2.8	3	3	NIA	3	3.1	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.7
Englishtown, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	2.2	NIA	2.2	1.9	2.2
Fair Haven, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	2.5	2.2	1.9	2

Jurisdiction	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter							Winter Storm	Dam Failure	Landslide	Drought	Earthquake	Wildfire
	Extreme Temps.	Extreme Wind	Lightning	Tornado	Hurricane	Nor'easter	Coastal Erosion	Flood	Storm Surge	Wave Action	Tsunami						
Farmingdale, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	NIA	NIA	2.2	1.9	2.2
Freehold, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	NIA	NIA	NIA	NIA	2.7	NIA	NIA	2.2	1.9	2
Freehold, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	2.2	2.2	2.2	1.9	3.1
Hazlet, Township of	2.7	2.9	2.2	2.8	3.3	3	NIA	3	3.1	NIA	NIA	2.7	NIA	NIA	2.2	1.9	2
Highlands, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	3.1	2.2	1.9	1.7
Holmdel, Township of	2.7	2.9	2.2	2.8	3	3	NIA	3	2.7	NIA	NIA	2.7	NIA	NIA	2.2	1.9	2.8
Howell, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	2.7	NIA	NIA	2.7	2.2	2.2	2.2	1.9	3.1
Interlaken, Borough of	2.7	2.9	2.2	2.8	3.3	3	NIA	3	3.1	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.7
Keansburg, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3.2	3.3	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Keyport, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	2
Lake Como, Borough of	2.7	2.9	2.2	2.8	3.3	3	NIA	3	3.3	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.5
Little Silver, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.3	NIA	2.3	2.7	NIA	2.5	2.2	1.9	2
Loch Arbour, Village of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.3	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.5
Long Branch, City of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Manalapan, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	2.2	NIA	2.2	1.9	2.2
Manasquan, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.3	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Marlboro, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	NIA	NIA	2.2	1.9	2.2
Matawan, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	3.1	NIA	NIA	2.7	2.2	NIA	2.2	1.9	2
Middletown, Township of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	2.2	2.5	2.2	1.9	2.2
Millstone, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	NIA	NIA	NIA	2.7	2.2	NIA	2.2	1.9	2.5
Monmouth Beach, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3.2	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Neptune City, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	2.8	3.1	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Neptune, Township of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	2.2	NIA	2.2	1.9	2.2
Ocean, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	3	3.1	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.7
Oceanport, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.3	2.7	2.3	2.7	NIA	2.2	2.2	1.9	1.7

	Severe Weather				Hurricane/ Tropical Storm/ Nor'easter												
Jurisdiction	Extreme Temps.	Extreme Wind	Lightning	Tornado	Hurricane	Nor'easter	Coastal Erosion	Flood	Storm Surge	Wave Action	Tsunami	Winter Storm	Dam Failure	Landslide	Drought	Earthquake	Wildfire
Red Bank, Borough of	2.7	2.9	2.2	2.8	2.7	3	2.1	2.8	2.9	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Roosevelt, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	2.2	NIA	NIA	NIA	2.7	NIA	NIA	2.2	1.9	3
Rumson, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.1	2.7	2.3	2.7	NIA	2.5	2.2	1.9	2.8
Sea Bright, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3.2	3.3	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.5
Sea Girt, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.3	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Shrewsbury, Borough of	2.7	2.9	2.2	2.8	3.3	3	NIA	3	3.1	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.9
Shrewsbury, Township of	2.7	2.9	2.2	2.8	2.7	3	NIA	2	NIA	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.9
Spring Lake, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3	3.3	2.7	2.3	2.7	NIA	NIA	2.2	1.9	1.7
Spring Lake Hts., Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	2.8	3.1	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.7
Tinton Falls, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	2.8	2.9	NIA	NIA	2.7	2.2	2.8	2.2	1.9	2.8
Union Beach, Borough of	2.7	2.9	2.2	2.8	3.3	3	2.7	3.2	3.3	2.9	2.3	2.7	NIA	NIA	2.2	1.9	1.9
Upper Freehold, Township of	2.7	2.9	2.2	2.8	3.3	3	NIA	3.3	NIA	NIA	NIA	2.7	2.2	NIA	2.2	1.9	2.2
Wall, Township of	2.7	2.9	2.2	2.8	2.7	3	2.7	2.8	3.1	2.7	2.3	2.7	2.2	NIA	2.2	1.9	3.1
West Long Branch, Borough of	2.7	2.9	2.2	2.8	2.7	3	NIA	2.8	3.1	NIA	NIA	2.7	NIA	NIA	2.2	1.9	1.7
Monmouth County	2.7	2.9	2.2	2.8	3.3	3	3	3.3	3.1	3	2.3	2.7	2.2	2.5	2.2	1.9	2.8

Table 4.16 - 9 PRI Results of Human Hazards for Each Jurisdiction

Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Aberdeen, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Allenhurst, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Allentown, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Asbury Park, City of	2.1	2.6	2.8	3.1	2.1	2.6
Atlantic Highlands, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Avon-By-The-Sea, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Belmar, Borough of	2.1	2.6	2.8	3.1	2.1	2.6

Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Bradley Beach, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Brielle, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Colts Neck, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Deal, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Eatontown, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Englishtown, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Fair Haven, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Farmingdale, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Freehold, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Freehold, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Hazlet, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Highlands, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Holmdel, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Howell, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Interlaken, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Keansburg, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Keyport, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Lake Como, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Little Silver, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Loch Arbour, Village of	2.1	2.6	2.8	3.1	2.1	2.6
Long Branch, City of	2.1	2.6	2.8	3.1	2.1	2.6
Manalapan, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Manasquan, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Marlboro, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Matawan, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Middletown, Township	2.1	2.6	2.8	3.1	2.1	2.6
Millstone, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Monmouth Beach, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Neptune City, Borough	2.1	2.6	2.8	3.1	2.1	2.6
Neptune, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Ocean, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Oceanport, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Red Bank, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Roosevelt, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Rumson, Borough of	2.1	2.6	2.8	3.1	2.1	2.6

Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Sea Bright, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Sea Girt, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Shrewsbury, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Shrewsbury, Township	2.1	2.6	2.8	3.1	2.1	2.6
Spring Lake, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Spring Lake Hts., Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Tinton Falls, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Union Beach, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Upper Freehold, Township of	2.1	2.6	2.8	3.1	2.1	2.6
Wall, Township of	2.1	2.6	2.8	3.1	2.1	2.6
West Long Branch, Borough of	2.1	2.6	2.8	3.1	2.1	2.6
Monmouth County	2.1	2.6	2.8	3.1	2.1	2.6

4.16.3 FINAL DETERMINATIONS

The conclusions drawn from the application of the PRI process for Monmouth County, including the PRI results and input from the Steering Committee, resulted in the classification of risk for each identified hazard according to three categories: High Risk (H), Moderate Risk (M) and Low Risk (L). Hazards with a PRI of 3.0 or more were deemed "high risk"; hazards with a PRI between 2.4 and 2.9 were deemed "moderate risk"; and hazards with a PRI of 2.3 or less were deemed "low risk". For purposes of these classifications, risk is expressed in relative terms according to the estimated impact that a hazard will have on human life and property throughout all of Monmouth County. It should be noted that although some hazards are classified below as posing low risk, their occurrence of varying or unprecedented magnitudes is still possible in some cases and their assigned classification will continue to be evaluated during future plan updates. Table 4.16– 10 Hazard Risk Rankings for Monmouth County presents conclusions on hazard risk for the County as a whole, based on the PRI scores for each hazard in the County. Table 4.16 – 11 Natural Hazard Risk Rankings, by Jurisdiction and Table 4.17-12 Human-based Hazard Risk Rankings, by Jurisdiction presents an overview of the resultant hazard risk rankings for each jurisdiction.

Table 4.16 - 10 Hazard Risk Rankings for Monmouth County

Hazard Risk Rankings for Monmouth County	
HIGH RISK PRI ≥ 3.0	Hurricane and Tropical Storm Nor'easter Coastal Erosion Flood Storm Surge Wave Action Pandemic

Hazard Risk Rankings for Monmouth County	
MODERATE RISK 2.4 ≤ PRI ≤ 2.9	Extreme Temperatures Extreme Wind Tornado Winter Storm Wildfire Cyber Attack Economic Disruption Terrorism Landslide
LOW RISK PRI ≤ 2.3	Lightning Dam Failure Drought Earthquake Tsunami Civil Unrest Power Failure

Table 4.16 - 11 Natural Hazard Risk Rankings, by Jurisdiction

Jurisdiction	Extreme Temperatures	Extreme Wind	Hurricane/ Tropical Storm	Lightning	Nor'easter	Tornado	Winter Storm	Coastal Erosion	Dam Failure	Landslide	Drought	Flood	Storm Surge	Wave Action	Earthquake	Wildfire
Aberdeen, Township of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Allenhurst, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Allentown, Borough of	M	M	M	L	H	M	M	N/A	L	N/A	L	H	N/A	N/A	L	H
Asbury Park, City of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Atlantic Highlands, Borough of	M	M	H	L	H	M	M	M	N/A	H	L	H	H	M	L	L
Avon-By-The-Sea, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Belmar, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Bradley Beach, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Brielle, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Colts Neck, Township of	M	M	M	L	H	M	M	N/A	L	N/A	L	H	N/A	N/A	L	M
Deal, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Eatontown, Borough of	M	M	H	L	H	M	M	N/A	N/A	N/A	L	H	H	N/A	L	L
Englishtown, Borough of	M	M	M	L	H	M	M	N/A	L	N/A	L	H	N/A	N/A	L	L
Fair Haven, Borough of	M	M	H	L	H	M	M	M	N/A	M	L	H	H	M	L	L
Farmingdale, Borough of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	H	N/A	N/A	L	L
Freehold, Borough of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	N/A	N/A	N/A	L	L
Freehold, Township of	M	M	M	L	H	M	M	N/A	L	L	L	H	N/A	N/A	L	H
Hazlet, Township of	M	M	H	L	H	M	M	N/A	N/A	N/A	L	H	H	N/A	L	L
Highlands, Borough of	M	M	H	L	H	M	M	M	N/A	H	L	H	H	M	L	L

Jurisdiction	Extreme Temperatures	Extreme Wind	Hurricane/ Tropical Storm	Lightning	Nor'easter	Tornado	Winter Storm	Coastal Erosion	Dam Failure	Landslide	Drought	Flood	Storm Surge	Wave Action	Earthquake	Wildfire
Holmdel, Township of	M	M	H	L	H	M	M	N/A	N/A	N/A	L	H	M	N/A	L	M
Howell, Township of	M	M	M	L	H	M	M	N/A	L	L	L	H	M	N/A	L	H
Interlaken, Borough of	M	M	H	L	H	M	M	N/A	N/A	N/A	L	H	H	N/A	L	L
Keansburg, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Keyport, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Lake Como, Borough of	M	M	H	L	H	M	M	N/A	N/A	N/A	L	H	H	N/A	L	L
Little Silver, Borough of	M	M	H	L	H	M	M	M	N/A	M	L	H	H	N/A	L	L
Loch Arbour, Village of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Long Branch, City of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Manalapan, Township of	M	M	M	L	H	M	M	N/A	L	N/A	L	H	N/A	N/A	L	L
Manasquan, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Marlboro, Township of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	H	N/A	N/A	L	L
Matawan, Borough of	M	M	M	L	H	M	M	N/A	L	N/A	L	H	H	N/A	L	L
Middletown, Township of	M	M	H	L	H	M	M	M	L	M	L	H	H	M	L	L
Millstone, Township of	M	M	M	L	H	M	M	N/A	L	N/A	L	H	N/A	N/A	L	M
Monmouth Beach, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Neptune City, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	M	H	M	L	L
Neptune, Township of	M	M	H	L	H	M	M	M	L	N/A	L	H	H	M	L	L
Ocean, Township of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	H	H	N/A	L	L
Oceanport, Borough of	M	M	H	L	H	M	M	M	N/A	L	L	H	H	M	L	L
Red Bank, Borough of	M	M	M	L	H	M	M	L	N/A	N/A	L	M	M	M	L	L
Roosevelt, Borough of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	L	N/A	N/A	L	H
Rumson, Borough of	M	M	H	L	H	M	M	M	N/A	M	L	H	H	M	L	M
Sea Bright, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Sea Girt, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Shrewsbury, Borough of	M	M	H	L	H	M	M	N/A	N/A	N/A	L	H	H	N/A	L	L
Shrewsbury, Township of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	L	N/A	N/A	L	L
Spring Lake, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Spring Lake Hts., Borough of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	M	H	N/A	L	L
Tinton Falls, Borough of	M	M	M	L	H	M	M	N/A	L	M	L	M	M	N/A	L	M
Union Beach, Borough of	M	M	H	L	H	M	M	M	N/A	N/A	L	H	H	M	L	L
Upper Freehold, Township of	M	M	H	L	H	M	M	N/A	L	N/A	L	H	N/A	N/A	L	L
Wall, Township of	M	M	M	L	H	M	M	M	L	N/A	L	M	H	M	L	H
West Long Branch, Borough of	M	M	M	L	H	M	M	N/A	N/A	N/A	L	M	H	N/A	L	L
Monmouth County	M	M	N	L	N	M	M	N	L	M	L	N	N	N	L	M

Table 4.16 - 12 Human-based Hazard Risk Rankings, by Jurisdiction

Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Aberdeen, Township of	L	M	M	H	L	M
Allenhurst, Borough of	L	M	M	H	L	M
Allentown, Borough of	L	M	M	H	L	M
Asbury Park, City of	L	M	M	H	L	M
Atlantic Highlands, Borough of	L	M	M	H	L	M
Avon-By-The-Sea, Borough of	L	M	M	H	L	M
Belmar, Borough of	L	M	M	H	L	M
Bradley Beach, Borough of	L	M	M	H	L	M
Brielle, Borough of	L	M	M	H	L	M
Colts Neck, Township of	L	M	M	H	L	M
Deal, Borough of	L	M	M	H	L	M
Eatontown, Borough of	L	M	M	H	L	M
Englishtown, Borough of	L	M	M	H	L	M
Fair Haven, Borough of	L	M	M	H	L	M
Farmingdale, Borough of	L	M	M	H	L	M
Freehold, Borough of	L	M	M	H	L	M
Freehold, Township of	L	M	M	H	L	M
Hazlet, Township of	L	M	M	H	L	M
Highlands, Borough of	L	M	M	H	L	M
Holmdel, Township of	L	M	M	H	L	M
Howell, Township of	L	M	M	H	L	M
Interlaken, Borough of	L	M	M	H	L	M
Keansburg, Borough of	L	M	M	H	L	M
Keyport, Borough of	L	M	M	H	L	M
Lake Como, Borough of	L	M	M	H	L	M
Little Silver, Borough of	L	M	M	H	L	M
Loch Arbour, Village of	L	M	M	H	L	M
Long Branch, City of	L	M	M	H	L	M
Manalapan, Township of	L	M	M	H	L	M
Manasquan, Borough of	L	M	M	H	L	M
Marlboro, Township of	L	M	M	H	L	M
Matawan, Borough of	L	M	M	H	L	M
Middletown, Township of	L	M	M	H	L	M
Millstone, Township of	L	M	M	H	L	M
Monmouth Beach, Borough of	L	M	M	H	L	M
Neptune City, Borough of	L	M	M	H	L	M
Neptune, Township of	L	M	M	H	L	M
Ocean, Township of	L	M	M	H	L	M
Oceanport, Borough of	L	M	M	H	L	M
Red Bank, Borough of	L	M	M	H	L	M
Roosevelt, Borough of	L	M	M	H	L	M
Rumson, Borough of	L	M	M	H	L	M
Sea Bright, Borough of	L	M	M	H	L	M
Sea Girt, Borough of	L	M	M	H	L	M
Shrewsbury, Borough of	L	M	M	H	L	M
Shrewsbury, Township of	L	M	M	H	L	M
Spring Lake, Borough of	L	M	M	H	L	M
Spring Lake Hts., Borough of	L	M	M	H	L	M
Tinton Falls, Borough of	L	M	M	H	L	M

Jurisdiction	Civil Unrest	Cyber Attack	Economic Disruption	Pandemic	Power Failure	Terrorism
Union Beach, Borough of	L	M	M	H	L	M
Upper Freehold, Township of	L	M	M	H	L	M
Wall, Township of	L	M	M	H	L	M
West Long Branch, Borough of	L	M	M	H	L	M
Monmouth County	L	M	M	H	L	M

4.16.4 KEY RISK FINDINGS

Key Risk Findings are problem statements developed from the risk assessment by each participating jurisdiction. Each jurisdiction was encouraged to consider different types of mitigation actions for addressing their highest hazards and Key Risk Findings. Key Risk Findings for Monmouth County are presented in Table 4.16- 13 Key Risk Findings for Monmouth County.

Table 4.16 - 13 Key Risk Findings for Monmouth County

- The CRS program, which is run by FEMA through the National Flood Insurance Program (NFIP), scores communities on their effectiveness in dealing with flood plain management and development. Towns that take action steps to increase their resiliency to future storm events can help residents and businesses increase their eligibility for policy holder discounts. The program differentiates amongst ten classes. Communities enter at Class 10, and then as additional activities undertaken, they accumulate points toward moving up into the next higher class and achieving an associated decrease in insurance premiums for policyholders in their jurisdiction. Currently, there are eight Monmouth County towns that are part of the CRS program. Many communities in the County lack the resources to undertake the more technical aspects of the program in-house. In turn, many communities have either not accessed the program at all or have entered at only the lowest levels. Many homeowners and businesses in Monmouth County may see an increase in their flood insurance premiums as the new FEMA Flood Maps are adopted. Currently there are 16 communities in the CRS programs: Aberdeen, Avon-By-The-Sea, Belmar, Bradley Beach, Hazlet, Keansburg, Long Branch, Manasquan, Middletown, Monmouth Beach, Neptune, Ocean, Oceanport, Sea Bright, Spring Lake, and Union Beach are listed by FEMA as Community Rating System (CRS) participating communities.
- All communities in Monmouth County participate in FEMA's NFIP. Many communities and residents suffer from flooding events on a regular basis, and incur significant damages and costs associated with preparation, response, and recovery from these events. There is a disconnect in some communities between local master plans and floodplain management issues.
- Many local officials in Monmouth County lack direct access to mapping services (i.e., GIS). This creates a gap in their full understanding of natural hazards in their communities; significant costs are incurred each year for hazard response, recovery, and damage repair. Lack of access to mapping services such as GIS creates a situation in some communities where mitigation project development is sometimes hindered, and public education warning programs are not as efficient targeted as they could be. Having more direct access to mapping services tools could facilitate local communities’ efforts to guide development away from hazard areas, improve public education warning for their residents in hazard areas, and enhance their mitigation project development.
- Monmouth County has an active history of hurricanes and tropical storms. Implementation of

evacuation orders related to an impending hurricane would have a significant impact on travel patterns and operating conditions on the area's transportation system. For example, prevailing directional patterns would be altered substantially as westbound and coastal residents and visitors traveling away from the coast to higher ground would heavily utilize northbound travel lanes. Congestion levels at locations that already have constrained service rate issues, such as merge junctions, ramps, and signalized major intersections would be exacerbated. The timing of an evacuation order would have a significant effect on traffic flows, the shorter the timeframe, the more intense delays and queuing potential. Operational, physical and long-term improvements (either by route or by type) would greatly enhance to capacity of these evacuation routes during an evacuation order.
-The general public's understanding of natural hazards and mitigation possibilities could be improved. The community's overall level of disaster resistance would increase if a greater number of households undertook low-cost or no-cost, small-scale mitigation activities.
- A section of the Henry Hudson Trail located in Atlantic Highlands along Sandy Hook Bay was destroyed by Superstorm Sandy. The adjacent coastal bluff experienced erosion at the base of the slope from wave action and storm surge. Above the trail, located on the bluff, there are numerous high value residences that have taken advantage of the unique location. The bluff is subject to slump block failure usually associated with a rain event and disruption of the slope.
- Within Hartshorne Woods Park (Middletown) there are two unique sites; Claypit Creek and Portland Place. The sites are protected by coastal river-edge bluffs which were severely eroded during the Superstorm Sandy event. Both sites offer passive recreation activities for County residents and have a south-eastern orientation steep bluff, which received the most direct exposure of winds, flooding and wave action from the storm.
- The County Park System acquires land for open space preservation, public park & recreation purposes and natural resources conservation. Some of the properties that are identified for acquisition are ones that are subject to flooding, winter storms or associated storm surges. These properties may be located in coastal zones or located along stream and river corridors throughout the county. When many properties along a watercourse are acquired, they form a protected greenway along the stream or river. By purchasing these properties, any buildings located in the flood zone are removed and the land is restored to a natural condition. Protected lands adjacent to coastal zones and river courses helps to reduce regional flooding by not increasing impervious cover and also allows natural systems of forests and marshes to mitigate some of the effects of flooding.
- Fisherman's Cove Conservation Area, Seven Presidents Oceanfront Park, Henry Hudson Trail - Popamora Point, and Bayshore Waterfront Park have all experienced some coastal dunes loss, erosion of coastal zone open space real estate, sedimentation of adjacent channels, and/or loss of protective features for adjacent private properties.
- Pine Brook (Pine Brook Golf Course, Manalapan) and Ramanessin Brook (Holmdel Park, Holmdel) stream bank stabilization, Manasquan River (Turkey Swamp Park, Freehold) floodplain restoration. The Manasquan River has been increasingly more flood prone and suffers potable water quality issues related to increased watershed development and past stream channel straightening impacts. A proposal has been in the planning phase for many years to re-introduce stream form and function in the upper reaches of the watershed where extensive straightening occurred in the past. This will result in more stream stability and improved water quality with improve stream function.
- Certain wild-lands and urban interface areas pose a risk to losses by fire. Fisherman's Cove Conservation Area (Manasquan Borough), Turkey Swamp Park (Freehold Township) and Bayshore Waterfront Park (Middletown Township) are all park areas that have been subject to wildfires, which

have potential to destroy adjacent residential properties as well as park building infrastructure.
- Lack of fuel supply in a key location of Monmouth County (Highway District Yard #6 in the Borough of Eatontown), which is detrimental to operational and emergency services provided during a time of disaster or crisis.
- Telecommunication and electrical systems at key Monmouth County Operational Buildings are negatively impacted during periods of Power Failure (interruption or loss of electrical service caused by disruption of power transmission caused by accident, sabotage, natural hazards, or equipment failure).
-Capacity and integrity issues of NJDEP defined Class 1 dams (those structures which, should they fail, would likely cause loss of life) and Class 2 dams (those structures which, should they fail, would likely cause substantial downstream property damage but are not considered to be a threat to life) as well as the associated bridge, bridge approaches and roadways. Locations include, but are not limited to, the following: 1) Lake Lefferts Dam, County Bridge MA-9, Ravine Dr. (CR 6A), Matawan; 2) Matawan Lake Dam, County Bridge MA-13, Main St. (CR 516), Matawan; 3) Perrineville Dam, County Bridge MS-48, Perrineville Rd. (CR 1), Millstone; 4) Shadow Lake Dam, County Bridges MT-30 & MT-45, Hubbard Ave. (CR 12), Middletown; 5) Indian Dam, County Bridge U-18, Church St. (CR 526), Allentown; 6) Hurley Pond Dam, County Bridge W-18, Allenwood Rd., Wall Township.
- Roadways and bridges below base elevation incur flooding. Locations include, but are not limited to: County Bridge H-5 & H-5A, Palmer Ave. (CR 7), Holmdel & Middletown; County Bridges ML-17, ML-18, & ML-19, Station Rd., Marlboro; County Bridge R-5, Florence Ave. (CR 39), Union Beach; and Union Ave.(CR 39), Union Beach. Road flooding, resulting in damage to infrastructure reduced safe passage, and isolation of neighborhoods by flood waters.
- Storm events and subsequent flooding wash substantial amounts of debris and sedimentation in creeks and waterways, compounding the effects of natural siltation and buildup of debris and fallen trees, which obstruct the natural flow of some surface waters, resulting in increased inland and coastal flooding.
- Structural integrity of bridges that are exposed to wave, tidal, and storm surges. These bridges may carry coastal evacuation routes and any damage to the bridge, or their approach roads may impair safe passage, ultimately jeopardizing human life.
- Monmouth County's population is growing modestly; it is projected to have a population increase 10.6% of 2010 values by the year 2040.
- Sea level rise and climate change will contribute to more frequent and severe flooding and surge events over a larger area.
-Climate change will contribute to more frequent and severe weather events.
- Monmouth County has established a large County evacuation center at Brookdale Community College. The building although structurally sound does have some exterior windows and doors that could become compromised during a wind generating event.

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