5.4.4 Flood

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

5.4.4.1 Profile

Hazard Description

Floods are one of the most common natural hazards in the U.S. They can develop slowly over a period of days or develop quickly, with disastrous effects that can be local (impacting a neighborhood or community) or regional (affecting entire river basins, coastlines and multiple counties or states) (Federal Emergency Management Agency [FEMA] 2008). Most communities in the U.S. have experienced some kind of flooding, after spring rains, heavy thunderstorms, coastal storms, or winter snow thaws (George Washington University 2001).

Floods are the most frequent and costly natural hazards in New York State in terms of human hardship and economic loss, particularly to communities that lie within flood prone areas or flood plains of a major water source. As defined in the NYS HMP (NYS DHSES 2014), flooding is a general and temporary condition of partial or complete inundation on normally dry land from the following:

- Riverine overbank flooding;
- Flash floods;
- Alluvial fan floods;
- Mudflows or debris floods;
- Dam- and levee-break floods;
- Local draining or high groundwater levels;
- Fluctuating lake levels;
- Ice-jams; and
- Coastal flooding

Many floods fall into three categories: riverine, coastal and shallow (FEMA 2005). Other types of floods may include ice-jam floods, alluvial fan floods, dam failure floods, and floods associated with local drainage or high groundwater (as indicated in the previous flood definition). For the purpose of this HMP and as deemed appropriate by the Rockland County Steering Committee, riverine, shallow, flash, ice jam, and dam failure flooding are the main flood types of concern for the County. These types of flood or further discussed below.

Riverine (Inland) and Flash Flooding

Riverine floods are the most common flood type. They occur along a channel and include overbank and flash flooding. Channels are defined, ground features that carry water through and out of a watershed. They may be called rivers, creeks, streams, or ditches. When a channel receives too much water, the excess water flows over its banks and inundates low-lying areas (FEMA 2008; The Illinois Association for Floodplain and Stormwater Management 2006).

Flash floods are “a rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). However, the actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters" (National Weather Service [NWS] 2009).

Shallow Flooding

Stormwater flooding described below is due to local drainage issues and high groundwater levels. Locally, heavy precipitation may produce flooding in areas other than delineated floodplains or along recognizable channels. If local conditions cannot accommodate intense precipitation through a combination of infiltration and surface runoff, water may accumulate and cause flooding problems. During winter and spring, frozen ground and snow accumulations may contribute to inadequate drainage and localized ponding. Flooding issues of this nature generally occur in areas with flat gradients and generally increase with urbanization which speeds the accumulation of floodwaters because of impervious areas. Shallow street flooding can occur unless channels have been improved to account for increased flows (FEMA 1997).

High groundwater levels can be a concern and cause problems even where there is no surface flooding. Basements are susceptible to high groundwater levels. Seasonally high groundwater is common in many areas, while elsewhere high groundwater occurs only after a long periods of above-average precipitation (FEMA 1997).

Urban drainage flooding is caused by increased water runoff due to urban development and drainage systems. Drainage systems are designed to remove surface water from developed areas as quickly as possible to prevent localized flooding on streets and other urban areas. They make use of a closed conveyance system that channels water away from an urban area to surrounding streams. This bypasses the natural processes of water filtration through the ground, containment, and evaporation of excess water. Since drainage systems reduce the amount of time the surface water takes to reach surrounding streams, flooding in those streams can occur more quickly and reach greater depths than prior to development in that area (FEMA 2008).

Ice Jam Flooding

An ice jam occurs when pieces of floating ice are carried with a stream's current and accumulate behind any obstruction to the stream flow. Obstructions may include river bends, mouths of tributaries, points where the river slope decreases, as well as dams and bridges. The water held back by this obstruction can cause flooding upstream, and if the obstruction suddenly breaks, flash flooding can occur as well (NOAA 2011). The formation of ice jams depends on the weather and physical condition of the river and stream channels. They are most likely to occur where the channel slope naturally decreases, in culverts, and along shallows where channels may freeze solid. Ice jams and resulting floods can occur during at different times of the year: fall freeze-up from the formation of frazil ice; mid-winter periods when stream channels freeze solid, forming anchor ice; and spring breakup when rising water levels from snowmelt or rainfall break existing ice cover into pieces that accumulate at bridges or other types of obstructions (NYS DHSES 2014).

There are two main types of ice jams: freeze-up and breakup. Freeze-up jams occur when floating ice may slow or stop due to a change in water slope as it reaches an obstruction to movement. Breakup jams occur during periods of thaw, generally in late winter and early spring. The ice cover breakup is usually associated with a rapid increase in runoff and corresponding river discharge due to a heavy rainfall, snowmelt or warmer temperatures (USACE 2002; NYS DHSES 2014).

Ice jams are common in the northeast U.S. and New York is not an exception. In fact, according to the USACE, New York State ranks second in the U.S. for total number of ice jam events, with over 1,500 incidents documented between 1867 and 2010. Areas of New York State that include characteristics lending to ice jam flooding include the northern counties of the Finger Lakes region and far western New York, the Mohawk Valley of central and eastern New York State, and the North Country (NYS DHSES, 2013).

The Ice Jam Database, maintained by the Ice Engineering Group at the USACE Cold Regions Research and Engineering Laboratory (CRREL), currently consists of over 19,000 records from across the U.S. According to the USACE-CRREL, Rockland County experienced two historic ice jam events between 1780 and 2015 (USACE 2015). Ice jams typically have formed along Ramapo River and Stony Brook (USACE 2015). Recent events are further mentioned in the "Previous Occurrences" section of this hazard profile.

Dam Failure Flooding

A dam is an artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material for the purpose of storage or control of water (FEMA 2010). Dams are man-made structures built across a stream or river that impound water and reduce the flow downstream (FEMA 2003). They are built for the purpose of power production, agriculture, water supply, recreation, and flood protection. Dam failure is any malfunction or abnormality outside of the design that adversely affects a dam's primary function of impounding water (FEMA 2011). Dams can fail for one or a combination of the following reasons:

- Overtopping caused by floods that exceed the capacity of the dam (inadequate spillway capacity);
- Prolonged periods of rainfall and flooding;
- Deliberate acts of sabotage (terrorism);
- Structural failure of materials used in dam construction;
- Movement and/or failure of the foundation supporting the dam;
- Settlement and cracking of concrete or embankment dams;
- Piping and internal erosion of soil in embankment dams;
- Inadequate or negligent operation, maintenance and upkeep;
- Failure of upstream dams on the same waterway; or
- Earthquake (liquefaction / landslides) (FEMA 2010).

A break in a dam can produce extremely dangerous flood situations because of the high velocities and large volumes of water released by such a break. Sometimes they can occur with little to no warning. Breaching of dams often occurs within hours after the first visible sign of dam failure, leaving little or no time for evacuation (FEMA 2006).

According to the NYSDEC Division of Water Bureau of Flood Protection and Dam Safety, the hazard classification of a dam is assigned according to the potential impacts of a dam failure pursuant to 6 NYCRR Part 673.3 (NYSDEC 2009). Dams are classified in terms of potential for downstream damage if the dam were to fail. These hazard classifications are identified and defined below:

- *Low Hazard (Class A)* is a dam located in an area where failure will damage nothing more than isolated buildings, undeveloped lands, or township or county roads and/or will cause no significant economic loss or serious environmental damage. Failure or mis-operation would result in no probable loss of human life. Losses are principally limited to the owner's property
- *Intermediate Hazard (Class B)* is a dam located in an area where failure may damage isolated homes, main highways, minor railroads, interrupt the use of relatively important public utilities, and/or will cause significant economic loss or serious environmental damage. Failure or mis-operation would result in no probable loss of human life, but can cause economic loss, environment damage, disruption of lifeline facilities, or impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.
- *High Hazard (Class C)* is a dam located in an area where failure may cause loss of human life, serious damage to homes, industrial or commercial buildings, important public utilities, main highways or

railroads and/or will cause extensive economic loss. This is a downstream hazard classification for dams in which excessive economic loss (urban area including extensive community, industry, agriculture, or outstanding natural resources) would occur as a direct result of dam failure.

- *Negligible or No Hazard (Class D)* is a dam that has been breached or removed, or has failed or otherwise no longer materially impounds waters, or a dam that was planned but never constructed. Class "D" dams are considered to be defunct dams posing negligible or no hazard. The department may retain pertinent records regarding such dams.

According to the Dam Incident Notification (DIN) system maintained by the National Performance of Dam Program (NPDP), there are 32 dams in Rockland County. Of the 32 dams, there are three classified as low hazard, 15 classified as significant hazard, 13 classified as high hazard, and one classified as unknown hazard (NPDP 2015). However, these numbers differ from the New York State Inventory of Dams, which identifies 102 dams in Rockland County: 60 low hazard, 16 intermediate hazard, 13 high hazard, and 13 negligible or no hazard classification (NYS GIS 2015).

Location

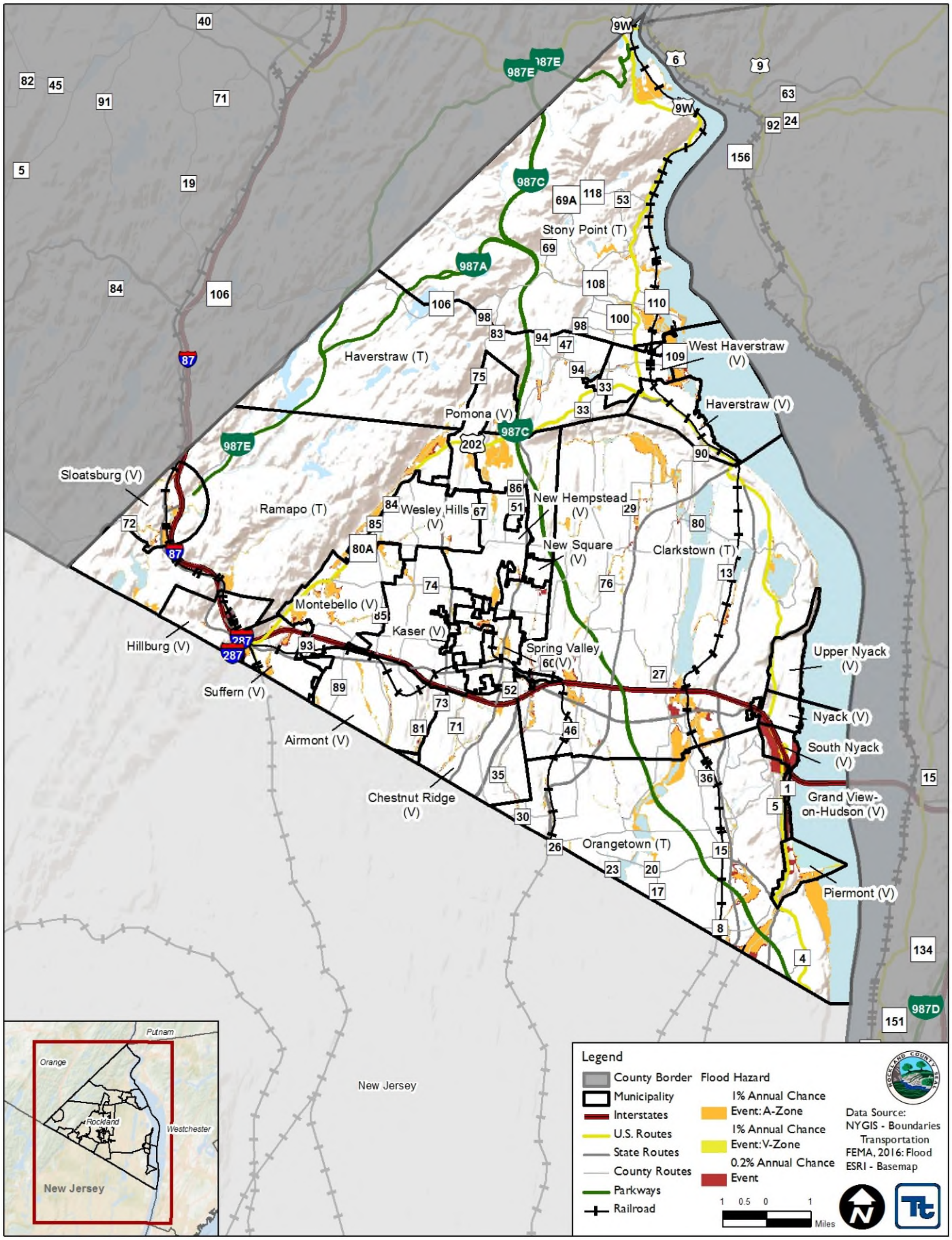
Water drains from the land surface through drainage features that range from rivulets in parking lots to large rivers like the Hudson River. The entire area drained by a particular body of water is called a drainage basin or watershed. In Rockland County, there are two major drainage basins, with most of the land in the County located within the Lower Hudson River drainage basin. For details regarding the drainage basins in Rockland County, refer to Section 4 (County Profile) of this plan.

A floodplain is defined as the land adjoining the channel of a river, stream, ocean, lake, or other watercourse or water body that becomes inundated with water during a flood. Most often floodplains are referred to as 100-year floodplains. A 100-year floodplain is not a flood that will occur once every 100 years, rather it is a flood that has a 1% chance of being equaled or exceeded each year. Thus, the 100-year flood could occur more than once in a relatively short period of time. Due to this misleading term, FEMA has properly defined it as the 1% annual chance flood. This 1% annual chance flood is now the standard used by most federal and state agencies and by the NFIP (FEMA 2002). Similarly, the 500-year floodplain will not occur every 500 years, but is an event with a 0.2% chance of being equaled or exceeded each year. In Rockland County, floodplains line the rivers and streams of the County. The boundaries of the floodplains are altered as a result of changes in land use, the amount of impervious surface, placement of obstructing structures in floodways, changes in precipitation and runoff patterns, improvements in technology for measuring topographic features, and utilization of different hydrologic modeling techniques.

Figure 5.4.4-1 illustrates the FEMA flood hazard zones in Rockland County. According to this figure, the 1% annual chance of flood hazard zones are located along the bodies of water located throughout the County. The 0.2% annual chance of flood hazard zones are mainly found in southeastern Rockland County.

Please refer to Section 9 (Jurisdictional Annexes) for information regarding specific areas of flooding for each participating municipality in Rockland County.

Figure 5.4.4-1. FEMA Flood Hazard Areas in Rockland County



Source: *FEMA*
FEMA *Federal Emergency Management Agency*

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 severity of a flood depends not only on the amount of water that accumulates in a period of time, but also on the land's ability to manage this water. The size of rivers and streams in an area and infiltration rates are significant factors. When it rains, soil acts as a sponge. When the land is saturated or frozen, infiltration rates decrease and any more water that accumulates must flow as runoff (Harris 2001).

The frequency and severity of flooding are measured using a discharge probability, which is the probability that a certain river discharge (flow) level will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels. The flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge has a 1% chance of being equaled or exceeded in any given year. The "annual flood" is the greatest flood event expected to occur in a typical year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river.

One hundred-year floodplains (or 1% annual chance floodplain) can be described as a bag of 100 marbles containing 99 clear marbles and one black marble. Every time a marble is pulled out from the bag, and it is the black marble, it represents a 100-year flood event. The marble is then placed back into the bag and shaken up again before another marble is drawn. It is possible that the black marble can be picked one out of two or three times in a row, demonstrating that a "100-year flood event" could occur several times in a row (Interagency Floodplain Management Review Committee 1994).

The 1% annual chance floodplain, which is the standard used by most federal and state agencies, is used by the NFIP as the standard for floodplain management and to determine the need for flood insurance. Also referred to as the SFHA, this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. A structure located within a SFHA shown on an NFIP map has a 26% chance of suffering flood damage during the term of a 30-year mortgage.

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. 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.

The term "500-year flood" is the flood that has a 0.2% chance of being equaled or exceeded each year. The 500-year flood could occur more than once in a relatively short period of time. Statistically, the 0.2% (500-year) flood has a 6% chance of occurring during a 30-year period of time, the length of many mortgages.

The 500-year floodplain is referred to as Zone X500 for insurance purposes on FIRMs. Base flood elevations or depths are not shown within this zone and insurance purchase is not required in this zone.

Previous Occurrences and Losses

Many sources provided flooding information regarding previous occurrences and losses associated with flooding events throughout Rockland County. With so many sources reviewed for the purpose of this Hazard Mitigation Plan (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 2016, FEMA included New York State in 54 flood-related major disaster (DR) or emergency (EM) declarations classified as one or a combination of the following disaster types: severe storms, flooding, hurricane, tropical depression, heavy rains, landslides, ice storm, high tides, Nor'Easter, tornado, snowstorm, severe winter storm, and inland/coastal flooding. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. Rockland County was included in nine of these flood-related declarations.

For this Plan update, flood events were summarized from 2009 to 2016. Known flood events, including FEMA disaster declarations, which have impacted Rockland County between 2009 and 2016 are identified in Table 5.4.4-1. For events prior to 2009, refer to the 2010 Rockland County Multi-Jurisdictional Hazard Mitigation Plan. Please note that not all events that have occurred in Rockland County are included due to the extent of documentation and the fact that not all sources may have been identified or researched. Loss and impact information 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 Update. Please see Section 9 for detailed information regarding impacts and losses to each municipality.

Table 5.4.4-1. Flood Events in Rockland County, 2009 to 2016

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
March 13-31, 2010	Severe Storms and Flooding	DR-1899	Yes	March 13 – A Nor'Easter developed producing heavy rainfall as it moved slowly across the northeast. This storm caused widespread flooding across portions of southeast New York State. In Rockland County, the Mahwah River at Suffern (village) exceeded bankful and crested at 7.06 feet on March 14th. The Ramapo River at Ramapo (town) also rose out of its banks causing Route 17 to be closed due to flooding in the Villages of Sloatsburg and Hillburn. Several other rivers and small streams in the county also rose out of their banks and caused flooding. The New York State Thruway was closed from exit 15A to the Orange County line. March 23 – A low pressure system produced heavy rainfall which caused isolated small stream flooding in Rockland County. The Mahwah River in Suffern (village) exceeded bankful and crested at 4.88 feet. March 29 – A Nor'Easter produced heavy rain across the area as it moved to the northeast. This caused widespread flooding across portions of the Lower Hudson Valley, New York City and Long Island. In Rockland County, Route 59 eastbound at Route 303 south in West Nyack (Town of Clarkstown) was closed due to flooding. Rainfall totals ranged from 2.91 inches in the Village of Suffern to 3.82 inches in the Village of Spring Valley.
August 1, 2011	Heavy Rain and Flash Flood	N/A	N/A	Severe thunderstorms moved across Rockland County, producing flash flooding in some areas. In the Village of West Haverstraw, flash flooding was reported along Route 9W, forcing it to be closed.
August 28, 2011	Hurricane Irene	DR-4020	Yes	As Hurricane Irene moved north along the Atlantic coast, it weakened and made its second landfall as a Tropical Storm near Little Egg Inlet along the southeast New Jersey coast. The storm made its third landfall in New York City on August 28th. This storm brought sustained winds, heavy rain, destructive storm surge and two confirmed tornadoes. Heavy rainfall resulted in widespread moderate flooding across the area. Seven deaths resulted from Irene. At least 600,000 people were ordered to evacuate their homes from storm surge and inland flooding. Widespread power outages of up to one week followed the storm. The strong winds from Irene pushed a three to five foot storm surge of water along western Long Island South, New York Harbor, the southern and eastern bays of Long Island, and southern bays of New York City. This resulted in moderate to major coastal flooding, wave damage and erosion along the coast, with heavy damage to public beaches and other public and private facilities. In Rockland County, prior to the start of the storm, a countywide state of emergency was declared. The New York State Thruway was closed from the Tappan Zee

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
				Bridge to the Rockland/Orange County line. The Montebello Road Bridge was destroyed. All county transportation services, along with Metro North, NJ Transit, Amtrak, and New York City subway service were suspended. Over 11,000 customers were without power. Rainfall totals ranged from 7.52 inches in Tappan (Town of Orangetown) to 9.22 inches in the Village of Hillburn. Multiple municipalities experienced flooding as a result of the rain from Irene. There were deaths in Rockland County attributed to the storm. Overall, Rockland County received over $13 million in reimbursements from FEMA.
October 29, 2012	Hurricane Sandy	DR-4085	Yes	Hurricane Sandy moved up the east coast of the United States during the last week of October 2012. As the storm made landfall in southern New Jersey, bands of rain moved across eastern New York State. Rainfall totals in this part of the State were minimal and did not cause any flooding. The storm did bring strong and gusty winds to the area, bringing down trees and power lines across the region. Wind gusts ranged from 40 to 60 mph. Additionally, the low lying areas along the Hudson River experienced moderate coastal flooding as storm surge moved north along the river as the storm made landfall in southern New Jersey. In Rockland County, Hurricane Sandy brought high winds and record storm surge. Numerous residents and businesses were damaged and tens of thousands were without power. Residents living near the Hudson River were the hardest hit in the County. Shelters and heating stations were opened. Up to two to five feet of inundation occurred in the low lying areas of the Hudson River causing moderate to major flooding. The Town of Stony Point and the Village of Piermont sustained the most widespread major damage. In Stony Point, storm surge and waves up to 12 feet in height struck the Town's Hudson River shoreline. Waterfront homes and businesses were damaged. In the Town of Clarkstown, wind gusts ranged from 60 to 70 mph, downing trees and power lines and causing severe power outages and damaging buildings and infrastructure. Due to the inundation, mandatory evacuations were ordered in the Grassy Point section of the Town of Stony Point. Approximately 400 people were evacuated from their homes. In the Village of Piermont, approximately 300 people were directed to evacuate their homes and businesses. In the Town of Haverstraw, River Road was closed due to tidal flooding during high tide. The largest shelter in the county was at Rockland Community College. A State of Emergency was declared in the County. Overall, Rockland County received over $24 million in reimbursements from FEMA.
April 30, 2014	Heavy Rain and Flooding	N/A	N/A	Periods of heavy rain resulted in flash flooding across portions of New York City and in Nassau, Rockland and Westchester Counties. In Rockland County, the Mahwah River at Suffern exceeded its flood stage of 4.0 feet, cresting at 5.0 feet. Rainfall totals from the storm ranged from 2.85 inches in the Village of Suffern to 3.78 inches in the Village of Spring Valley.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
August 1, 2014	Heavy Rain and Flash Flood	N/A	N/A	Showers and thunderstorms produced heavy rain which led to flash flooding in Rockland County. There were multiple water rescues conducted after vehicles became stuck in high water on Route 303 in Tappan (Town of Orangetown).
July 27, 2015	Heavy Rain and Flash Flood	N/A	N/A	Showers and thunderstorms resulted in isolated flash flooding in Orange and Rockland Counties. In Rockland County, Fourth Street in the Village of Hillburn was closed near I-87 due to flash flooding.

Sources: FEMA 2016; NOAA-NCDC 2016; NYS HMP 2014; SPC 2016
FEMA Federal Emergency Management Agency
HMP Hazard Mitigation Plan
Mph Miles Per Hour
NCDC National Climatic Data Center
NOAA National Oceanic and Atmospheric Administration
NYS New York State
N/A Not Applicable
SPC Storm Prediction Center

Probability of Future Occurrences

Based on the historic and more recent flood events in Rockland County, it is clear that the County has a high probability of flooding for the future. The fact that the elements required for flooding exist and that major flooding has occurred throughout the County in the past suggests that many people and properties are at risk from the flood hazard in the future. It is estimated that Rockland County will continue to experience direct and indirect impacts of flooding events annually that may induce secondary hazards such as coastal erosion, storm surge in coastal areas, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents and inconveniences.

As defined by FEMA, geographic areas within the 1% annual chance flood area in Rockland County are estimated to have a one-percent chance of flooding in any given year. A structure located within a 1% annual chance flood area has a 26-percent chance of suffering flood damage during the term of a 30-year mortgage. Geographic areas in Rockland County located within the 0.2% annual chance flood area boundary are estimated to have a 0.2-percent chance of being flooded in any given year (FEMA, 2015).

According to the 2014 New York State Hazard Mitigation Plan Update, between 1960 and 2012, Rockland County had 32 flooding events which resulted in one fatality, three injuries, over $27 million in property damage and over $800,000 in crop damage. These statistics showed that the County had a 62% chance of floods occurring in the future with a recurrence interval of two (NYS DHSES 2014). However, according to the NOAA National Climate Data Center (NCDC) and the CRREL database, Rockland County experienced 33 flood events between 1950 and 2015, including 13 floods, 17 flash floods, 2 ice jams, and one dam failure. The table below shows these statistics, as well as the annual average number of events and the percent chance of these individual flood hazards occurring in Rockland County in future years (NOAA NCDC 2016).

Table 5.4.4-2. Probability of Future Occurrence of Flooding Events

Hazard Type	Number of Occurrences Between 1950 and 2015	Rate of Occurrence or Annual Number of Events (average)	Recurrence Interval (in years) (# Years/Number of Events)	Probability of Event in any given year	% chance of occurrence in any given year
Flash Flood	17	0.26	3.88	0.26	25.76
Flood	13	0.20	5.08	0.20	19.70
Dam Failure	1	0.02	66.00	0.02	1.52
Ice Jams	2	0.03	33.00	0.03	3.03
TOTAL	**33**	**0.51**	**2.00**	**0.50**	**50.00**

Source: NOAA-NCDC 2016; CRREL 2016; NPDP 2015

In Section 5.3, the identified hazards of concern for Rockland 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 drought in the County is considered 'frequent' (likely to occur within 25 years, as presented in Table 5.3-3).

Climate Change Impacts

The climate of Rockland County is already changing, and will continue to change in the future. Climate change is beginning to affect both people and resources of the State and County and the impacts of climate change will continue. Impacts related to increasing temperatures and sea level rise are already being felt in the County. 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).

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).

Sea level rise projections that do not include significant melting of polar ice sheets suggest one to five inches of rise by the 2020s; five to 12 inches by the 2050s; and eight to 23 inches by the 2080s. Scenarios that include rapid melting of polar ice projects four to 10 inches by the 2020s; 17 to 29 inches by the 2050s; and 37 to 55 inches by the 2080s (NYSERDA 2011).

Each region in New York State, as defined by ClimAID, has attributes that will be affected by climate change. Rockland County is part of Region 2, Catskill Mountains and West Hudson River Valley (NYSERDA 2011). In Region 2, it is estimated that temperatures will increase by 3.1ºF to 6.9ºF by the 2050s and 4.0ºF to 10.7ºF by the 2080s (baseline of 50.0ºF). Precipitation totals will increase between 1 and 14% by the 2050s and 2 to 18% by the 2080s (baseline of 46.0 inches). Table 5.4.4-3 displays the projected seasonal precipitation change for the Catskill Mountains and West Hudson River Valley ClimAID Region (NYSERDA 2014).

Table 5.4.4-3. Projected Seasonal Precipitation Change in Region 2, 2050s (% change)

Winter	Spring	Summer	Fall
0 to +15	0 to +10	-5 to +10	-5 to +10

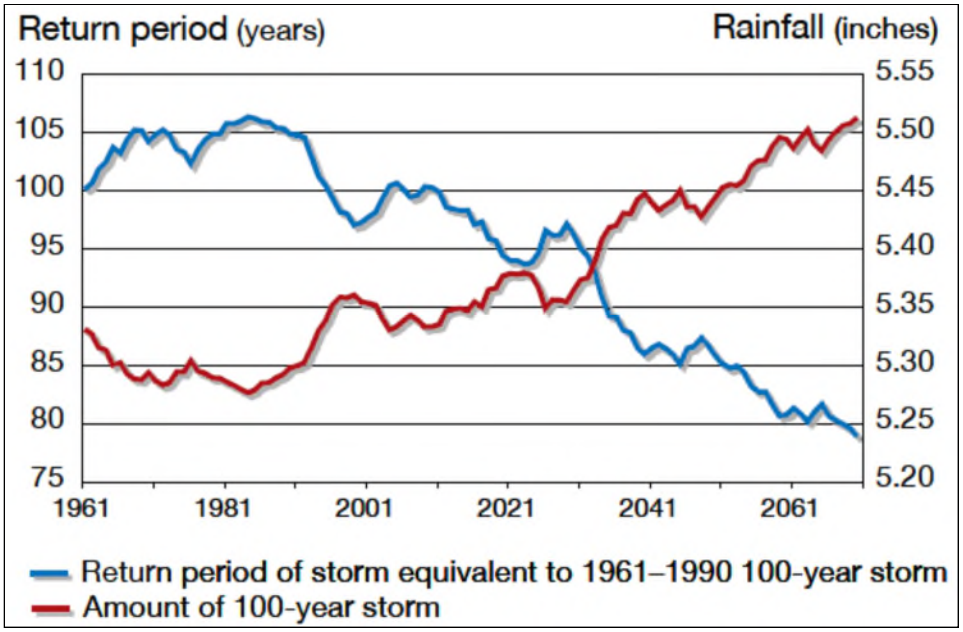
Source: NYSERDA 2011

The projected increase in precipitation is expected to fall in heavy downpours and less in light rains. The increase in heavy downpours has the potential to affect drinking water; heighten the risk of riverine flooding; flood key rail lines, roadways and transportation hugs; and increase delays and hazards related to extreme weather events (NYSERDA 2011).

Sea level is projected to rise along the New York State coastline and in the tidal Hudson River by three to eight inches by the 2020s, nine to 21 inches by the 2050s, and 14 to 39 inches by the 2080s. The high-end estimate for sea level rise by the 2080s is 58 inches (NYSERDA 2014). The projected increase in sea level rise has the potential to increase risk of storm surge-related flooding along the coast; expand areas at-risk of coastal flooding; increase vulnerability of energy facilities located in coastal areas; flood transportation and telecommunication facilities; and cause saltwater intrusion into some freshwater supplies near the coasts. This could impact several municipalities in Rockland County. Sea level rise will lead to more frequent and extensive coastal flooding (NYSERDA 2011).

Increasing air temperatures intensify the water cycle by increasing evaporation and precipitation. This can cause an increase in rain totals during events with longer dry periods in between those events. These changes can have a variety of effects on the State's water resources (NYSERDA 2011). Figure 5.4.4-2 displays the project rainfall and frequency of extreme storms in New York State. The amount of rain fall in a 100-year event is projected to increase, while the number of years between such storms (return period) is projected to decrease. Rainstorms will become more severe and more frequent (NYSERDA 2011).

Figure 5.4.4-2. Projected Rainfall and Frequency of Extreme Storms



Source: NYSERDA 2011

5.4.4.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed and vulnerable in the identified hazard area. For the flood hazard, areas identified as hazard areas include the 1-percent and 0.2-percent annual chance flood event boundaries (Figure 5.4.4-1). The following text evaluates and estimates the potential impact of flooding for Rockland County including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2010 Rockland County Hazard Mitigation Plan
- Further data collections that will assist understanding this hazard over time

Overview of Vulnerability

Flood is a significant concern for Rockland County. To assess vulnerability, exposure to the 1- and 0.2-percent annual chance flood events was examined and potential losses were calculated for 1- percent annual chance flood event. The flood hazard exposure and loss estimate analysis is presented below.

Data and Methodology

The 1- and 0.2-percent annual chance flood events were examined to evaluate the County's risk to the flood hazard. These flood events are generally those considered by planners and evaluated under federal programs such as the NFIP.

The 1-percent annual chance flood event was examined to evaluate the County's risk and vulnerability to the flood hazard. The FEMA effective work map released in April 2016 for Rockland County was used to evaluate the County's exposure to this hazard. The data used for this analysis is shown in Figure 5.4.4-1.

To estimate potential losses, the Hazards U.S. Multi-Hazard (HAZUS-MH) version 3.2 flood model was used. A depth grid was created using base-flood elevation and cross section data from FEMA and a 1/3 Arc-second DEM model provided by the USGS; areas without flood elevation data from FEMA were generated using the FEMA flood boundaries and USGS DEM. The depth grids were integrated into HAZUS-MH and the model was run to estimate potential losses at the Census Block level using the Hazus-MH default building stock data.

The HAZUS-MH 3.2 model uses 2010 U.S. Census demographic data. HAZUS-MH 3.2 calculated the estimated damages to the general building stock and critical facilities based on the custom inventories, provided depth grid and the default HAZUS damage functions in the flood model.

Impact on Life, Health and Safety

The impact of the hydrologic hazards on life, health and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time is provided to residents. Exposure represents the population living in or near the hazard areas that could be impacted should an event occur. Additionally, exposure should not be limited to only those who reside in a defined hazard zone, but everyone who may be affected by the cascading impacts of a hazard event (e.g., people are at risk while traveling in flooded areas, or their access to emergency services is compromised during an event). The degree of that impact will vary and is not strictly measurable.

Cascading impacts may also include exposure to pathogens such as mold. After flood events, excess moisture and standing water contribute to the growth of mold in buildings. Mold may present a health risk to building occupants, especially those with already compromised immune systems such as infants, children, the elderly and pregnant women. The degree of impact will vary and is not strictly measurable. Molds can grow in as short a period as 24-48 hours in wet and damaged areas of buildings that have not been properly cleaned. Very small mold spores can easily be inhaled, creating the potential for allergic reactions, asthma episodes, and other respiratory problems. Buildings should be properly cleaned and dried out to safely prevent mold growth (CDC, 2015).

Molds and mildews are not the only public health risk associated with flooding. Floodwaters can be contaminated by pollutants such as sewage, human and animal feces, pesticides, fertilizers, oil, asbestos, and rusting building materials. Common public health risks associated with flood events also include:

- Unsafe food
- Contaminated drinking and washing water and poor sanitation
- Mosquitos and animals
- Carbon monoxide poisoning
- Secondary hazards associated with re-entering/cleaning flooded structures
- Mental stress and fatigue

Current loss estimation models such as HAZUS-MH are not equipped to measure public health impacts. The best level of mitigation for these impacts is to be aware that they can occur, educate the public on prevention, and be prepared to deal with these vulnerabilities in responding to flood events.

To estimate the population exposed to the 1- and 0.2-percent flood events, the floodplain boundaries were overlaid upon the 2010 U.S. Census population data in GIS (U.S. Census 2010). The 2010 Census blocks with their centroid in the flood boundaries were used to calculate the estimated population exposed to this hazard.

Within the floodplain population, senior citizens and the population in poverty are two especially vulnerable groups that must be taken under special consideration when planning for disaster preparation, response, and recovery.

Census blocks do not follow the boundaries of the floodplain and can grossly over or under estimate the population exposed when using the centroid or intersect of the Census block with these zones. The limitations of these analyses are recognized, and as such the results are only used to provide a general estimate. The total land area located in the one-percent and 0.2-percent annual chance flood zones was calculated using the regulatory FIRM for each jurisdiction, as presented in Table 5.4.4-4.

Table 5.4.4-4. Total Land Area in the 1-Percent and 0.2-Percent Annual Chance Flood Zones (Acres)

Municipality	Total Area (acres)	1% Flood Event Hazard Area		0.2% Flood Event Hazard Area	
		Area (acres)	% of Total	Area (acres)	% of Total
Airmont, Village of	2,921.4	98.5	3.4%	113.3	3.9%
Chestnut Ridge, Village of	3,169.6	117.4	3.7%	139.2	4.4%
Clarkstown, Town of	29,915.3	6,259.4	20.9%	6,509.6	21.8%
Grand View on Hudson, Village of	111.7	2.4	2.2%	111.7	100.0%
Haverstraw, Town of	15,540.8	3,793.6	24.4%	3,904.0	25.1%
Haverstraw, Village of	1,254.7	44.5	3.5%	58.2	4.6%
Hillburn, Village of	1,442.2	62.5	4.3%	90.4	6.3%
Kaser, Village of	110.0	1.8	1.6%	2.8	2.5%
Montebello, Village of	2,766.8	320.2	11.6%	375.0	13.6%
New Hempstead, Village of	1,823.2	105.9	5.8%	109.5	6.0%
New Square, Village of	232.8	1.8	<1%	2.9	1.2%
Nyack, Village of	492.7	3.5	<1%	22.1	4.5%
Orangetown, Town of	20,601.2	5,383.7	26.1%	5,653.5	27.4%
Piermont, Village of	714.4	374.9	52.5%	461.3	64.6%
Pomona, Village of	1,521.7	63.3	4.2%	65.1	4.3%
Ramapo, Town of	20,250.1	920.6	4.5%	987.4	4.9%
Sloatsburg, Village of	1,624.6	183.5	11.3%	214.0	13.2%
South Nyack, Village of	385.8	1.4	<1%	196.7	51.0%
Spring Valley, Village of	1,283.0	92.2	7.2%	114.9	9.0%
Stony Point, Town of	17,982.0	627.8	3.5%	656.7	3.7%
Suffern, Village of	1,358.6	125.6	9.2%	164.0	12.1%
Upper Nyack, Village of	780.0	2.9	<1%	4.3	<1%
Wesley Hills, Village of	2,134.5	53.3	2.5%	65.8	3.1%
West Haverstraw, Village of	984.2	38.5	3.9%	54.5	5.5%
Rockland County	**129,401.3**	**18,678.9**	**14.4%**	**20,077.0**	**15.5%**

Source: *FEMA 2016*
Note: The area presented includes the area of inland waterways and excludes bays or oceans.

Table 5.4.4-5. Estimated Population Exposed to the Flood Hazard

Municipality	Total Population	1-Percent Chance Event		0.2-Percent Chance Event	
		Total Number	% of Total	Total Number	% of Total
Airmont, Village of	8,628	670	7.8%	683	7.9%
Chestnut Ridge, Village of	7,916	147	1.9%	147	1.9%
Clarkstown, Town of	78,867	1,894	2.4%	2,740	3.5%
Grand View on Hudson, Village of	285	0	0.0%	285	100.0%
Haverstraw, Town of	12,808	121	<1%	171	1.3%
Haverstraw, Village of	11,910	724	6.1%	724	6.1%
Hillburn, Village of	951	76	8.0%	132	13.9%
Kaser, Village of	4,724	0	0.0%	11	<1%
Montebello, Village of	4,526	673	14.9%	702	15.5%
New Hempstead, Village of	5,132	17	<1%	17	<1%
New Square, Village of	6,944	0	0.0%	0	0.0%
Nyack, Village of	6,765	0	0.0%	168	2.5%
Orangetown, Town of	36,832	460	1.2%	1,034	2.8%
Piermont, Village of	2,510	709	28.2%	954	38.0%
Pomona, Village of	3,103	63	2.0%	63	2.0%
Ramapo, Town of	38,252	169	<1%	353	<1%
Sloatsburg, Village of	3,039	112	3.7%	191	6.3%
South Nyack, Village of	3,510	0	0.0%	1,975	56.3%
Spring Valley, Village of	31,347	1,214	3.9%	1,527	4.9%
Stony Point, Town of	15,059	363	2.4%	548	3.6%
Suffern, Village of	10,723	651	6.1%	787	7.3%
Upper Nyack, Village of	2,063	0	0.0%	0	0.0%
Wesley Hills, Village of	5,628	0	0.0%	0	0.0%
West Haverstraw, Village of	10,165	125	1.2%	125	1.2%
Rockland County	**311,687**	**8,188**	**2.6%**	**13,337**	**4.3%**

Sources: U.S. Census 2010; FEMA, 2016

The table above shows that approximately 2.6-percent of the total population is exposed to the 1-percent annual chance flood event and that approximately 4.3-percent of the total population is exposed to the 0.2-percent annual chance flood event. The Village of Piermont will experience the greatest impact to population with approximately 28.2% and 38.0% for the 1-percent chance event and 0.2-percent chance event, respectively. For this project, the potential population impacted is used as a guide.

Of the population exposed, the most vulnerable include the economically disadvantaged and the population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact to their family. The population over the age of 65 is also more vulnerable because they are more likely to seek or need medical attention which may not be available to due isolation during a flood event and they may have more difficulty evacuating.

Using 2010 U.S. Census data, HAZUS-MH 3.2 estimates the potential sheltering needs as a result of a 1-percent chance flood event. For the 1-percent flood event, HAZUS-MH 3.2 estimates 7,384 households will be displaced and 4,393 people will seek short-term sheltering. These statistics, by municipality, are presented in **Table 5.4.4-6**.

Table 5.4.4-6. Estimated Population Displaced or Seeking Short-Term Shelter from the 1-Percent Annual Chance Flood Event

Municipality	U.S. Census 2010 Population	1-Percent Annual Chance Event	
		Displaced Households	Persons Seeking Short-Term Sheltering
Airmont, Village of	8,628	119	21
Chestnut Ridge, Village of	7,916	136	21
Clarkstown, Town of	78,867	1,730	942
Grand View on Hudson, Village of	285	21	7
Haverstraw, Town of	12,808	111	40
Haverstraw, Village of	11,910	229	196
Hillburn, Village of	951	18	3
Kaser, Village of	4,724	95	76
Montebello, Village of	4,526	267	111
New Hempstead, Village of	5,132	73	35
New Square, Village of	6,944	78	59
Nyack, Village of	6,765	54	49
Orangetown, Town of	36,832	511	183
Piermont, Village of	2,510	356	282
Pomona, Village of	3,103	18	1
Ramapo, Town of	38,252	444	147
Sloatsburg, Village of	3,039	299	183
South Nyack, Village of	3,510	11	0
Spring Valley, Village of	31,347	1,407	1,127
Stony Point, Town of	15,059	421	194
Suffern, Village of	10,723	705	573
Upper Nyack, Village of	2,063	13	1
Wesley Hills, Village of	5,628	80	25
West Haverstraw, Village of	10,165	188	117
Rockland County	**311,687**	**7,384**	**4,393**

Source: HAZUS-MH 3.2

The total number of injuries and casualties resulting from flooding is generally limited based on advance weather forecasting, blockades and warnings. Therefore, injuries and deaths generally are not anticipated if proper warning and precautions are in place. Ongoing mitigation efforts should help to avoid the most likely cause of injury, which results from persons trying to cross flooded roadways or channels during a flood.

Impact on General Building Stock

After considering the population exposed and vulnerable to the flood hazard, the built environment was evaluated. Exposure in the flood zone includes those buildings located in the flood zone. Potential damage is the modeled loss that could occur to the exposed inventory, including structural and content value.

To provide a general estimate of the structural/content replacement value exposure, the 1- and 0.2-percent DFIRM flood boundaries were overlaid upon the Hazus-MH default building stock data at the census block level. The census blocks with their centroid in the hazard areas were totaled for each municipality. Table 5.4.4-7 and Table 5.4.4-8 summarize these results. In summary, there are 2,611 buildings located in 1-percent annual chance flood boundary with an estimated $1.8 billion of building/contents exposed. In total, this represents approximately 3.0% of the County's total general building stock inventory (approximately $59.9 billion).

There are 4,222 buildings located in the 0.2-percent annual chance flood boundary with an estimated $3.2 billion of building/contents exposed. This represents approximately 5.4% of the County's total general building stock inventory.

Table 5.4.4-7. Estimated General Building Stock Exposure to the 1- Percent Annual Chance Flood Event – All Occupancies

Municipality	Total # Buildings	Total Replacement Cost Value (Structure and Contents)	Total (All Occupancies)			
			# Buildings	% Total	Total Replacement Cost Value (Structure and Contents	% Total
Airmont, Village of	2,769	$1,918,825,000	219	7.9%	$111,087,000	5.8%
Chestnut Ridge, Village of	2,966	$2,012,432,000	63	2.1%	$75,364,000	3.7%
Clarkstown, Town of	26,894	$17,738,436,000	620	2.3%	$444,309,000	2.5%
Grand View on Hudson, Village of	146	$90,160,000	0	0.0%	$9,000	0.0%
Haverstraw, Town of	3,978	$2,105,505,000	49	1.2%	$34,376,000	1.6%
Haverstraw, Village of	2,304	$1,383,509,000	172	7.5%	$129,081,000	9.3%
Hillburn, Village of	343	$274,003,000	26	7.6%	$12,000,000	4.4%
Kaser, Village of	605	$905,538,000	0	0.0%	$0	0.0%
Montebello, Village of	1,432	$1,087,531,000	245	17.1%	$119,081,000	10.9%
New Hempstead, Village of	1,402	$761,317,000	9	<1%	$4,107,000	<1%
New Square, Village of	503	$469,065,000	0	0.0%	$0	0.0%
Nyack, Village of	1,854	$2,151,804,000	0	0.0%	$0	0.0%
Orangetown, Town of	12,622	$9,753,484,000	172	1.4%	$181,745,000	1.9%
Piermont, Village of	902	$607,070,000	291	32.3%	$196,328,000	32.3%
Pomona, Village of	1,177	$751,081,000	20	1.7%	$11,687,000	1.6%
Ramapo, Town of	8,174	$4,907,209,000	44	<1%	$23,094,000	0.5%
Sloatsburg, Village of	1,147	$560,532,000	54	4.7%	$32,844,000	5.9%
South Nyack, Village of	962	$909,458,000	0	0.0%	$0	0.0%
Spring Valley, Village of	4,397	$3,250,707,000	232	5.3%	$202,569,000	6.2%
Stony Point, Town of	5,612	$3,203,457,000	148	2.6%	$83,982,000	2.6%
Suffern, Village of	3,159	$2,003,083,000	199	6.3%	$87,329,000	4.4%
Upper Nyack, Village of	814	$420,682,000	0	0.0%	$0	0.0%
Wesley Hills, Village of	1,734	$1,046,454,000	0	0.0%	$0	0.0%
West Haverstraw, Village of	2,688	$1,607,273,000	48	1.8%	$37,014,000	2.3%
Rockland County	**88,584**	**$59,918,615,000**	**2,611**	**2.9%**	**$1,786,006,000**	**3.0%**

Source: FEMA 2016, Hazus-MH 3.2

Table 5.4.4-8. Estimated General Building Stock Exposure to the 0.2-Percent Annual Chance Flood Event – All Occupancies

Municipality	Total # Buildings	Total Replacement Cost Value (Structure and Contents)	Total (All Occupancies)			
			# Buildings	% Total	Total Replacement Cost Value (Structure and Contents	% Total
Airmont, Village of	2,769	$1,918,825,000	238	8.6%	$211,942,000	11.0%
Chestnut Ridge, Village of	2,966	$2,012,432,000	64	2.2%	$76,333,000	3.8%
Clarkstown, Town of	26,894	$17,738,436,000	931	3.5%	$682,621,000	3.8%
Grand View on Hudson, Village of	146	$90,160,000	146	100.0%	$90,160,000	100.0%

Municipality	Total # Buildings	Total Replacement Cost Value (Structure and Contents)	Total (All Occupancies)			
			# Buildings	% Total	Total Replacement Cost Value (Structure and Contents	% Total
Haverstraw, Town of	3,978	$2,105,505,000	78	2.0%	$65,366,000	3.1%
Haverstraw, Village of	2,304	$1,383,509,000	172	7.5%	$129,081,000	9.3%
Hillburn, Village of	343	$274,003,000	44	12.8%	$45,375,000	16.6%
Kaser, Village of	605	$905,538,000	1	<1%	$186,000	<1%
Montebello, Village of	1,432	$1,087,531,000	255	17.8%	$123,236,000	11.3%
New Hempstead, Village of	1,402	$761,317,000	9	<1%	$4,107,000	<1%
New Square, Village of	503	$469,065,000	0	0.0%	$0	0.0%
Nyack, Village of	1,854	$2,151,804,000	42	2.3%	$21,256,000	1.0%
Orangetown, Town of	12,622	$9,753,484,000	423	3.4%	$336,204,000	3.4%
Piermont, Village of	902	$607,070,000	375	41.6%	$255,930,000	42.2%
Pomona, Village of	1,177	$751,081,000	20	1.7%	$11,687,000	1.6%
Ramapo, Town of	8,174	$4,907,209,000	91	1.1%	$44,228,000	<1%
Sloatsburg, Village of	1,147	$560,532,000	89	7.8%	$48,256,000	8.6%
South Nyack, Village of	962	$909,458,000	442	45.9%	$614,031,000	67.5%
Spring Valley, Village of	4,397	$3,250,707,000	290	6.6%	$235,004,000	7.2%
Stony Point, Town of	5,612	$3,203,457,000	219	3.9%	$112,938,000	3.5%
Suffern, Village of	3,159	$2,003,083,000	245	7.8%	$107,047,000	5.3%
Upper Nyack, Village of	814	$420,682,000	0	0.0%	$0	0.0%
Wesley Hills, Village of	1,734	$1,046,454,000	0	0.0%	$0	0.0%
West Haverstraw, Village of	2,688	$1,607,273,000	48	1.8%	$37,014,000	2.3%
Rockland County	**88,584**	**$59,918,615,000**	**4,222**	**4.8%**	**$3,252,002,000**	**5.4%**

Source: FEMA 2016, Hazus-MH 3.2

The HAZUS-MH model estimated potential damages to the buildings in Rockland County at the structure level using the custom County structure inventory developed for this plan. The potential damage estimated by HAZUS-MH to the general building stock inventory associated with the 1-percent annual chance flood is approximately $777 million or 1.3-percent of the total building stock improvement value.

Table 5.4.4-9. Estimated General Building Stock Potential Loss to the 1-Percent Annual Chance Flood Event

Municipality	Total Replacement Cost Value	1% Annual Chance Event							
		All Occupancies		Residential		Commercial		Industrial, Religious, Education and Government	
		Estimated Loss	% of Total	Estimated Loss	% of Total	Estimated Loss	% of Total	Estimated Loss	% of Total
Airmont, Village of	$1,918,825,000	$10,637,000	<1%	$7,880,000	<1%	$1,926,000	<1%	$831,000	<1%
Chestnut Ridge, Village of	$2,012,432,000	$23,321,000	1.2%	$14,764,000	<1%	$4,786,000	<1%	$3,771,000	<1%
Clarkstown, Town of	$17,738,436,000	$241,547,000	1.4%	$116,892,000	<1%	$92,729,000	<1%	$31,926,000	<1%
Grand View on Hudson, Village of	$90,160,000	$1,921,000	2.1%	$1,688,000	1.9%	$233,000	<1%	$0	0.0%
Haverstraw, Town of	$2,105,505,000	$23,046,000	1.1%	$10,560,000	<1%	$10,037,000	<1%	$2,449,000	<1%
Haverstraw, Village of	$1,383,509,000	$9,293,000	<1%	$4,605,000	<1%	$400,000	<1%	$4,288,000	<1%
Hillburn, Village of	$274,003,000	$2,194,000	<1%	$1,708,000	<1%	$459,000	<1%	$27,000	<1%
Kaser, Village of	$905,538,000	$4,388,000	<1%	$2,796,000	<1%	$1,040,000	<1%	$552,000	<1%
Montebello, Village of	$1,087,531,000	$33,763,000	3.1%	$26,079,000	2.4%	$6,624,000	<1%	$1,060,000	<1%
New Hempstead, Village of	$761,317,000	$2,592,000	<1%	$1,915,000	<1%	$420,000	<1%	$257,000	<1%
New Square, Village of	$469,065,000	$3,760,000	<1%	$2,566,000	<1%	$799,000	<1%	$395,000	<1%
Nyack, Village of	$2,151,804,000	$4,361,000	<1%	$3,728,000	<1%	$509,000	<1%	$124,000	<1%
Orangetown, Town of	$9,753,484,000	$77,642,000	<1%	$26,018,000	<1%	$26,901,000	<1%	$24,723,000	<1%
Piermont, Village of	$607,070,000	$29,203,000	4.8%	$19,586,000	3.2%	$6,551,000	1.1%	$3,066,000	<1%
Pomona, Village of	$751,081,000	$1,911,000	<1%	$1,563,000	<1%	$273,000	<1%	$75,000	<1%
Ramapo, Town of	$4,907,209,000	$37,076,000	<1%	$26,824,000	<1%	$6,530,000	<1%	$3,722,000	<1%
Sloatsburg, Village of	$560,532,000	$34,603,000	6.2%	$26,851,000	4.8%	$6,137,000	1.1%	$1,615,000	<1%
South Nyack, Village of	$909,458,000	$646,000	<1%	$515,000	<1%	$127,000	<1%	$4,000	<1%
Spring Valley, Village of	$3,250,707,000	$98,824,000	3.0%	$64,028,000	2.0%	$22,231,000	<1%	$12,565,000	<1%
Stony Point, Town of	$3,203,457,000	$37,172,000	1.2%	$18,346,000	<1%	$9,760,000	<1%	$9,066,000	<1%
Suffern, Village of	$2,003,083,000	$64,792,000	3.2%	$53,297,000	2.7%	$5,684,000	<1%	$5,811,000	<1%
Upper Nyack, Village of	$420,682,000	$889,000	<1%	$705,000	<1%	$156,000	<1%	$28,000	<1%
Wesley Hills, Village of	$1,046,454,000	$13,090,000	1.3%	$6,919,000	<1%	$5,449,000	<1%	$722,000	<1%
West Haverstraw, Village of	$1,607,273,000	$20,641,000	1.3%	$9,499,000	<1%	$6,624,000	<1%	$4,518,000	<1%
Rockland County	**$59,918,615,000**	**$777,312,000**	**1.3%**	**$449,332,000**	**<1%**	**$216,385,000**	**<1%**	**$111,595,000**	**<1%**

Source: HAZUS-MH 3.2

NFIP Statistics

In addition to total building stock modeling, individual data available on flood policies, claims, Repetitive Loss Properties (RLP) and severe RLP (SRLs) were analyzed. FEMA Region 2 provided a list of residential properties with NFIP policies, past claims and multiple claims (RLPs). According to the metadata provided: "The (*sic* National Flood Insurance Program) NFIP Repetitive Loss File contains losses reported from individuals who have flood insurance through the Federal Government. A property is considered a repetitive loss property when there are two or more losses reported which were paid more than $1,000 for each loss. The two losses must be within 10 years of each other & be as least 10 days apart. Only losses from (*sic* since) 1/1/1978 that are closed are considered."

SRLs were then examined for the County. According to section 1361A of the National Flood Insurance Act, as amended (NFIA), 42 U.S.C. 4102a, an SRL property is defined as a residential property that is covered under an NFIP flood insurance policy and:

- 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
- 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.
- For both of the above, at least two of the referenced claims must have occurred within any 10- year period, and must be greater than 10 days apart.

Table 5.4.4-10 through Table 5.4.4-12 summarize the NFIP policies, claims and repetitive loss statistics for Rockland County. According to FEMA, Table 5.4.4-10 summarizes the occupancy classes of the RL and SRL properties in Rockland County. The majority of the RL occupancy class is single family residences (81.2%). The majority of SRL occupancy class is also single family residences (80%) (FEMA Region 2, 2016). This information is current as of June 30th, 2016.

The location of the properties with policies, claims and repetitive and severe repetitive flooding were geocoded by FEMA with the understanding that there are varying tolerances between how closely the longitude and latitude coordinates correspond to the location of the property address, or that the indication of some locations are more accurate than others.

Table 5.4.4-10. Occupancy Class of Repetitive Loss Structures in Rockland County

Occupancy Class	Total Number of Repetitive Loss Properties	Total Number of Severe Repetitive Loss Properties	Total (RL + SRL)
Single Family	69	16	85
Condo	3	0	3
2-4 Family	7	0	7
Other Residential	4	0	4
Non-Residential	2	4	6
Total	**85**	**20**	**105**

Source: FEMA Region 2 2016
Note (1): Policies, claims, repetitive loss and severe repetitive loss statistics provided by FEMA Region 2, and are current as of 06/30/2016.
Note (2): Total number of repetitive loss properties does not include severe repetitive loss properties.
RL Repetitive Loss
SRL Severe Repetitive Loss

Table 5.4.4-11. Occupancy Class of Repetitive Loss Structures in Rockland County, by Municipality

Municipality	Repetitive Loss Properties					Severe Repetitive Loss Properties				
	2-4 Family	Assumed Condo	Non Residential	Other Residential	Single Family	2-4 Family	Assumed Condo	Non Residential	Other Residential	Single Family
Airmont, Village of	0	0	0	0	0	0	0	0	0	0
Chestnut Ridge, Village of	0	0	0	0	0	0	0	0	0	0
Clarkstown, Town of	0	0	0	1	23	0	0	0	3	7
Grand View on Hudson, Village of	0	0	0	0	3	0	0	0	0	0
Haverstraw, Town of	0	0	0	0	0	0	0	0	0	0
Haverstraw, Village of	0	0	0	0	0	0	0	0	0	0
Hillburn, Village of	0	0	0	0	0	0	0	0	0	0
Kaser, Village of	0	0	0	0	0	0	0	0	0	0
Montebello, Village of	0	0	0	0	5	0	0	0	0	0
New Hempstead, Village of	0	0	0	0	0	0	0	0	0	0
New Square, Village of	0	0	0	0	0	0	0	0	0	0
Nyack, Village of	0	0	3	0	1	0	0	0	1	0
Orangetown, Town of	1	3	0	0	8	0	0	0	0	1
Piermont, Village of	5	0	0	0	7	0	0	0	0	1
Pomona, Village of	0	0	0	0	0	0	0	0	0	0
Ramapo, Town of	0	0	0	0	0	0	0	0	0	0
Sloatsburg, Village of	0	0	0	0	2	0	0	0	0	1
South Nyack, Village of	0	0	0	0	2	0	0	0	0	1
Spring Valley, Village of	0	0	1	0	0	0	0	0	0	2
Stony Point, Town of	0	0	0	0	2	0	0	0	0	0
Suffern, Village of	1	0	0	1	15	0	0	0	0	2
Upper Nyack, Village of	0	0	0	0	0	0	0	0	0	1
Wesley Hills, Village of	0	0	0	0	1	0	0	0	0	0
West Haverstraw, Village of	0	0	0	0	0	0	0	0	0	0
Rockland County	**7**	**3**	**4**	**2**	**69**	**0**	**0**	**0**	**4**	**16**

Source: FEMA, 2016
Note (1): Policies, claims, repetitive loss and severe repetitive loss statistics provided by FEMA Region 2, and are current as of 06/30/2016
Note (2): The statistics were summarized using the Community Name provided by FEMA Region 2.
Note (3): The total number of repetitive loss properties does not include the severe repetitive loss properties.

Table 5.4.4-12. NFIP Policies, Claims and Repetitive Loss Statistics

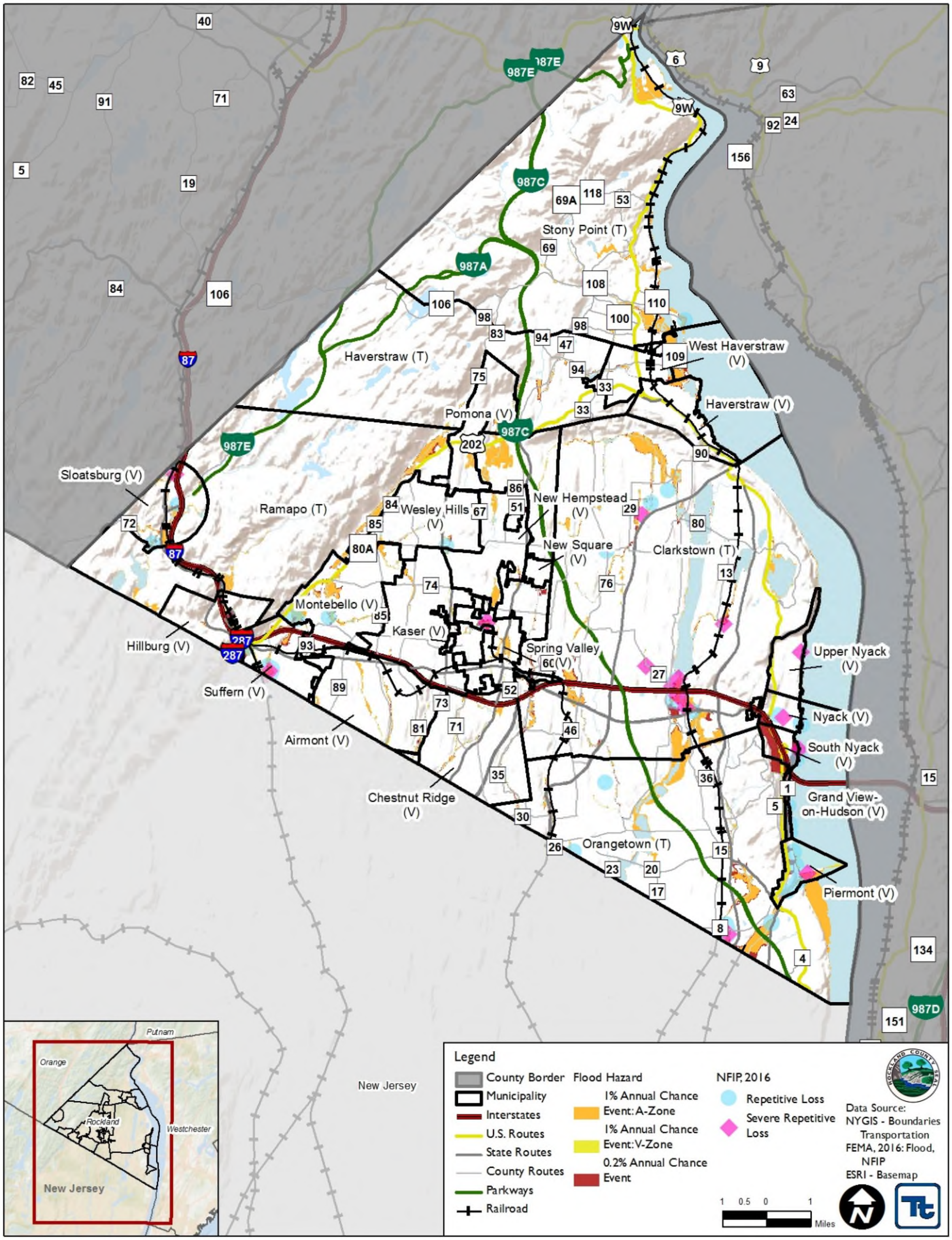
Municipality	# Policies (1)	# Claims (Losses) (1)	Total Loss Payments (2)	# Rep. Loss Prop. (1)	# Severe Rep. Loss Prop. (1)	# Policies in the 1% Flood Boundary (3)
Airmont, Village of	6	0	$0	0	0	1
Chestnut Ridge, Village of	22	8	$122,825	0	0	3
Clarkstown, Town of	550	677	$7,586,945	24	10	116
Grand View on Hudson, Village of	31	26	$1,248,200	3	0	1
Haverstraw, Town of	29	33	$370,691	0	0	0
Haverstraw, Village of	22	3	$7,768	0	0	2
Hillburn, Village of	13	31	$1,267,279	0	0	1
Kaser, Village of	1	0	$0	0	0	0
Montebello, Village of	60	32	$974,960	5	0	32
New Hempstead, Village of	15	6	$45,073	0	0	2
New Square, Village of	0	10	$29,707	0	0	0
Nyack, Village of	43	73	$2,620,449	4	1	10
Orangetown, Town of	152	256	$3,108,915	12	1	38
Piermont, Village of	129	97	$4,521,489	12	1	39
Pomona, Village of	18	28	$103,707	0	0	4
Ramapo, Town of	113	369	$2,095,053	0	0	18
Sloatsburg, Village of	41	50	$505,680	2	1	8
South Nyack, Village of	18	23	$560,654	2	1	3
Spring Valley, Village of	78	249	$1,332,851	1	2	32
Stony Point, Town of	89	70	$2,883,613	2	0	45
Suffern, Village of	154	390	$5,188,302	17	2	123
Upper Nyack, Village of	24	7	$227,317	0	1	0
Wesley Hills, Village of	26	2	$2,806	1	0	1
West Haverstraw, Village of	22	19	$3,919,162	0	0	18
Rockland County	**1,656**	**2,459**	**$38,723,445**	**85**	**20**	**497**

Source: *FEMA Region 2, 2016*
(1) *Policies, claims, repetitive loss and severe repetitive loss statistics provided by FEMA Region 2, and are current as of 06/30/2016.*
The total number of repetitive loss properties does not include the severe repetitive loss properties. The number of claims represents claims closed by 06/30/16.
(2) *Total building and content losses from the claims file provided by FEMA Region 2.*

(3) The policies inside and outside of the flood zones is based on the latitude and longitude provided by FEMA Region 2 in the policy file.

Notes: FEMA noted that where there is more than one entry for a property, there may be more than one policy in force or more than one GIS possibility.
A zero percentage denotes less than 1/100th percentage and not zero damages or vulnerability as may be the case.
Number of policies and claims and claims total exclude properties located outside county boundary, based on provided latitude and longitude.

Figure 5.4.4-3. NFIP Repetitive Loss Areas – Rockland County



Source: FEMA Region 2, 2016

Impact on Critical Facilities

HAZUS-MH was used to estimate the flood loss potential to critical facilities exposed to the flood risk. Using depth/damage function curves, HAZUS estimates the percent of damage to the building and contents of critical facilities. Table 5.4.4-13 and Table 5.4.4-14 summarize the number of critical facilities located in the FEMA flood zones by type and by jurisdiction. Table 5.4.4-15 details the estimated percent damage to the critical facilities affected by the 1% and 0.2% Annual Chance Flood Zones as calculated by HAZUS-MH 3.2.

In cases where short-term functionality is impacted by a hazard, other facilities of neighboring municipalities may need to increase support response functions during a disaster event. Mitigation planning should consider means to reduce impact to critical facilities and ensure sufficient emergency and school services remain when a significant event occurs. Actions addressing shared services agreements are included in Section 9 (Mitigation Strategies) of this plan.

Table 5.4.4-13. Number of Critical Facilities Located in the 1-Percent Annual Chance Flood Zone

Municipality	Facility Types										
	Day Care	Electric Power	Fire Station	Hazmat	Municipal Hall	Post Office	Senior	Water Tower	Well	Wastewater Pump	Wastewater Treatment
Airmont, Village of	0	0	0	0	0	0	0	0	2	1	0
Chestnut Ridge, Village of	0	0	0	0	0	0	0	0	0	0	0
Clarkstown, Town of	1	0	0	0	0	0	0	0	2	2	0
Grand View on Hudson, Village of	0	0	0	0	1	0	0	0	0	0	0
Haverstraw, Town of	0	1	0	1	0	0	0	0	1	0	0
Haverstraw, Village of	0	0	0	1	0	0	0	0	0	0	0
Hillburn, Village of	0	0	0	0	0	0	0	0	0	0	0
Kaser, Village of	0	0	0	0	0	0	0	0	0	0	0
Montebello, Village of	0	0	0	0	0	0	0	0	0	3	0
New Hempstead, Village of	0	0	0	0	0	0	0	0	0	0	0
New Square, Village of	0	0	0	0	0	0	0	0	0	0	0
Nyack, Village of	0	0	0	0	0	0	0	0	0	0	0
Orangetown, Town of	0	0	1	1	0	1	0	0	0	0	0
Piermont, Village of	0	0	0	0	0	1	0	0	0	0	0
Pomona, Village of	0	0	0	0	0	0	0	0	0	0	0
Ramapo, Town of	0	0	0	0	0	0	0	0	0	1	0
Sloatsburg, Village of	0	0	0	0	0	0	0	1	0	0	2
South Nyack, Village of	0	0	0	0	0	0	0	0	0	0	0
Spring Valley, Village of	1	0	0	0	0	0	1	0	0	0	0
Stony Point, Town of	0	0	0	0	0	0	0	0	2	0	0
Suffern, Village of	0	0	0	0	0	0	0	0	4	0	0
Upper Nyack, Village of	0	0	0	0	0	0	0	0	0	0	0

Table 5.4.4-13. Number of Critical Facilities Located in the 1-Percent Annual Chance Flood Zone

Municipality	Facility Types										
	Day Care	Electric Power	Fire Station	Hazmat	Municipal Hall	Post Office	Senior	Water Tower	Well	Wastewater Pump	Wastewater Treatment
Wesley Hills, Village of	0	0	0	0	0	0	0	0	0	0	0
West Haverstraw, Village of	0	0	0	0	0	0	0	0	1	0	0
Rockland County	**2**	**1**	**1**	**3**	**1**	**2**	**1**	**1**	**13**	**7**	**2**

Source: FEMA 2016, Rockland County

Table 5.4.4-14. Number of Critical Facilities Located in the 0.2-Percent Annual Chance Flood Zone

Municipality	Facility Types														
	Communication	Day Care	DPW	Electric Power	EMS	Fire Station	Hazmat	Municipal Hall	Post Office	School	Senior	Water Tower	Well	Wastewater Pump	Wastewater Treatment
Airmont, Village of	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0
Chestnut Ridge, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clarkstown, Town of	0	2	0	0	1	0	1	0	1	0	0	0	2	3	0
Grand View on Hudson, Village of	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Haverstraw, Town of	0	0	0	1	0	1	1	0	0	0	0	0	1	0	0
Haverstraw, Village of	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hillburn, Village of	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Kaser, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montebello, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
New Hempstead, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Square, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nyack, Village of	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Orangetown, Town of	0	0	0	0	1	2	1	0	1	0	0	0	0	0	1
Piermont, Village of	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Pomona, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ramapo, Town of	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sloatsburg, Village of	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
South Nyack, Village of	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Spring Valley, Village of	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0
Stony Point, Town of	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Suffern, Village of	0	0	0	0	0	0	1	0	0	0	0	0	4	0	1

Table 5.4.4-14. Number of Critical Facilities Located in the 0.2-Percent Annual Chance Flood Zone

Municipality	Facility Types														
	Communication	Day Care	DPW	Electric Power	EMS	Fire Station	Hazmat	Municipal Hall	Post Office	School	Senior	Water Tower	Well	Wastewater Pump	Wastewater Treatment
Upper Nyack, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wesley Hills, Village of	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Haverstraw, Village of	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
Rockland County	**1**	**6**	**2**	**1**	**2**	**3**	**6**	**2**	**3**	**2**	**1**	**1**	**13**	**9**	**4**

Source: FEMA 2016, Rockland County

Impact on the Economy

For impact on economy, estimated losses from a flood event are considered. Losses include but are not limited to general building stock damages, agricultural losses, business interruption, impacts to tourism and tax base to Rockland County. Damages to general building stock can be quantified using HAZUS-MH as discussed above. Other economic components such as loss of facility use, functional downtime and social economic factors are less measurable with a high degree of certainty.

Flooding can cause extensive damage to public utilities and disruptions to the delivery of services. Loss of power and communications may occur; and drinking water and wastewater treatment facilities may be temporarily out of operation. According to Table 5.4.4-13, 34 facilities are affected by the 1-percent annual chance flood hazard. Flooded streets and road blocks make it difficult for emergency vehicles to respond to calls for service. Floodwaters can wash out sections of roadway and bridges (Foster, Date Unknown). In addition to travel along the roadways, public transit will be greatly impacted, causing problems for emergency responders.

Direct building losses are the estimated costs to repair or replace the damage caused to the building. Refer to the 'Impact on General Building Stock' subsection which discusses these potential losses. These dollar value losses to the County's total building inventory replacement value, in addition to damages to roadways and infrastructure, would greatly impact the local economy.

HAZUS-MH estimates the amount of debris generated from the flood events as a result of 1- and 0.2-percent events. The model breaks down debris into three categories: 1) finishes (dry wall, insulation, etc.); 2) structural (wood, brick, etc.) and 3) foundations (concrete slab and block, rebar, etc.). The distinction is made because of the different types of equipment needed to handle the debris. Table 5.4.4-15 summarizes the debris HAZUS-MH 3.2 estimates for these events.

Please note this table only represents estimated debris generated by coastal flooding and does not include additional potential damage and debris which may be generated with the presence of storm surge and/or wind.

Table 5.4.4-15. Estimated Debris Generated from the 1-Percent Flood Event

Municipality	1% Flood Event			
	Total (tons)	Finish (tons)	Structure (tons)	Foundation (tons)
Airmont, Village of	2,120	340	1,011	768

Table 5.4.4-15. Estimated Debris Generated from the 1-Percent Flood Event

Municipality	1% Flood Event			
	Total (tons)	Finish (tons)	Structure (tons)	Foundation (tons)
Chestnut Ridge, Village of	4,044	571	2,002	1,472
Clarkstown, Town of	29,130	5,487	13,307	10,336
Grand View on Hudson, Village of	97	83	6	8
Haverstraw, Town of	2,642	401	1,234	1,006
Haverstraw, Village of	286	270	10	6
Hillburn, Village of	535	91	241	202
Kaser, Village of	928	200	334	394
Montebello, Village of	6,447	1,092	2,970	2,386
New Hempstead, Village of	362	82	164	116
New Square, Village of	922	210	364	348
Nyack, Village of	187	187	0	0
Orangetown, Town of	6,592	1,289	2,966	2,337
Piermont, Village of	799	799	0	0
Pomona, Village of	219	36	108	75
Ramapo, Town of	4,259	764	1,970	1,525
Sloatsburg, Village of	6,825	1,167	3,093	2,565
South Nyack, Village of	28	27	0	1
Spring Valley, Village of	13,510	2,322	6,529	4,659
Stony Point, Town of	1,928	996	522	410
Suffern, Village of	11,921	2,509	4,934	4,477
Upper Nyack, Village of	36	35	1	1
Wesley Hills, Village of	2,074	278	1,003	793
West Haverstraw, Village of	2,158	372	1,021	766
Rockland County	**98,051**	**19,607**	**43,792**	**34,651**

Source: HAZUS-MH 3.2

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 as flood events. While predicting changes of flood 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], 2006).

Change of Vulnerability

Rockland County and its municipalities continue to be vulnerable to the flood hazard. However, there are several differences between the exposure and potential loss estimates between this plan update to the results in the original 2010 Rockland County Hazard Mitigation Plan. The original HMP looked at the damages caused by past storms and used this to create an estimated annual loss for each municipality. For the Plan Update, new and updated population (U.S. Census 2010 is now available) and a custom building inventory were used; a more accurate flood depth grid was used to estimate potential losses in HAZUS-MH due to the availability of their DFIRM.

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

Future Growth and Development

As discussed in Sections 4 and 9, areas targeted for future growth and development have been identified across Rockland County. Any areas of growth could be potentially impacted by the flood hazard if located within the identified hazard areas. Please refer to the specific areas of development indicated in tabular form and/or on the hazard maps included in the jurisdictional annexes in Volume II, Section 9 of this plan.

Additional Data and Next Steps

A HAZUS-MH flood analysis was conducted for Rockland County using the most current and best available data including updated building and critical facility inventories, and DFIRM. For future plan updates, more accurate loss estimates can be produced by replacing the national default demographic inventory with 2010 U.S. Census data when it becomes available in the HAZUS-MH model.

Specific mitigation actions addressing improved data collection and further vulnerability analysis is included in Volume II, Section 9 of this plan.