5.4.6 Severe Winter Storm

This section provides a profile and vulnerability assessment for the severe winter storm hazard.

5.4.6.1 Hazard Profile

This section provides profile information including description, extent, location, previous occurrences and losses and the probability of future occurrences.

Description

For the purpose of this HMP and as deemed appropriated by Putnam County, most severe winter storm hazards include heavy snow (snowstorms), blizzards, sleet, freezing rain, ice storms, and Nor'Easters. According to the New York State Hazard Mitigation Plan (NYS HMP), winter storms are frequent events for the State of New York and occur from late October until mid-April. These types of winter events or conditions are further defined below.

Heavy Snow

According to the National Snow and Ice Data Center, snow is precipitation in the form of ice crystals. It originates in clouds when temperatures are below the freezing point (32°F), when water vapor in the atmosphere condenses directly into ice without going through the liquid stage. Once an ice crystal has formed, it absorbs and freezes additional water vapor from the surrounding air, growing into a snow crystals or snow pallet, which then falls to the earth. Snow falls in different forms: snowflakes, snow pellets, or sleet. Snowflakes are clusters of ice crystals that form from a cloud. Snow pellets are opaque ice particles in the atmosphere. They form as ice crystals fall through super-cooled cloud droplets, which are below freezing but remain a liquid. The cloud droplets then freeze to the crystals. Sleet is made up of drops of rain that freeze into ice as they fall. They are usually smaller than 0.30 inches in diameter (NSIDC, 2014).

Heavy snow accumulations can immobilize a region and paralyze a city, stranding commuters, stopping the flow of supplies, and disrupting emergency and medical services. Ice storms can be accompanied by high winds, and they have similar impacts, especially to trees, power lines, and residential utility services. Snowstorms are the most obvious manifestation of intense winter weather.

Blizzards

A blizzard is a winter snowstorm with sustained or frequent wind gusts of 35 mph or more, accompanied by falling or blowing snow reducing visibility to or below 0.25 mile. These conditions must be the predominant over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions, but are not a formal part of the definition. The hazard created by the combination of snow, wind, and low visibility significantly increases; however, with temperatures below 20°. A severe blizzard is categorized as having temperatures near or below 10° F, winds exceeding 45 mph, and visibility reduced by snow to near zero. Storm systems powerful enough to cause blizzards usually form when the jet stream dips far to the south, allowing cold air from the north to clash with warm air from the south. Blizzard conditions often develop on the northwest side of an intense storm system. The difference between the lower pressure in the storm and the higher pressure to the west creates a tight pressure gradient, resulting in strong winds and extreme conditions caused by the blowing snow (The Weather Channel, 2012).

Sleet or Freezing Rain Storms

Sleet is defined as pellets of ice composed of frozen or mostly frozen raindrops or refrozen partially melted snowflakes. These pellets of ice usually bounce after hitting the ground or other hard surfaces. Freezing rain is rain that falls as a liquid but freezes into glaze upon contact with the ground. Both types of precipitation, even in small accumulations, can cause significant hazards to a community (NWS, 2009).

Ice Storms

An ice storm describes those events when damaging accumulations of ice are expected during freezing rain situations. Significant ice accumulations are typically accumulations of ¼" or greater (NWS, 2009). Heavy accumulations of ice can bring down trees, power lines and utility poles, and communication towers. Ice can disrupt communications and power for days. Even small accumulations of ice can be extremely dangerous to motorists and pedestrians (NWS, 2013).

Nor'Easter

Nor'Easters (abbreviated form of North Easter) are named for the strong northeasterly winds that blow in from the ocean ahead of the storm and over coastal areas. They are also referred to as a type of extra-tropical cyclones (mid-latitude storms, or Great Lake storms). A Nor'Easter is a macro-scale extra-tropical storm whose winds come from the northeast, especially in the coastal areas of the northeastern U.S. and Atlantic Canada. Wind gusts associated with Nor'Easters can exceed hurricane forces in intensity. Unlike tropical cyclones that form in the tropics and have warm cores (including tropical depressions, tropical storms and hurricanes); Nor'Easters contain a cold core of low barometric pressure that forms in the mid-latitudes. Their strongest winds are close to the earth's surface and often measure several hundred miles across. Nor'Easters may occur at any time of the year but are more common during fall and winter months (September through April) (NYCOEM, Date Unknown).

Nor'Easters can cause heavy snow, rain, gale force winds and oversized waves (storm surge) that can cause beach erosion, coastal flooding, structural damage, power outages and unsafe human conditions. If a Nor'Easter cyclone stays just offshore, the results are much more devastating than if the cyclone travels up the coast on an inland track. Nor'Easters that stay inland are generally weaker and usually cause strong winds and rain. The ones that stay offshore can bring heavy snow, blizzards, ice, strong winds, high waves, and severe beach erosion. In these storms, the warmer air is aloft. Precipitation falling from this warm air moves into the colder air at the surface, causing crippling sleet or freezing rain.

If a significant pressure drop occurs within a Nor'Easter, this change can turn a simple extra-tropical storm into what is known as a "bomb". "Bombs" are characterized by a pressure drop of at least 24 millibars within 24 hours (similar to a rapidly-intensifying hurricane). Even though "bombs" occasionally share some characteristics with hurricanes, the two storms have several differences. "Bombs" are a type of Nor'Easter and are extra-tropical; therefore, they are associated with fronts, higher latitudes, and cold cores. They require strong upper-level winds, which would destroy a hurricane (McNoldy, Date Unknown).

Extent

The magnitude or severity of a severe winter storm depends on several factors including a region's climatologically susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and time of occurrence during the day (e.g., weekday versus weekend), and time of season. 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 U.S. The RSI ranks snowstorm impacts on a scale from one to five, which is similar to the Fujita scale for tornadoes or the Saffir-

Simpson scale for hurricanes. The RSI differs from the NESIS because it includes population. RSI is based on the spatial extent of the storm, the amount of snowfall, and the combination 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 (NCDC, Date Unknown). Table 5.4.6-1 explains the five categories:

Table 5.4.6-1. RSI 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+

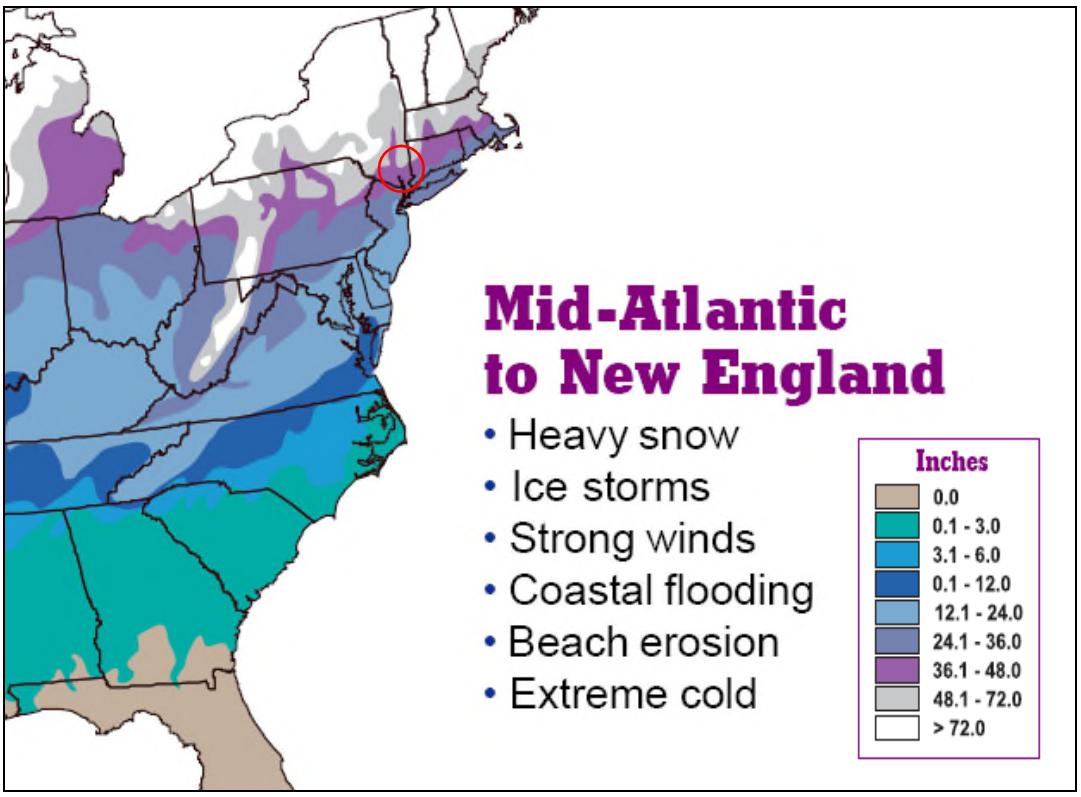
Source: NOAA-NCDC, Date Unknown

Location

The climate of New York State is marked by abundant snowfall. Winter weather can reach New York State as early as October and is usually in full force by late November with average winter temperatures between 20 and 40° F. As indicated in the NYS HMP, communities in New York State receive more snow than most other communities in the nation. Although the entire State is subject to winter storms, the easternmost and west-central portions of the State are more likely to suffer under winter storm occurrences than any other location (NYS DHSES, 2014). With the exception of coastal New York State, the State receives an average seasonal amount of 40 inches of snow or more. The average annual snowfall is greater than 70 inches over 60-percent of New York State's area; with Putnam County's average between 24.1 and 72 inches (Figure 5.4.6-1). However, normal seasonal snowfall in Putnam County is 35.37 inches (USA.com, 2014).

The southeastern portion of New York State, in comparison to the rest of the State, is milder in the winter. Due in part to its geography (proximity to the Atlantic Ocean and being shielded to the north and west by hillier terrain), the southeastern area usually sees far less snow than the rest of the State. Lake-effect snow rarely affects area. Winters also tend to be noticeably shorter here than the rest of the State. Based on this information, all of Putnam County is susceptible to winter storms; however, most storms are not expected to be as severe as other locations of the State.

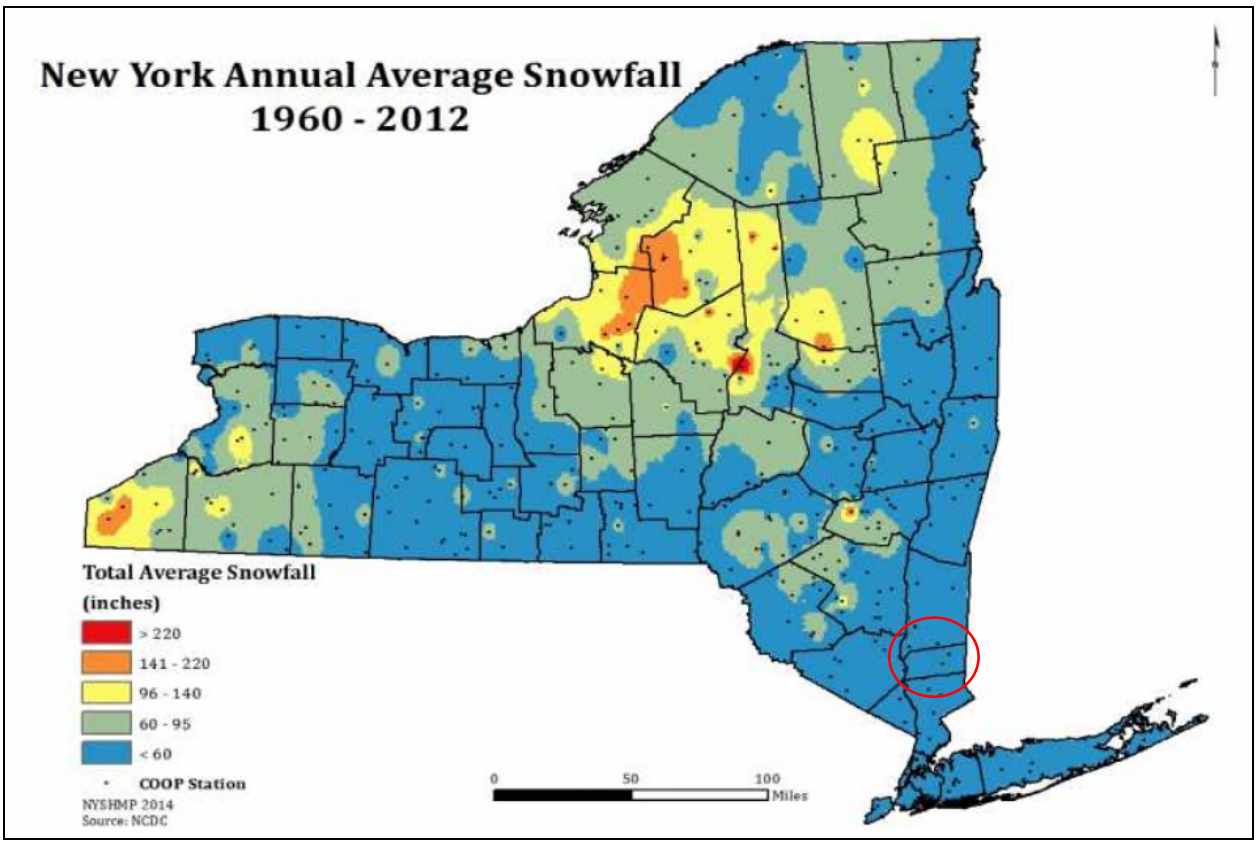
Figure 5.4.6-1. Annual Mean Snowfall within the Eastern U.S.



Source: NWS, 2001

Figure 5.4.6-2, an annual average snowfall map, illustrates the annual average snowfall totals over a 50 year period for New York State. The general indication of the average annual snowfall map shows areas that are subject to a consistent risk for large quantities of snow (NYS DHSES, 2014).

Figure 5.4.6-2. Annual Average Snowfall for New York State



Source: NYS DHSES, 2014
Note: Putnam County is indicated by a red oval with an annual average snow accumulation of greater than 60 inches.

Previous Occurrences and Losses

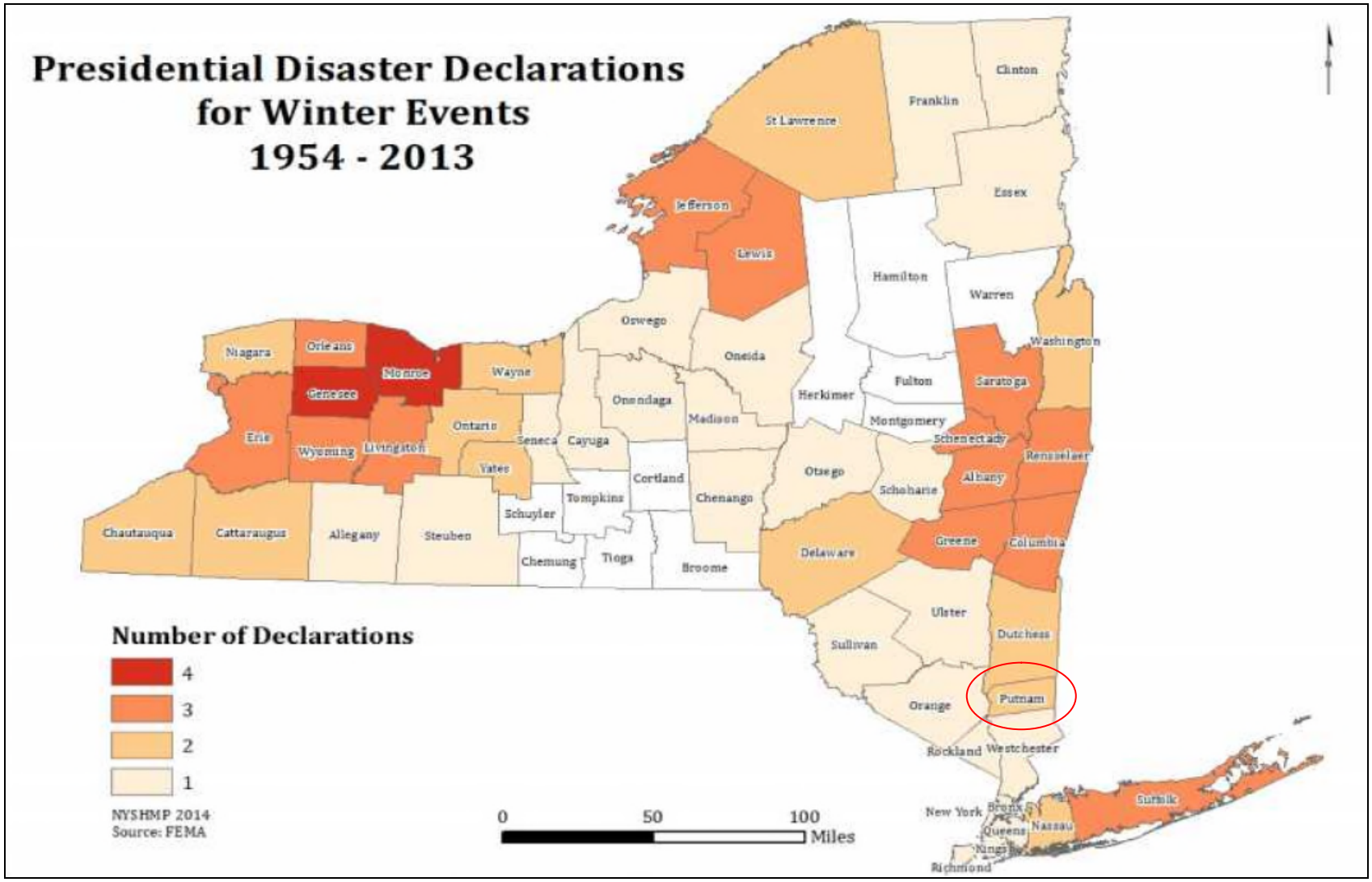
Many sources provided historical information regarding previous occurrences and losses associated with severe winter storms and extreme cold events throughout New York State and Putnam County. With so many sources reviewed for the purpose of this HMP, loss and impact information for many events could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP.

Between 1954 and 2014, FEMA declared that New York State experienced 22 winter storm-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types: ice storm, severe storm, flooding, snowstorm, severe winter storm, blizzard, and winter storm. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations. Of those events, the NYS HMP and other sources indicate that Putnam County has been declared as a disaster area as a result of five winter storm-related events (FEMA, 2014).

Figure 5.4.6-3 shows the FEMA disaster declarations (DR) for "winter storms" and "blizzards" in New York State, from 1953 to 2013. This figure indicates that Putnam County has been included in two disaster declarations. Since the date of this figure, Putnam County has been included in no other FEMA disaster declarations due to winter weather. However, FEMA records indicate that the County has been included in five disasters.

For this plan, known winter storm events that have impacted and caused damages in Putnam County between 1993 and 2013 are identified in Table 5.4.6-2. With winter storm documentation for New York State and Putnam County being so extensive, not all sources have been identified or researched. Therefore, Table 5.4.6-2 may not include all events that have occurred in the County.

Figure 5.4.6-3. Presidential Disaster Declarations in New York State from Winter Snow Storms and Blizzards (1954 to 2013)



Source: NYS DHSES, 2014
Note: The red oval indicates the approximate location of Putnam County. Putnam County has been included in two winter storm/blizzard disaster declaration in New York State between 1954 and 2013.

Table 5.4.6-2. Winter Storm Events Between 1950 and 2014

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
October 1987	Severe Winter Storm	DR-801	Yes	No losses and/or impacts have been identified for this event.
January 3, 1993	Freezing Rain	N/A	N/A	Freezing rain and freezing drizzle resulted in over a thousand traffic accidents throughout the area. $5 million in property damages were reported.
March 1, 1993	Snow	N/A	N/A	Due to the weight of the snow that fell during the month of March, there were numerous reports of barns and roofs of buildings being damaged or collapsing. $500,000 in property damages were reported.
March 13-17, 1993	Severe Blizzard	EM-3107	Yes	This blizzard resulted in total eligible damages of approximately $8.5 million through New York State. County-specific damage information was not available.
September 20, 1993	Frost	N/A	N/A	$5 million in crop loss.
January 12, 1994	Snow/Ice Storm	N/A	N/A	Snowfall totals ranged between four and eight inches. A dangerous coating of ice followed as the snow changed to sleet and freezing rain before ending. Traffic throughout the area was significantly affected.
January 17, 1994	Heavy Snow	N/A	N/A	Accumulations ranged between 6 and 12 inches however some isolated amounts of 17 inches were reported. This brought traffic to a standstill throughout the area. In addition, trees and power lines were snapped from the weight of the snow. This closed roads and knocked power off to thousands of residents.
February 8, 1994	Snow/Ice Storm	N/A	N/A	After depositing between six and nine inches, snow began to mix then change to sleet and freezing rain. This added a dangerous coating of ice which caused major transportation problems.
February 11, 1994	Snow/Ice Storm	N/A	N/A	A strong high pressure system over Canada kept very cold air in place across the region. Elsewhere a low pressure center moved northeastward along the Atlantic coast. Snow accumulated between 6 and 14 inches before it mixed or changed to sleet and/or freezing rain in some locations. The wintery mix caused major transportation problems throughout the region.
February 23, 1994	Snow/Ice Storm	N/A	N/A	The region saw between three and five inches of snow before a dangerous coating of ice was added as the snow changed to sleet and/or freezing rain. Major transportation problems developed as roadways became extremely hazardous.
March 3, 1994	Snow/Ice Storm	N/A	N/A	Several locations reported gust of around 60 mph. These winds brought down large branches and some relatively small trees. These in turn brought down numerous power lines which left thousands of residents without power. In addition, snow and ice accumulated between five and eight inches. This caused significant transportation problems for trains, planes, and motorists.

Table 5.4.6-2. Winter Storm Events Between 1950 and 2014

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
February 27-28, 1995	Ice Storm	N/A	N/A	Freezing rain and drizzle during the night and early morning hours caused a significant disruption of transportation. Numerous traffic accidents were reported as roadways became extremely hazardous due to ice. The ice also coasted trees and caused numerous branches to break off.
January 7-8, 1996	Blizzard	DR-1083	Yes	The major effects from this storm in New York State were felt across the southeastern sections of the State, resulting in property damages ranging from $21.3 to $70 million. Property damage information for Putnam County was not available.
March 31, 1997	Winter Storm	N/A	N/A	Strong gusty winds (to at least 40 mph) combined with heavy wet snow caused numerous trees and power lines to fall. Many roads were closed due to fallen trees and power lines. In Putnam County, snow measured from 6 inches at Croton Falls to 18 inches at both Carmel and Brewster.
November 13-14, 1997	Mixed Precipitation	N/A	N/A	A mixture of snow, sleet, and freezing rain created hazardous weather conditions across the area. Precipitation accumulated on roads, making both driving and walking hazardous. Several, mostly minor, traffic accidents occurred. Freezing rain also accumulated on trees, causing some tree limbs to fall on power lines that resulted in scattered power outages.
January 15-16, 1998	Ice Storm	DR-1196	No	1/2 to 1 inch of mainly liquid precipitation fell. Precipitation developed as light snow, and changed to freezing rain. Icing became widespread and significant. As ice accumulated on roads, there was widespread and significant traffic accidents that led to numerous injuries across the area. Several parts of roads were closed due to severe icing.
January 15, 1999	Winter Storm	EM-3166	No	Significant icing caused widespread disruptions to mass transit and traffic. Ice also accumulated on trees and power lines and caused significant power outages in Putnam County.
March 14-15, 1999	Heavy Snow	N/A	N/A	Snowfall amounts generally ranged from 6 to 11 inches across the lower Hudson Valley and Long Island. Heavy wet snow downed many tree limbs and power lines across the region. In Putnam County, amounts ranged from 6 to 9 inches.
January 25, 2000	Winter Storm	N/A	N/A	Snowfall rates up to 2 inches per hour occurred during the peak of the morning rush hour. White-out conditions caused massive traffic interruptions. As warm air in the lower levels wrapped around this storm, snow changed to freezing rain and sleet. Snowfall in Putnam County ranged from 7 inches at Croton Falls to 8 inches at both Carmel and Brewster.
February 18-19, 2000	Winter Storm	N/A	N/A	Snowfall became heavy, falling at the rate of at least 1 inch per hour from around 10 am across the entire area until around 4 pm across Orange and Putnam Counties. This first round of heavy precipitation was followed by up to a 1/8th-inch thick ice coating, which caused serious and widespread traffic disruptions. Snowfall in Putnam County ranged from 3 inches at Lake Carmel to 6 inches at Croton Falls. 1 fatality was reported.

Table 5.4.6-2. Winter Storm Events Between 1950 and 2014

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
December 14, 2000	Ice Storm	N/A	N/A	A mixture of freezing rain and sleet created treacherous travel for the morning commute on December 14th. Power outages resulted as tree limbs fell due to significant ice accretion. Ice accumulated at least one quarter inch throughout the area, with some locations receiving up to one half inch of ice.
January 21, 2001	Winter Storm	N/A	N/A	Ice accumulations ranged from 0.25 to 0.50 inches. This accretion of ice on tree limbs caused some tree branches to fall, and led to power outages. 8.1 inches of snow was measured at Fahnestock State Park.
February 25, 2001	Ice Storm	N/A	N/A	Total ice accumulations ranged from 1/4 to 1/3-inch, which resulted in some power outages. In Middletown, a blown transformer on Wawayanda Avenue, near the Mount Carmel School, took out power in much of downtown.
March 5-6, 2001	Winter Storm	N/A	N/A	The combination of very heavy wet snow and strong winds with this prolonged coastal storm produced scattered power outages across southeast New York. Many schools and businesses were closed for several days due to the hazardous nature of this storm. Snowfall in Putnam County ranged from 6 inches at Carmel, to 14 inches at Mahopac.
February 17-18, 2003	Heavy Snow	EM-3184	Yes	Record heavy snowfalls crippled mass transit. Putnam County received between 15.5 inches at West Mahopac to 20.0 inches at Carmel. The storm caused $20 million in damages throughout the region.
December 5-7, 2003	Heavy Snow	N/A	N/A	There were major impacts to mass transit operations during the evening's "rush" hours. Snowfall in Putnam County ranged from 8.3 inches at Pearl River to 15.0 inches at Kent.
January 28, 2004	Heavy Snow	EM-3195	No	A light mixture of snow, sleet, and freezing rain spread north across the area. A light coating of ice on area roads made traveling extremely hazardous toward evening. As the precipitation rate increased during the evening, the mixture changed to a steady snow, which became heavy at times. Snowfall in Putnam County ranged from 7.0 inches at Carmel to 8.0 inches at Patterson.
February 6, 2004	Winter Storm	N/A	N/A	Significant ice accumulations on the wet snow pack led to hazardous road conditions and many traffic accidents across the region.
January 6, 2005	Winter Storm	N/A	N/A	A 4 to 6 inch snowfall was followed by up to 0.25 inches of ice. This created widespread hazardous travel conditions across the region, which disrupted mass transit.
January 11, 2005	Winter Storm	N/A	N/A	A 5 to 7 inch snowfall was followed by up to between 0.25 and 0.50 inches of ice. This created widespread hazardous travel conditions across the region, which disrupted mass transit.
March 2, 2006	Winter Storm	N/A	N/A	Snowfall totals ranged from 3 to 5 inches. During the early afternoon hours the snow mixed with sleet and freezing drizzle. This event had a high impact as it affected both the morning and early evening commutes. Many traffic accidents were reported across the region.

Table 5.4.6-2. Winter Storm Events Between 1950 and 2014

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
December 19-20, 2008	Severe Winter Storm	DR-1827; EM-3299	DR- No EM- Yes	8.5 inches of snow fell in Mahopac. Public assistance throughout the State totaled over $11 million. Information on damages in Putnam County was not available.
January 6-7, 2009	Ice Storm	N/A	N/A	Ice accumulations in Putnam County ranged from 0.50 inches in Mahopac to 0.60 inches in Putnam Lake and Carmel. Emergency management officials in Putnam County reported trees and wires down during the late morning hours.
December 26-27, 2010	Severe Winter Storm and Snowstorm	DR-1957	No	Snow measured 20 to 30 inches across the NYC metro and Lower Hudson Valley. The heavy snow was accompanied by area wide winds of 25 to 40 mph and gusts in excess of 60 mph, resulting in near whiteout conditions with blowing and drifting snow and making all forms of travel extremely difficult to nearly impossible. 8,500 customers in Putnam County lost power.
January 18, 2011	Winter Storm	N/A	N/A	Between 2 and 4 inches of snow and sleet fell across the region, with one quarter to one half of an inch of ice accumulation on top of that. This made for dangerous road conditions.
January 26-27, 2011	Heavy Snow	N/A	N/A	Snow totals of 15-20 inches were reported across much of the region. Amtrak suspended its passenger rail service from New York to Boston and cut service between New York and Albany.
February 1-2, 2011	Winter Storm	N/A	N/A	3 to 7 inches of snow and sleet fell across interior portions of the Lower Hudson valley, with 1 to 3 inches across southern portions of the Lower Hudson Valley, the NYC metro, and Long Island. The highest ice amounts were found across southern portions of the Lower Hudson Valley, the NYC Metro and the northern half of Long Island with between 3/10th and 6/10ths of an inch of ice. Between 1/10 and 3/10ths of an inch occurred elsewhere.
October 29-30, 2011	Heavy Snow	N/A	N/A	Widespread tree damage and power outages occurred due to 7 to 12 inches of heavy wet snow. The heavier amounts fell in the higher elevations.
January 2-3, 2014	Heavy Snow	N/A	N/A	Up to 6 inches of snow fell in Brewster, Kent Cliffs, and Mahopac. County offices were closed.

Sources: *NCDC, 2014; FEMA, 2014; Kocin & Uccellini, 2004; McFadden, 2006; Kennedy, 1996*

Note: *Monetary figures within this table were U.S. Dollar (USD) figures calculated during or within the approximate time of the event. If such an event would occur in the present day, monetary losses would be considerably higher in USDs as a result of inflation.*

DR *Disaster Declaration*
EM *Emergency Declaration*
FEMA *Federal Emergency Management Agency*
HMP *Hazard Mitigation Plan*
N/A *Not Applicable*
NCDC *National Climatic Data Center*
NOAA *National Oceanic and Atmospheric Administration*
NWS *National Weather Service*
PA *Public Assistance*
SHELDUS *Spatial Hazard Events and Losses Database for the United States*
TSTM *Thunderstorm*

Probability of Future Events

Winter storm hazards in New York State are virtually guaranteed yearly since the State is located at relatively high latitudes resulting in winter temperatures that range between 0ºF and 32 ºF for a good deal of the fall through early spring season (late October until mid-April). In addition, the State is exposed to large quantities of moisture from both the Great Lakes and the Atlantic Ocean. While it is almost certain that a number of significant winter storms will occur during the winter and fall season, what is not easily determined is how many such storms will occur during that time frame (NYS DHSES, 2014).

The New York State HMP includes a similar ranking process for hazards that affect the State. Based on historical records and input from the Planning Committee, the probability of at least one winter snow storm of emergency declaration proportions, occurring during any given calendar year is virtually certain in the State. Based on historical snow related disaster declaration occurrences, New York State can expect a snow storm of disaster declaration proportions, on average, once every three to five years. Similarly, for ice storms, based on historical disaster declarations, it is expected that on average, ice storms of disaster proportions will occur once every seven to 10 years within the State (NYS DHSES, 2014). It is estimated that Putnam County will continue to experience direct and indirect impacts of severe winter storms annually.

In Section 5.3, the identified hazards of concern for Putnam County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for severe winter storms in the County is considered 'frequent' (event that occurs within 25 years, as presented in Table 5.3-3).

Climate Change Impacts

New York State averages more than 40 inches of snow each year. Snowfall varies regionally, based on topography and the proximity to large lakes and the Atlantic Ocean. Maximum snowfall is more than 165 inches in parts of the Adirondacks and Tug Hill Plateau, as well as in the westernmost parts of the State. The warming influence of the Atlantic Ocean keeps snow in the New York City and Long Island areas below 36 inches each year.

Climate change is beginning to affect both people and resources in New York State, and these impacts are projected to continue growing. Impacts related to increasing temperatures and sea level rise are already being felt in the State. ClimAID: the Integrated Assessment for Effective Climate Change in New York State (ClimAID) was undertaken to provide decision-makers with information on the State's vulnerability to climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge (New York State Energy Research and Development Authority [NYSERDA], 2011).

Each region in New York State, as defined by ClimAID, has attributes that will be affected by climate change. Putnam County is part of Region 5, East Hudson and Mohawk River Valleys. Some of the issues in this region, affected by climate change, include: more frequent heat waves and above 90°F days, more heat-related deaths, increased frequency of heavy precipitation and flooding, decline in air quality, etc. (NYSERDA, 2011).

Temperatures in New York State are warming, with an average rate of warming over the past century of 0.25° F per decade. Average annual temperatures are projected to increase across New York State by 2° F to 3.4° F by the 2020s, 4.1° F to 6.8° F by the 2050s, and 5.3° F to 10.1° F by the 2080s. By the end of the century, the greatest warming is projected to be in the northern section of the State (NYSERDA, 2014).

Regional precipitation across New York State is projected to increase by approximately one to eight-percent by the 2020s, three to 12-percent by the 2050s, and four to 15-percent by the 2080s. By the end of the century, the greatest increases in precipitation are projected to be in the northern areas of the State (NYSERDA, 2014).

In Region 5, it is estimated that temperatures will increase by 3.5ºF to 7.1ºF by the 2050s and 4.1ºF to 11.4ºF by the 2080s (baseline of 47.6ºF). Precipitation totals will increase between 2 and 15% by the 2050s and 3 to 17% by the 2080s (baseline of 38.6 inches). Table 5.4.6-3 displays the projected seasonal precipitation change for the East Hudson and Mohawk River Valleys ClimAID Region (NYSERDA, 2011).

Table 5.4.6-3. Projected Seasonal Precipitation Change in Region 5, 2050s (% change)

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

Source: NYSERDA, 2011

It is uncertain how climate change will impact winter storms. Based on historical data, it is expected that the following will occur at least once per 100 years:

- Up to eight inches of rain fall in the rain band near the coast over a 36-hour period
- Up to four inches of freezing rain in the ice band near central New York State, of which between one and two inches of accumulated ice, over a 24-hour period
- Up to two feet of accumulated snow in the snow band in northern and western New York State over a 48-hour period (NYSERDA, 2011)

New York State is already experiencing the effects of climate change during the winter season. Winter snow cover is decreasing and spring comes, on average, about a week earlier than it did a few years ago. Nighttime temperatures are measurably warmer, even during the colder months (NYSDEC, Date Unknown). Overall winter temperatures in New York State are almost five degrees warmer than in 1970 (NYSDEC, Date Unknown). The State has seen a decrease in the number of cold winter days (below 32°F) and can expect to see a decrease in snow cover, by as much as 25 to 50% by end of the next century. The lack of snow cover may jeopardize opportunities for skiing, snowmobiling and other types of winter recreation; and natural ecosystems will be affected by the changing snow cover (Cornell University College of Agriculture and Life Sciences, 2011).

Some climatologists believe that climate change may play a role in the frequency and intensity of Nor'Easters. Two ingredients are needed to produce strong Nor'Easters and intense snowfall: (1) temperatures which are just below freezing, and (2) massive moisture coming from the Gulf of Mexico. When temperatures are far below freezing, snow is less likely. As temperatures increase in the winter months they will be closer to freezing rather than frigidly cold. Climate change is expected to produce more moisture, thus increasing the likelihood that these two ingredients (temperatures just below freezing and intense moisture) will cause more intense snow events.

5.4.6.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the severe winter storm hazard, all of Putnam County has been identified as exposed. Therefore, all assets in the County (population, structures, critical facilities and lifelines), as described in the County Profile (Section 4), are exposed and potentially vulnerable to a winter storm event. The following text evaluates and estimates the potential impact of severe winter storm events on the County including:

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

Overview of Vulnerability

Severe winter storms are of significant concern to Putnam County because of the frequency and magnitude of these events in the region, the direct and indirect costs associated with these events, delays caused by the storms, and impacts on the people and facilities of the region related to snow and ice removal, health problems, cascade effects such as utility failure (power outages) and traffic accidents, and stress on community resources.

Data and Methodology

The 2010 Census data, and custom general building stock and critical facility inventories were used to support an evaluation of assets exposed to this hazard and the potential impacts associated with this hazard.

Impact on Life, Health and Safety

According to the NOAA National Severe Storms Laboratory (NSSL); every year, winter weather indirectly and deceptively kills hundreds of people in the U.S., primarily from automobile accidents, overexertion and exposure. Winter storms are often accompanied by strong winds creating blizzard conditions with blinding wind-driven snow, drifting snow and extreme cold temperatures and dangerous wind chill. They are considered deceptive killers because most deaths and other impacts or losses are indirectly related to the storm. People can die in traffic accidents on icy roads, heart attacks while shoveling snow, or of hypothermia from prolonged exposure to cold. Heavy accumulations of ice can bring down trees and power lines, disabling electric power and communications for days or weeks. Heavy snow can immobilize a region and paralyze a city, shutting down all air and rail transportation and disrupting medical and emergency services. Storms near the coast can cause coastal flooding and beach erosion as well as sink ships at sea. The economic impact of winter weather each year is huge, with costs for snow removal, damage and loss of business in the millions (NSSL, 2006).

Heavy snow can immobilize a region and paralyze a city, stranding commuters, stopping the flow of supplies, and disrupting emergency and medical services. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. In the mountains, heavy snow can lead to avalanches. The cost of snow removal, repairing damages, and loss of business can have large economic impacts on cities and towns (NSSL, 2006).

Heavy accumulations of ice can bring down trees, electrical wires, telephone poles and lines, and communication towers. Communications and power can be disrupted for days while utility companies work to repair the extensive damage. Even small accumulations of ice may cause extreme hazards to motorists and

pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces (NSSL, 2006).

For the purposes of this HMP, the entire population of Putnam County (99,710) is exposed to severe winter storm events (U.S. Census Bureau, 2014). Snow accumulation and frozen/slippery road surfaces increase the frequency and impact of traffic accidents for the general population, resulting in personal injuries. Refer to the County Profile for population statistics for each participating municipality.

The elderly are considered most susceptible to this hazard due to their increased risk of injuries and death from falls and overexertion and/or hypothermia from attempts to clear snow and ice. In addition, severe winter storm events can reduce the ability of these populations to access emergency services. Residents with low incomes may not have access to housing or their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply).

Impact on General Building Stock

The entire general building stock inventory in Putnam County is exposed and vulnerable to the severe winter storm hazard. In general, structural impacts include damage to roofs and building frames, rather than building content. Table 5.4.6-4 presents the total exposure value for general building stock for each participating municipality (structure only).

Current modeling tools are not available to estimate specific losses for this hazard. As an alternate approach, this plan considers percentage damages that could result from severe winter storm conditions. Table 5.4.6-4 below summarizes percent damages that could result from severe winter storm conditions for the County's total general building stock (structure only). Given professional knowledge and information available, the potential losses for this hazard are considered to be overestimated.

Table 5.4.6-4. General Building Stock Exposure (Structure Only) and Estimated Losses from Severe Winter Storm Events in Putnam County

Municipality	Total RCV (Structure only)	1% Damage Loss Estimate	5% Damage Loss Estimate	10% Damage Loss Estimate
Village of Brewster	$201,581,179	$2,015,812	$10,079,059	$20,158,118
Town of Carmel	$3,847,178,692	$38,471,787	$192,358,935	$384,717,869
Village of Cold Spring	$269,493,110	$2,694,931	$13,474,656	$26,949,311
Town of Kent	$1,329,512,766	$13,295,128	$66,475,638	$132,951,277
Village of Nelsonville	$75,570,251	$755,703	$3,778,513	$7,557,025
Town of Patterson	$1,180,896,788	$11,808,968	$59,044,839	$118,089,679
Town of Philipstown	$1,048,614,861	$10,486,149	$52,430,743	$104,861,486
Town of Putnam Valley	$1,352,509,644	$13,525,096	$67,625,482	$135,250,964
Town of Southeast	$1,905,798,783	$19,057,988	$95,289,939	$190,579,878
Putnam County	**$11,211,156,075**	**$112,111,561**	**$560,557,804**	**$1,121,115,607**

Source: Putnam County; RS Means 2014
Notes: RCV = Replacement Cost Value

A specific area that is vulnerable to the severe winter storm hazard is the floodplain. Severe winter storms can cause flooding through blockage of streams or through snow melt. At risk residential infrastructure are presented in the presentation for the flood hazard. Generally, losses resulting from flooding associated with

severe winter storms should be less than that associated with a 100-year flood. Please refer to the flood profile (Section 5.4.3). In addition, coastal areas are at high risk during winter storm events that involve high winds. Please refer to the Severe Storms profile for losses resulting from wind (Section 5.4.5).

Impact on Critical Facilities

Full functionality of critical facilities such as police, fire and medical facilities is essential for response during and after a severe winter storm event. These critical facility structures are largely constructed of concrete and masonry; therefore, they should only suffer minimal structural damage from severe winter storm events. Because power interruption can occur, backup power is recommended. Infrastructure at risk for this hazard includes roadways that could be damaged due to the application of salt and intermittent freezing and warming conditions that can damage roads over time. Severe snowfall requires the clearing roadways and alerting citizens to dangerous conditions; following the winter season, resources for road maintenance and repair are required.

Impact on Economy

The cost of snow and ice removal and repair of roads from the freeze/thaw process can drain local financial resources. Another impact on the economy includes impacts on commuting into, or out of, the area for work or school. The loss of power and closure of roads prevents the commuter population traveling to work within and outside of the County.

The Putnam County Department of Highways & Facilities clears County roads of snow and ice (Putnam County Department of Highways & Facilities, 2014), while the State Highway Department is responsible for State highways and Town Highway Departments are responsible for local roads.

Future Growth and Development

As discussed in Sections 4 and 9, areas targeted for future growth and development have been identified across the County. Any areas of growth could be potentially impacted by the severe winter storm hazard because the entire planning area is exposed and vulnerable. Areas targeted for potential future growth and development in the next five (5) years have been identified across the County at the municipal level. Refer to the jurisdictional annexes in Volume II of this HMP.

Current New York State land use and building codes incorporate standards that address and mitigate snow accumulation. Some local municipalities in the State have implemented the following activities to eliminate loss of life and property and infrastructure damages during winter storm events:

- Removal of snow from roadways
- Removal of dead trees and trim trees/brush from roadways to lessen falling limbs and trees
- Ensure proper road signs are visible and installed properly
- Bury electrical and telephone utility lines to minimize downed lines
- Removal of debris/obstructions in waterways and develop routine inspections/maintenance plans to reduce potential flooding
- Replace substandard roofs of critical facilities to reduce exposure to airborne germs resulting from leakage
- Purchase and install backup generators in evacuation facilities and critical facilities to essential services to residents
- Install cell towers in areas where limited telecommunication is available to increase emergency response and cell phone coverage (NYS DHSES, 2014)

Effect of Climate Change on Vulnerability

Climate is defined not simply as average temperature and precipitation but also by the type, frequency and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extremes such winter storms. While predicting changes of winter storm events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society and the environment (U.S. Environmental Protection Agency [EPA], 2013).

The 2011 'Responding to Climate Change in New York State' report was prepared for New York State Energy Research and Development Authority to study the potential impacts of global climate change on New York State. According to the synthesis report, it is uncertain how climate change will influence extreme winter storm events. Winter temperatures are projected to continue to increase. In general, warmer winters may lead to a decrease in snow cover and an earlier arrival in spring; all of which have numerous cascading effects on the environment and economy. Annual average precipitation is also projected to increase. The increase in precipitation is likely to occur during the winter months as rain, with the possibility of slightly reduced precipitation projected for the late summer and early fall. Increased rain on snowpack may lead to increased flooding and related impacts on water quality, infrastructure, and agriculture in the State. Overall, it is anticipated that winter storms will continue to pass through New York State (NYSERDA, 2011). Future enhancements in climate modeling will provide an improved understanding of how the climate will change and impact the Northeast.

Additional Data and Next Steps

The assessment above identifies vulnerable populations and economic losses associated with this hazard of concern. Historic data on structural losses to general building stock are not adequate to predict specific losses to this inventory; therefore, the percent of damage assumption methodology was applied. This methodology is based on FEMA's How to Series (FEMA 386-2), Understanding Your Risks, Identifying and Estimating Losses (FEMA, 2001) and FEMA's Using HAZUS-MH for Risk Assessment (FEMA 433) (FEMA, 2004). The collection of additional/actual valuation data for general building stock and critical infrastructure losses would further support future estimates of potential exposure and damage for the general building stock inventory. Mitigation strategies addressing early warning, dissemination of hazard information, provisions for snow removal and back-up power are included in Volume II, Section 9 of this plan.