5.1 METHODOLOGY AND TOOLS

This section describes the methodology and tools used to support the risk assessment process.

Methodology

The risk assessment process used for this Plan is consistent with the process and steps presented in FEMA 386-2, State and Local Mitigation Planning How-to-Guide, Understanding Your Risks – Identifying Hazards and Estimating Losses (FEMA, 2001). This process identifies and profiles the hazards of concern and assesses the vulnerability of assets (population, structures, critical facilities and the economy) at risk in the community. A risk assessment provides a foundation for the community's decision makers to evaluate mitigation measures that can help reduce the impacts of a hazard when one occurs (Section 6 and Section 9 of this plan).

Step 1: The first step of the risk assessment process is to identify the hazards of concern. FEMA's current regulations only require an evaluation of natural hazards. Natural hazards are natural events that threaten lives, property, and many other assets. Often, natural hazards can be predicted, where they tend to occur repeatedly in the same geographical locations because they are related to weather patterns or physical characteristics of an area.

Step 2: The next step of the risk assessment is to prepare a profile for each hazard of concern. These profiles assist communities in evaluating and comparing the hazards that can impact their area. Each type of hazard has unique characteristics that vary from event to event. That is, the impacts associated with a specific hazard can vary depending on the magnitude and location of each event (a hazard event is a specific, uninterrupted occurrence of a particular type of hazard). Further, the probability of occurrence of a hazard in a given location impacts the priority assigned to that hazard. Finally, each hazard will impact different communities in different ways, based on geography, local development, population distribution, age of buildings, and mitigation measures already implemented.

Steps 3 and 4: To understand risk, a community must evaluate what assets it possesses and which assets are exposed or vulnerable to the identified hazards of concern. Hazard profile information combined with data regarding population, demographics, general building stock, and critical facilities at risk, located in Section 4, prepares the community to develop risk scenarios and estimate potential damages and losses for each hazard.

Tools

To address the requirements of DMA 2000 and better understand potential vulnerability and losses associated with hazards of concern, the Greater Greenburgh Planning Area used standardized tools, combined with local, state, and federal data and expertise to conduct the risk assessment. Our standardized tools used to support the risk assessment are described below.

Hazards U.S. – Multi-Hazard (HAZUS-MH)

In 1997, FEMA developed a standardized model for estimating losses caused by earthquakes, known as Hazards U.S. or HAZUS. HAZUS was developed in response to the need for more effective national-, state-, and community-level planning and the need to identify areas that face the highest risk and potential for loss. HAZUS was expanded into a multi-hazard methodology, HAZUS-MH with new models for estimating potential losses from wind (hurricanes) and flood (riverine and coastal) hazards. HAZUS-MH is a Geographic Information System (GIS)-based software tool that applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide defensible

damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards. The GIS framework also supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

HAZUS-MH uses GIS technology to produce detailed maps and analytical reports that estimate a community's direct physical damage to building stock, critical facilities, transportation systems and utility systems. To generate this information, HAZUS-MH uses default HAZUS-MH provided data for inventory, vulnerability, and hazards; this default data can be supplemented with local data to provide a more refined analysis. Damage reports can include induced damage (inundation, fire, threats posed by hazardous materials and debris) and direct economic and social losses (casualties, shelter requirements, and economic impact) depending on the hazard and available local data. HAZUS-MH's open data architecture can be used to manage community GIS data in a central location. The use of this software also promotes consistency of data output now and in the future and standardization of data collection and storage. The guidance Using HAZUS-MH for Risk Assessment: How-to Guide (FEMA 433) was used to support the application of HAZUS-MH for this risk assessment and plan. More information on HAZUS-MH is available at http://www.fema.gov/plan/prevent/hazus/index.shtm.

In general, probabilistic analyses were performed to develop estimates of long-term average losses (annualized losses) as well as an expected/estimated distribution of losses (mean return period losses) for the earthquake, flood and wind hazards. The probabilistic hazard generates estimates of damage and loss for specified return periods (e.g., 100- and 500-year). For annualized losses, HAZUS-MH MR4 calculates the maximum potential annual dollar loss resulting from various return periods averaged on a "per year" basis. It is the summation of all HAZUS-supplied return periods (e.g., 10, 50, 100, 200, 500) multiplied by the return period probability (as a weighted calculation). In summary, the estimated cost of a hazard each year is calculated.

Custom methodologies in HAZUS-MH MR4 were used to assess potential exposure and losses associated with hazards of concern for the Greater Greenburgh Planning Area:

- Inventory: The default demographic data in HAZUS-MH MR4, based on the 2000 U.S. Census, was used for analysis. The valuation of general building stock and the loss estimates determined in the Planning Area were based on the default general building stock database provided in HAZUS-MH MR4. The general building stock valuations are Replacement Cost Value from RSMeans as of 2006. The critical facility inventory (essential facilities, utilities, transportation features and user-defined facilities) was updated for the earthquake, flood and wind hazard models. This comprehensive inventory was developed by gathering input from numerous sources including HAZUS-MH MR4, Westchester County GIS, participating municipalities and input from the Planning Committee.

  The 'user-defined facilities' category includes all assets that the Planning Area deemed critical to include in the inventory and that do not fit within a pre-defined HAZUS-MH facility category. These facilities include shelters, senior care facilities and municipal-owned buildings and garages. Because user-defined facilities are points in HAZUS-MH, the asset's location was either provided by the municipality or is the calculated parcel centroid of the polygon provided.

- Earthquake: A Level 2 HAZUS-MH MR4 analysis using a probabilistic scenario was performed to analyze the earthquake hazard losses for the Greater Greenburgh Planning Area (annualized losses and 100-, 500- and 2,500-year mean return period [MRP] losses). A Level 1 analysis is a basic estimate of earthquake losses based on national databases and using the default data in the model. Default demographic and general building stock data in HAZUS-MH MR4 were used for the earthquake analysis. However, as described above, updated critical facility inventories were used.

Additionally, a local soil map provided by NYSOEM was entered into HAZUS-MH MR4 to replace default soil conditions. HAZUS-MH MR4 uses the seismic soil type classes recommended by the National Earthquake Hazard Reduction Program (NEHRP). The NEHRP soils classification system ranges from A to E, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses (NYSEMO, 2004; NYCEM, 2003). When a Level 1 HAZUS-MH MR4 earthquake analysis is conducted, the NEHRP soil classification type "D" is used as the soil type across the entire study region. For this HMP, a local soil map with the Planning Area's NEHRP soil types (A, B and D) provided by NYSOEM was entered into HAZUS-MH MR4 and used for all analyses.

- Flood: The HAZUS-MH MR4 riverine model; the FEMA Digital Flood Insurance Rate Maps (DFIRMs), effective September 28, 2007; and USGS one-third ArcSecond Digital Elevation Models (DEM) (10 meter resolution) were used to estimate exposure and losses associated with the flood hazard (see Figure 5.1-1).

  HAZUS-MH MR4 was used to run the hydrology and hydraulics for the selected river reaches, using the DFIRMs as a guide, HAZUS-MH MR4 generated the flood-depth grid and flood boundary for the specified return periods (annualized losses and the 100- and 500-year MRPs) and calculated the estimated damages to the general building stock and critical facilities based on this depth grid.

- Hurricane/Wind: A modified Level 1 HAZUS-MH probabilistic analysis was performed to analyze the wind hazard losses for the Planning Area. The probabilistic hurricane hazard activates a database of thousands of potential storms that have tracks and intensities reflecting the full spectrum of Atlantic hurricanes observed since 1886 and identifies those with tracks associated with the Planning Area. Annualized losses and the 100- and 500-year MRPs were examined for the wind/severe storm hazard.

  Default demographic and general building stock data in HAZUS-MH MR4 were used for the analysis. However, as described above, updated critical facility inventories were used. For the purposes of this Plan, exposure from storm surge is included using the Sea – Lake Overland Surge from Hurricanes – SLOSH Model Model inundation areas provided by NYSOEM, however at this time, estimated losses are not reported.

- Other Hazards: HAZUS-MH support was used to evaluate other hazards (severe winter storm, extreme temperature), as feasible. For many of the hazards evaluated in this risk assessment, historic data are not adequate to model future losses at this time. However, HAZUS-MH can map hazard areas and calculate exposures if geographic information on the locations of the hazards and inventory data are available. For some of the other hazards of concern, areas and inventory susceptible to specific hazards were mapped and exposure was evaluated to help guide mitigation efforts discussed in Section 6 and Section 9. For other hazards, a qualitative analysis was conducted using the best available data and professional judgment.

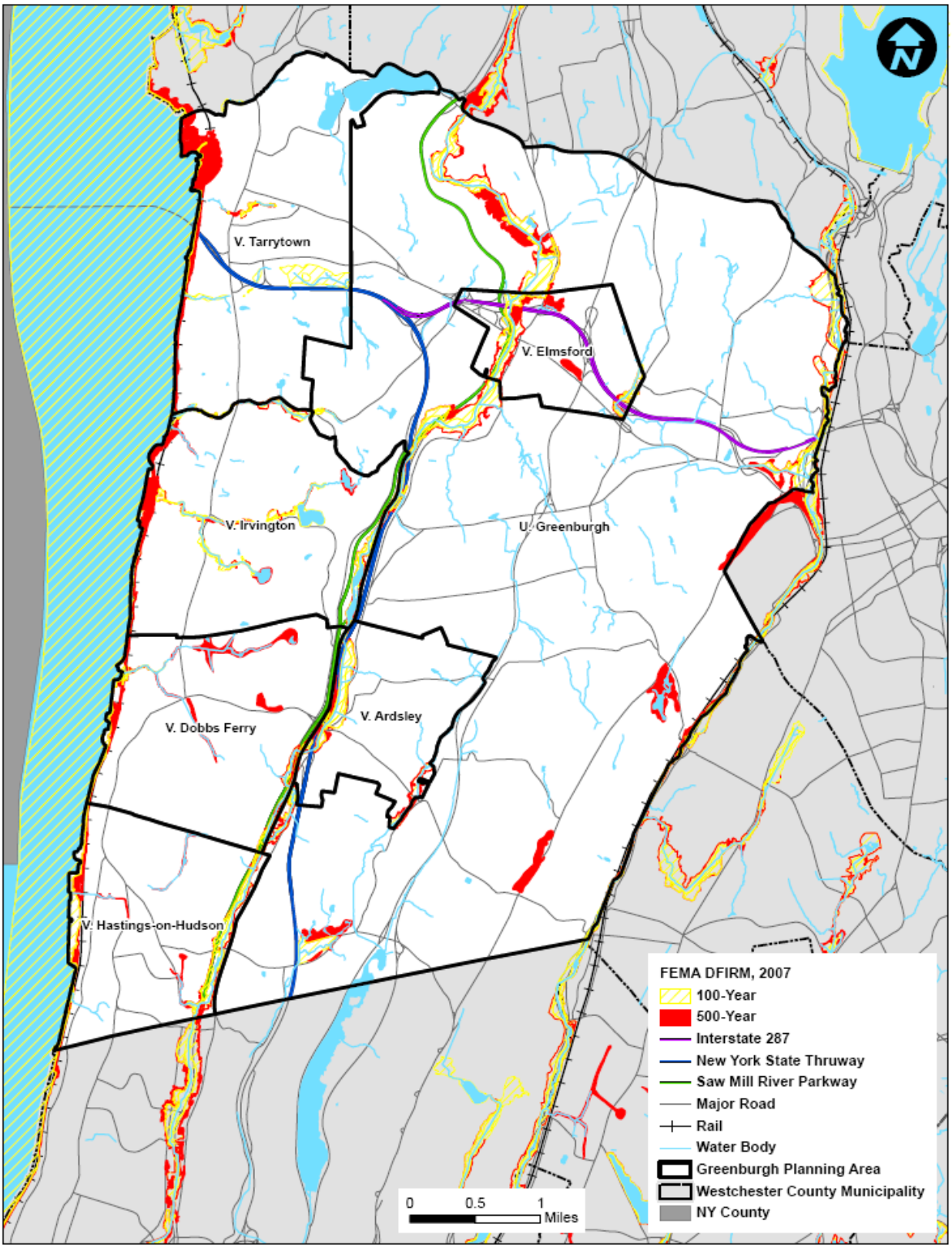
For this risk assessment, the loss estimates, exposure assessments, and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their affects on the built environment. Uncertainties also result from the following:

1) Approximations and simplifications necessary to conduct such a study
2) Incomplete or dated inventory, demographic, or economic parameter data
3) The unique nature, geographic extent, and severity of each hazard

4) Mitigation measures already employed by the participating municipalities and the amount of advance notice residents have to prepare for a specific hazard event

These factors can result in a range of uncertainty in loss estimates, possibly by a factor of two or more. Therefore, potential exposure and loss estimates are approximate. These results do not predict precise results and should be used to understand relative risk. Over the long term, the Greater Greenburgh Planning Area will collect additional data to assist in developing refined estimates of vulnerabilities to natural and non-natural hazards.

Figure 5.1-1. 100- and 500-Year Regulatory Floodplains within the Greater Greenburgh Planning Area



Source: FEMA DFIRM, 2007

5.2 IDENTIFICATION OF HAZARDS OF CONCERN

Hazards of Concern is defined as those hazards that are considered most likely to impact a community. These are identified using available data and local knowledge.

To provide a strong foundation for mitigation strategies considered in Section 6, the Town of Greenburgh and the Villages of Ardsley, Dobbs Ferry, Elmsford, Hastings-on-Hudson, Irvington, and Tarrytown in Westchester County, focused on considering a full range of hazards that could impact the area, and then identified and ranked those hazards that presented the greatest concern. The hazard of concern identification process incorporated input from the Greater Greenburgh Planning Area; review of the 2008 New York State Hazard Mitigation Plan (NYS HMP) and previous hazard identification efforts; research and local, state, and federal information on the frequency, magnitude, and costs associated with the various hazards that have previously, or could feasibly, impact the region; and qualitative or anecdotal information regarding natural hazards and the perceived vulnerability of the study area's assets to them. Table 5.2-1 documents the process of identifying the natural hazards of concern, and one man-made hazard of concern (transportation), for further profiling and evaluation.

For the purposes of this planning effort, the Planning Committee chose to group some natural hazards together, based on the similarity of hazard events, their typical concurrence or their impacts, consideration of how hazards have been grouped in Federal Emergency Management Agency (FEMA) guidance documents (FEMA 386-1, "Understanding Your Risks, Identifying Hazards and Estimating Losses; FEMA's "Multi-Hazard Identification and Risk Assessment – The Cornerstone of the National Mitigation Strategy"), and consideration of hazard grouping in the NYS HMP.

The "Flood" hazard includes riverine flooding, flash flooding, ice jam flooding, and dam failure flooding (overtopping or breaching from natural causes). Other types of flooding such as coastal or urban drainage do not generally occur within the township; therefore, they were not further considered for inclusion within this HMP. Inclusion of the various forms of flooding under a general "Flood" hazard is consistent with that used in FEMA's "Multi-Hazard Identification and Risk Assessment" guidance.

The "Severe Storm" hazard includes windstorms that often entail a variety of other influencing weather conditions including thunderstorms, hail, and tornadoes. While there is no history of the Town or Westchester County experiencing a full-force hurricane, residual tropical storms and depressions do impact the area as severe storm events and thus have also been included under this hazard category.

The "Severe Winter Storm" hazard includes heavy snow, blizzards, sleet, freezing rain, ice storms and Nor'Easters.

These groupings do not change the definition of the included specific events/hazards, as defined within FEMA guidance and other risk assessment documents, and does not affect the hazard analysis conducted through the use of HAZUS-MH, either directly or as a risk assessment support tool.

Due to the limited availability of budget resources, this mitigation planning effort has, at least initially, evaluated five natural hazards (earthquake, flood, severe storm, severe winter storm, and extreme temperature) and one man-made hazard (transportation hazards). The Planning Area may attempt to expand the scope of this HMP to include other less frequent natural hazards and/or additional technological and man-made (for example, terrorism, man-made dam breaches/failures) hazards as resources permit.

Table 5.2-1. Identification of Hazards of Concern for the Greater Greenburgh Planning Area, New York

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
Avalanche	No	No	• The NYS HMP does not identify avalanche as a hazard of concern for New York State. • The topography and climate of the Greater Greenburgh Planning Area does not readily support the occurrence of an avalanche event. • New York State in general has a very low occurrence of avalanche events based on statistics provided by National Avalanche Center – American Avalanche Association (NAC-AAA) between 1950 and 2006.	• NYSDPC • Review of NAC-AAA database between 1950 and 2006
Coastal Erosion / Coastal Storm	No	No	• The NYS HMP does not identify the Greater Greenburgh Planning Area as a Coastal Erosion Hazard Areas Communities within Westchester County. • The Planning Area is not bounded by coastal waters; therefore, not directly impacted by coastal storms that result in coastal erosion.	• NYSDPC
Drought	Yes	No	• The NYS HMP identifies drought and extreme heat events as hazards of concern for New York State. The NYS HMP indicated that Westchester County was impacted by drought between November 2001 and January 2002. • According to the NYSDEC, Westchester County is located in Drought Management Region IIA (New York City/Westchester). According to the NRCC, Westchester County is located in the Hudson Valley Climate Division and has experienced the following drought periods: o November 1908 – January 1909 o November – December 1909 o October 1910 – January 1911 o December 1930 – January 1931 o October 1941 – February 1942 o April – May 1942 o October – December 1949 o August – November 1957 o October – December 1963 o May 1964 – September 1966 o January – February 1967 o April – May 1985 o August – September 1995 o December 2001 – February 2002	• NYSDPC • NYSDEC • Westchester County Government • NYSEMO CEMP • USGS • NOAA-NCDC • Drought Reporter • SHELDUS • U.S. Drought Monitor Archive

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			• While there is historical record of drought events in the Greater Greenburgh Planning Area and Westchester County, there is very little evidence of significant impacts (human, structural, economic) resulting from these events. Further, these risks are properly managed through preparedness and response. Mitigation opportunities are limited or are being addressed along with other hazards and their resulting impacts. The County and Planning Area have experienced several major droughts which have impacted both the residential and business communities. Even with significant improvement to the water supply systems, the possibility of shortfalls or water emergencies always exists. • The Planning Committee identified drought as a low ranked hazard affecting the Greater Greenburgh Planning Area.	
Earthquake	Yes	Yes	• The NYS HMP identifies earthquake as a hazard of concern for New York State. • According to the NGDC, New York State has only had eight significant* earthquakes between 1823 and 2002. • NYCEM indicates that no earthquakes have taken place in or immediately surrounding the Greater Greenburgh Planning Area between 1730 and 2002. However, NY-NJ-CT Metro region, which includes Westchester County, does have a *low hazard / high risk* earthquake potential with its dense population, vulnerable infrastructure and substantial economic value. • According to the USGS online seismic hazard maps, the peak ground acceleration with a 10-percent probability of exceedance over 50 years for Westchester County is between 3 and 4 %g. FEMA guidance recommends earthquakes be evaluated further if an area has a 3 %g peak acceleration or more.	• NYSDPC • NOAA – Review of NGDC Earthquake Database from 1800 to present • NYCEM • USGS – Earthquake Hazards Program, Review of USGS Seismic Maps
Expansive Soils	No	No	• The NYS HMP identifies expansive soils as a hazard of concern for New York State. • USGS indicated that Westchester County has little or no clays with swelling potential with some locations having generally less than 50-percent of clay, having slight to moderate swelling potential that could result in expansive or swelling soils. • Based on all sources reviewed, no known historical occurrences are reported for the Greater Greenburgh Planning Area.	• NYSDPC • Review of USGS 1989 Swelling Clays Map of the Conterminous United States.

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
Extreme Temperature	Yes	Yes	Please see Severe Winter Storms for Extreme Cold Events	
Flood (Riverine, Flash, Stormwater, Ice Jam and Dam Failure Flooding [overtopping or breaching from natural causes])	Yes	Yes	• The NYS HMP identifies flooding as the main hazard of concern for New York State. • The NYS HMP, NYSEMO, FEMA, SHELDUS and USGS indicate that Westchester County has been issued nine FEMA Disaster Declarations for flood-related events, each event resulting in extensive damages. o **FEMA DR-311** (September 1971) - Westchester County experienced approximately $29 K in property and crop damages. o **FEMA DR-487** (Hurricane Eloise) (September 1975) - Losses in Westchester County are unknown. o **FEMA DR-702** (April 1984) - Losses in Westchester County are unknown. o **FEMA DR-974** (December 1992 Nor'Easter) - Westchester County received between 8 and 11 inches of rain, experiencing $7.1 M in flood damages. Over 20,000 power failures occurred throughout the County. o **FEMA DR-1146** (October 1996) – Coastal flooding event that caused over $16.1 M in property damages throughout Westchester and Suffolk Counties. Rainfall totals in Westchester County ranged from 2.37 inches at Ossining to 4.98 inches at the Village of Dobbs Ferry. o **FEMA DR-1589** (April 2005) - Westchester County experienced $4.3 M in property damages. o **FEMA DR-1650** (June-July, 2006) – Losses in Westchester County are unknown. o **FEMA DR-1692** (April 2007 Nor'Easter) - Flooding and coastal erosion, debris, damage to residential and commercial structures, utility lines, roads and other infrastructure throughout New York State. FEMA gave out more than $61 M in assistance to affected counties within the State. Losses in Westchester County are unknown; however, disaster assistance to the County totaled $30 M as of July 23, 2007. o **FEMA DR-1899** (March 2010) (Severe Storms and Flooding) - Caused seven deaths in Northeast U.S. and more than 300,000 customers were without power. Hurricane-force winds knocked down trees and power lines. Heavy rain caused flooding across the region. Con Ed reported that more than 86,000 customers were without power in New York City and	• NYSDPC • NYSEMO • FEMA • Hazards & Vulnerability Research Institute (SHELDUS) • NOAA-NCDC • NPDP • NYS DEP • NFIP • Westchester County GIS System

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			Westchester County. Wind speeds reached 75 mph at JFK airport in New York City and 72 mph winds were reported in Atlantic City. In Westchester County, schools were closed. The Town of Greenburgh was one of the hardest hit areas in the County. • NOAA's NCDC storm events database indicates that Westchester County was impacted by approximately 108 flood events between 1950 and 2010. • The 2008 NYS HMP indicated that Westchester County has been ranked as the 4th most flood vulnerable county in New York State based on potential flood exposure and vulnerability to loss. Over 11-percent of the County is located in a 100-year floodplain. • The NYS HMP and SHELDUS indicated that other undeclared flood events within County took place in June 1973 ($38 M in losses), September 1974, July 1975, January 1976, November 1977 ($833 K in losses), May 1979 ($1.3 M in losses) May 1984 ($2.4 M in losses) August 1990 ($3.5 M in losses). • NFIP identifies that the Greater Greenburgh Planning Area has made ~740 flood claims as of November 2009, receiving ~$9.4MM in total payments. • Ice Jams are mentioned separately in this Table but are grouped with the Flood hazard in this plan (see below).	
Hailstorm	Yes	Yes	Please see Severe Storm	
Hurricane (and other Tropical Cyclones)	Yes	Yes	Please see Severe Storm	
Ice Jams (categorized as a Flood hazard in this HMP)	No	No	• The NYS HMP does identify ice jam flooding as a hazard of concern for New York State (grouped as a type of flood). New York State ranks 2nd in the U.S. for total number of ice jam events, with 1,435 ice jam events between 1867 and 2007; however, no ice jams have occurred in Westchester County. • According to the USACE CRREL Ice Jam Database, there have been no reported ice jam events in Westchester County between 1857 and 2010.	• NYSDPC • Review of USACE CRREL Ice Jam Database
Ice Storm	Yes	Yes	Please see Severe Winter Storm	
Infestation	No	No	• The NYS HMP does not identify infestation as a hazard of concern for New York State.	• NYSDPC

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			• Based on all sources reviewed, no known significant occurrences are reported for the Greater Greenburgh Planning Area.	
Land Subsidence	No	No	• The NYS HMP indicates that New York State is vulnerable to land subsidence; however, this hazard is "extremely localized" and poses a "very low risk to population and property." The NYS HMP does not identify Westchester County as a community that has experienced land subsidence in the past. • According to USGS, Westchester County is not made up of unconsolidated aquifer systems, creating the unlikelihood of permanent subsidence and related ground failures.	• NYSDPC • USGS Fact Sheet 165-00 (Dec. 2000)
Landslide	No	No	• The NYS HMP does identify landslide as a hazard of concern for New York State, with most of Westchester County located in a low landslide incidence area. The NYS HMP indicates that Westchester County has had 11 landslide occurrences from 1837 to 2007. The NYS HMP listed Westchester County as the 12th county in the State most threatened by and vulnerable to landslides and landslide losses. • USGS indicates through the National Atlas Map Maker program Greater Greenburgh Planning Area has a low landslide incidence.	• NYSDPC • National Atlas.gov (USGS)
Nor'Easters (and other extra-tropical storms)	Yes	Yes	Please see Severe Winter Storm	
Severe Storm (Windstorms, Thunderstorms, Hail, Lightning, Tornados and Hurricanes)	Yes	Yes	• The NYS HMP does identify all types of severe storms as hazards of concern for New York State. Westchester County is identified as a high risk area for tornadoes and has experienced eight tornado events. NYS HMP listed Westchester County as the 8th county in the State most threatened by and vulnerable to extreme wind and wind losses. • The NYS HMP, NYSEMO, and FEMA indicate that Westchester County has been issued 11 FEMA Disaster Declarations for severe storm events, some also identified as flooding events. Losses and details regarding each of these events that were also identified as flooding events are discussed in 'Flood' above. o **FEMA DR-311** (September 1971) (Severe Storms/Flooding) o **FEMA DR-338** (June 1972) (Tropical Storm Agnes)	• NYSDPC • FEMA • Hazards & Vulnerability Research Institute (SHELDUS) • NOAA-NCDC

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			○ **FEMA DR-487** (September 1975) (Severe Storms, Heavy Rain, Landslides, Flooding) ○ **FEMA DR-702** (April 1984) (Coastal Storms/Flooding) ○ **FEMA DR-974** (December 1992) (Coastal Storm, High Tides, Heavy Rain, Flooding) ○ **FEMA DR-1146** (October 1996) (Severe Storms/Flooding) ○ **FEMA DR-1296** (September 1999) (Tropical Storm Floyd) ○ **FEMA DR-1589** (April 2005) (Severe Storms and Flooding) ○ **FEMA DR-1650** (June-July, 2006) (Severe Storms and Flooding) ○ **FEMA DR-1692** (April 2007) (Severe Storms and Inland and Coastal Flooding) ○ **FEMA DR-1899** (March 2010) (Severe Storms and Flooding) • Other severe storm events that specifically impacted the Town and Villages, include, but are not limited to: ○ July 10, 2001 (TSTM/Hail) – Village of Elmsford – A TSTM produced dime-size hail in the Village. ○ July 9, 2002 (Hail) – Village of Ardsley – Nickel-sized hail fell in the Village. ○ August 2, 2002 (TSTM/Wind) – Village of Dobbs Ferry – Winds from a TSTM knocked down a large tree in the Village. • NOAA's NCDC storm events database indicates that Westchester County was impacted by approximately 285 severe storm events between 1950 and 2010.	
Severe Winter Storm (Heavy Snow, Blizzards, Freezing Rain/Sleet, Ice Storms, Nor'Easters and Extreme Cold)	Yes	Yes	• The NYS HMP does identify all types of severe winter storms as hazards of concern for New York State. The NYSDPC and NYSEMO listed Westchester County as the 22nd County in the State most threatened by and vulnerable to snow and snow loss, with an annual average snowfall 32.3 inches. Westchester County is also listed as the 31st County in New York State most threatened by and vulnerable to ice storms and ice storm loss. • Westchester County was declared a disaster areas for three FEMA Disaster Declarations (DR) or Emergencies (EM) for severe storm events, including: ○ **FEMA DR-974** (December 1992 Nor'Easter) - Westchester County received between 8 and 11 inches of rain, experiencing $7.1 M in flood damages. Over 20,000 power failures occurred throughout the County. ○ **FEMA EM-3107** (March 1993 Blizzard) – Westchester County received	• NYSDPC • NYSEMO • FEMA • NOAA-NCDC • Hazards & Vulnerability Research Institute (SHELDUS) • Kocin and Uccellini • The Weather

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			between 10 and 20 inches of snow. Specific totals ranged from 13 inches in the City of Yonkers to 16.5 inches in Croton Falls. ○ **FEMA DR-1083** (January 1996 Blizzard) – 21 inches of snow fell in New York City. Wind gusts reached more than 50 mph. ○ **FEMA EM-3184** (February 2003 Snowstorm) – Almost two feet of snow fell in the New York City area. Westchester County had between 14.5 inches and 26 inches of snow and had approximately $1.8 M in damages. ○ **FEMA DR-1692** (April 2007 Nor'Easter) – Rainfall totals in Westchester County ranged from 5.85 inches to 8.22 inches. The County had over $83 M in property damage. • Various sources indicated that many other severe winter storm events impacted Westchester County, including, but not limited to: ○ February 1961 (Snowstorm) - Westchester County received between 20 and 30 inches of snow from this even and experienced approximately $80 K in property damages. ○ January 1983 (Record Snowstorm) - Created $238 K in property damages in Westchester County. ○ February 1983 (Sleet/Ice) - Created $27 M in property damages throughout the State. ○ April 1983 (Snow) - Created $238 K in property damages in Westchester County. ○ February 1984 (Freezing Rain) - Created $238 K in property damages in Westchester County. • The Town of Greenburgh, and the Villages Tarrytown, Irvington, Dobbs Ferry, Hastings-on-Hudson, Ardsley and Elmsford have been impacted by many extreme cold events, including: ○ December 1950 (Town of Greenburgh) – Record low temerpature of -5° F. ○ January 1961 (Town of Greenburgh) – Record low temperature of -10° F. ○ February 1963 (Villages of Tarrytown, Irvington, Dobbs Ferry, Hastings-on-Hudson, Ardsley, Elmsford) – Record low temperature of -5° F. ○ March 1967 (Town of Greenburgh) – Record low temperature of -3° F. ○ February 1979 (Town of Greenburgh) – Record low temperature of -14° F. ○ December 1980 (Villages of Tarrytown, Irvington, Dobbs Ferry, Hastings-on-Hudson, Ardsley, Elmsford) – Record low temperature of -4° F.	Channel

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			○ November 1989 (Town of Greenburgh, Villages of Tarrytown, Irvington, Dobbs Ferry, Hastings-on-Hudson, Ardsley, Elmsford) – Record low temperature of 12° F. ○ January 1994 (Villages of Tarrytown, Irvington, Dobbs Ferry, Hastings-on-Hudson, Ardsley, Elmsford) – Record low temperature of -10° F. ○ March 2003 (Villages of Tarrytown, Irvington, Dobbs Ferry, Hastings-on-Hudson, Ardsley, Elmsford) – Record low temperature of 2° F. • NOAA's NCDC storm events database indicates that Westchester County was impacted by approximately 63 winter storm events and six extreme cold / windchill events between 1950 and 2010. However, most events are of a regional extent rather then localized to just one county.	
Transportation	Yes	Yes	• The Greater Greenburgh Planning Area does not lie within the take-off and approach pattern of the Westchester County Airport; however, due to the Planning Area's proximity to the airport, however, the Planning Area is still exposed to some risk. • Flood-prone roads identified in the Planning Area: ○ Town of Greenburgh • West Hartsdale Road • Washington Place • Stadium Road • Jackson, Old Jackson and Sprain Avenue • Route 9A in the area of Beaver Hill • East Hartsdale Avenue • Hartsdale Brook in vicinity of East Hartsdale Avenue • Babbitt Court • Knollwood Road ○ Village of Ardsley • Ashford Avenue Bridge over NYS Thruway and Saw Mill Parkway • Intersection of Sprain Brook and Cross Roads • Route 9A just north of Revolutionary Road • King Street ○ Village of Dobbs Ferry	• NYSDEC • Planning Committee

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			• Beacon Hill Drive and Ashford Avenue • Washington Avenue o Village of Elmsford • Routes 119 and 9A • Alma Place and Woodside Avenue • Route 119, Old Road and Robbins Avenue intersection o Village of Irvington • Intersection of East Sunnyside Lane and Hudson View Park • East of the intersection of South Buckhout Street and South Astor Street • Station Road • Between Station Road and Dows Lane • Harriman Road between Parkside Way and Dunham Place o Village of Tarrytown • Sunnyside Lane area (bordering both the Villages of Tarrytown and Irvington) • Neperan Road adjacent to Tarrytown Lakes (Skate Shack) • Benedict Avenue • There are four main roads identified as truck routes, high traffic roads and/or roads in which HAZMAT is transported • According to the New York State Department of Environmental Conservation (NYSDEC) – Spill Incident Database (1978 – 2010), 102 HAZMAT spills have occurred in the Greater Greenburgh Planning Area.	
Tornado	Yes	Yes	Please see Severe Storm	
Tsunami	No	No	• Tsunami is not identified as a hazard of concern in the NYS HMP.	• NYSDPC
Volcano	No	No	• Volcanoes are not identified as a hazard of concern in the NYS HMP, because there are no known volcanoes located in the state.	• NYSDPC
Wildfire	No	No	• The NYS HMP does identify wildfires as hazards of concern for New York State. • Low reported incidences of wildfires within Westchester County. • The NWPD indicates that no records of wildfire incidences have been recorded	• NYSDPC • NWPD • GeoMAC • USGS

Hazard	Step 1	Step 2	Step 3	
	Is this a hazard that may occur in the Greater Greenburgh Planning Area?	If yes, does this hazard pose a significant threat to the Greater Greenburgh Planning Area?	Why was this determination made?	Source(s)
			for Westchester County. • GeoMac indicates that all of the Greater Greenburgh Planning Area is located within the Wildland-Urban Interface. However, no wildfires were experienced in the Planning Area between 2001 and 2010. • USGS indicates that no wildfires greater than 250 acres were experienced in the Greater Greenburgh Planning Area between 1980 and 2003. • NOAA's NCDC storm events database indicates that between 1950 and 2010, Westchester County was not experienced any wildfire events.	• NOAA-NCDC
Windstorm	Yes	Yes	Please see Severe Storm	

Note (1): A significant earthquake defined by NGDC is an earthquake that presented at least one of the following criteria: moderate damage (approximately $1 million or more); 10 or more deaths; magnitude 7.5 or greater; MMI X or higher; or an earthquake caused by a tsunami.

AAA	American Avalanche Association
CRREL	Cold Regions Research and Engineering Laboratory
CT	Connecticut
DR	Presidential Disaster Declaration Number
EM	Presidential Emergency Declaration
FEMA	Federal Emergency Management Agency
GeoMAC	Geospatial Multi-Agency Coordination
HMP	Hazard Mitigation Plan
K	Thousand ($)
M	Million ($)
NAC	National Avalanche Center
NCDC	National Climatic Data Center
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NPDP	National Performance of Dams Program
NWPD	National Wildfire Programs Database
NYCEM	New York City Area Consortium For Earthquake Loss Mitigation
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDPC	New York State Disaster Preparedness Commission
NYSEMO	New York State Emergency Management Office
SHELDUS	Spatial Hazard Events and Losses Database for the U.S.
TSTM	Thunderstorm
U.S.	United States
USACE	U.S. Army Corp of Engineers
USGS	U.S. Geologic Survey

According to input from the Greater Greenburgh Planning Area, and review of all available resources, a total of six hazards of concern (five natural and one man-made) were identified as significant hazards affecting the Planning Area, to be addressed within this plan:

- Earthquake
- Extreme Temperatures
- Flood (riverine, flash, stormwater, ice jam and dam failure)
- Severe Storm (windstorms, thunderstorms, hail, tornadoes and hurricanes/tropical storms)
- Severe Winter Storm (heavy snow, blizzards, ice storms, Nor'Easters)
- Transportation Hazards (vehicular accidents, HAZMAT in transit, aviation accidents, at-grade railroad crossings, and flood vulnerable roadways)

Other natural hazards of concern have occurred within the Planning Area, but typically have a low potential to result in significant impacts within the Planning Area. The Greater Greenburgh Planning Area deemed these hazards as minor in comparison to those bulleted above; therefore, these hazards will not be further addressed within this version of the Plan. However, if deemed necessary by the Planning Area, these hazards may be considered in future versions of the Plan.

5.3 HAZARD RANKING

After the hazards of concern were identified for the Greater Greenburgh Planning Area, the hazards were ranked to describe their probability of occurrence and their impact on population, property (general building stock including critical facilities) and the economy. Each participating Town or Village may have differing degrees of risk exposure and vulnerability compared to the Planning Area as a whole; therefore each Town or Village ranked the degree of risk to each hazard as it pertains to their community using the same methodology as applied to the Planning Area-wide ranking. This assures consistency in the overall ranking of risk process. The hazard ranking for each participating Town or Village can be found in their jurisdictional annex in Volume II of this Plan.

HAZARD RANKING METHODOLOGY

The methodology used to rank the hazards of concern for the Greater Greenburgh Planning Area is described below. Estimates of risk for the Planning Area were developed using methodologies promoted by FEMA's hazard mitigation planning guidance and generated by FEMA's HAZUS-MH risk assessment tool.

Probability of Occurrence

The probability of occurrence is an estimate of how often a hazard event occurs. A review of historic events assists with this determination. Each hazard of concern is rated in accordance with the numerical ratings and definitions in Table 5.3-1.

Table 5.3-1. Probability of Occurrence Ranking Factors

Rating	Probability	Definition
0	None	Hazard event is not likely to occur
1	Rare	Hazard event is not likely to occur within 100 years
2	Occasional	Hazard event is likely to occur within 100 years
3	Frequent	Hazard event is likely to occur within 25 years

Impact

The impact of each hazard is considered in three categories: impact on population, impact on property (general building stock including critical facilities), and impact on the economy. Based on documented historic losses and a subjective assessment by the Planning Committee, an impact rating of high, medium, or low is assigned with a corresponding numeric value for each hazard of concern. In addition, a weighting factor is assigned to each impact category: three (3) for population, two (2) for property, and one (1) for economy. This gives the impact on population the greatest weight in evaluating the impact of a hazard.

Table 5.3-2 presents the numerical rating, weighted factor and description for each impact category. The impact rating definitions for population and property are consistent with the New York State Hazard Mitigation Plan (NYS HMP) ranking methodology with minor modifications. Impact to the economy is also being evaluated.

Table 5.3-2. Numerical Values and Definitions for Impacts on Population, Property and Economy

Category	Weighting Factor	Low Impact (1)	Medium Impact (2)	High Impact (3)
Population*	3	14% or less of your developed land area is exposed to a hazard due to its extent and location	15% to 29% of your developed land area is exposed to a hazard due to its extent and location	30% or more of your developed land area is exposed to a hazard due to its extent and location
Property*	2	Property exposure is 14% or less of the total replacement cost for your community	Property exposure is 15% to 29% of the total replacement for your community	Property exposure is 30% or more of the total replacement cost for your community
Economy	1	Loss estimate is 9% or less of the total replacement cost for your community	Loss estimate is 10% to 19% of the total replacement cost for your community	Loss estimate is 20% or more of the total replacement cost for your community

Note: A numerical value of zero is assigned if there is no impact.
*For the purposes of this exercise, "impacted" means exposed for population and property and loss for economy.

Risk Ranking Value

The risk ranking for each hazard is then calculated by multiplying the numerical value for probability of occurrence by the sum of the numerical values for impact. The equation is as follows: Impact Value (1, 2, or 3) X Impact Value (6 to 18) = Hazard Ranking Value. Based on the total for each hazard, a priority ranking is assigned to each hazard of concern (high, medium, or low).

HAZARD RANKING RESULTS

Using the process described above, the risk ranking for the identified hazards of concern was determined for the Greater Greenburgh Planning Area. Based on the combined risk values for probability of occurrence and impact to the Planning Area, a priority ranking of "high", "medium" or "low" risk was assigned. The hazard ranking for the Planning Area, from high to low risk, is summarized below:

1. Severe Storm
2. Flood / Severe Winter Storm
3. Extreme Temperature
4. Transportation
5. Earthquake

The following tables present the step-wise process for the ranking. Table 5.3-3 shows the probability ranking assigned for likelihood of occurrence for each hazard.

Table 5.3-3. Probability of Occurrence Ranking for Hazards of Concern for the Greater Greenburgh Planning Area

Hazard of Concern	Probability	Numeric Value
Earthquake	Rare	1
Extreme Temperature	Frequent	3
Flood	Frequent	3
Severe Storm	Frequent	3
Severe Winter Storm	Frequent	3
Transportation	Frequent	3

Table 5.3-4 shows the impact evaluation results for each hazard of concern, including impact on property, structures, and the economy. The weighting factor results and a total impact for each hazard also are summarized.

Table 5.3-4. Impact Ranking for Hazards of Concern for the Greater Greenburgh Planning Area

Hazard of Concern	Population			Property			Economy			Total Impact Rating (Population + Property + Economy)
	Impact	Numeric Value	Multiplied by Weighting Factor (3)	Impact	Numeric Value	Multiplied by Weighting Factor (2)	Impact	Numeric Value	Multiplied by Weighting Factor (1)	
Earthquake	High	3	3 x 3 = 9	High	3	3 x 2 = 6	Low	1	1 x 1 = 1	16
Extreme Temperature	High	3	3 x 3 = 9	Low	1	1 x 2 = 2	Low	1	1 x 1 = 1	12
Flood	High	3	3 x 3 = 9	Medium	2	2 x 2 = 4	Medium	2	2 x 1 = 2	15
Severe Storm	High	3	3 x 3 = 9	High	3	3 x 2 = 6	Medium	2	2 x 1 = 2	17
Severe Winter Storm	High	3	3 x 3 = 9	Medium	2	2 x 2 = 4	Medium	2	2 x 1 = 2	15
Transportation	Low	1	1 x 3 = 3	Low	1	1 x 2 = 2	Low	1	1 x 1 = 1	6

Table 5.3-5 presents the total ranking value for each hazard.

Table 5.3-5. Total Risk Ranking Value for Hazards of Concern for the Greater Greenburgh Planning Area

Hazard of Concern	Probability	Impact	Total = (Probability x Impact)
Earthquake	1	16	16
Extreme Temperature	3	12	36
Flood	3	15	45
Severe Storm	3	17	51
Severe Winter Storm	3	15	45
Transportation	3	6	18

Table 5.3-6 presents the hazard ranking category assigned for each hazard of concern. The ranking categories are determined by an evaluation of the total risk ranking score into three categories, low, medium, and high whereby a total score of below 20 is categorized as low, 21 to 40 is medium, and 41 and over is considered a high risk category.

Table 5.3-6. Hazard Ranking Results for Hazards of Concern for the Greater Greenburgh Planning Area

Hazard Ranking	Hazard of Concern	Category
5	Earthquake	Low
3	Extreme Temperature	Medium
2	Flood	High
1	Severe Storm	High
2	Severe Winter Storm	High
4	Transportation	Low

On the following Table 5.3-7 summarizes the hazards ranking by jurisdiction. These rankings have been used as one of the bases for identifying the jurisdictional hazard mitigation strategies included in Section 9 of this plan.

Table 5.3-7. Summary of Overall Ranking of Natural Hazards by Jurisdiction

Activity	Unincorporated Greenburgh	Village of Ardsley	Village of Dobbs Ferry	Village of Elmsford	Village of Hastings-on-Hudson	Village of Irvington	Village of Tarrytown
Earthquake	L	L	L	L	L	L	L
Extreme Temperature	M	M	M	M	M	M	M
Flood	M	M	M	H	M	M	M
Severe Winter Storm	H	H	H	H	H	H	H
Severe Storm	H	H	H	H	H	H	H
Transportation	L	L	L	L	L	L	L

Note(s): H = High; M = Medium; L = Low

HAZARDS PROFILES AND VULNERABILITY ASSESSMENT

The following sections profile and assess vulnerability for each hazard of concern. For each hazard, the profile includes: the hazard description; its location and extent; previous occurrences and losses; and the probability of future events. The vulnerability assessment for each hazard includes: an overview of vulnerability; the data and methodology used; the impact on life, health and safety; impact on general building stock; impact on critical facilities; impact on the economy; additional data needs and next steps; and the overall vulnerability assessment finding. Hazards are presented as listed above, starting with the severe storm hazard and ending with the earthquake hazard.