5.4.2 Earthquake

This section provides a profile and vulnerability assessment for the earthquake hazard.

5.4.2.1 Hazard Profile

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

Description

An earthquake is the sudden movement of the Earth's surface caused by the release of stress accumulated within or along the edge of the Earth's tectonic plates, a volcanic eruption, or by a manmade explosion (Federal Emergency Management Agency [FEMA] 2001; Shedlock and Pakiser 1995). Most earthquakes occur at the boundaries where the Earth's tectonic plates meet (faults); less than 10 percent of earthquakes occur within plate interiors. As plates continue to move and plate boundaries change geologically over time, weakened boundary regions become part of the interiors of the plates. These zones of weakness within the continents can cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust (Shedlock and Pakiser 1995).

The location of an earthquake is commonly described by its focal depth and the geographic position of its epicenter. Focal depth of an earthquake is depth from earth's surface to the region where an earthquake's energy originates (the focus or hypocenter). The epicenter of an earthquake is the point on the earth's surface directly above the hypocenter (Shedlock and Pakiser 1997). Earthquakes usually occur without warning, and their effects can impact areas a great distance from the epicenter (FEMA 2001).

According to the U.S. Geological Society (USGS) Earthquake Hazards Program, an earthquake hazard is any disruption associated with an earthquake that may affect residents' normal activities. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches; each of these terms is defined below:

- *Surface faulting*: Displacement that reaches the earth's surface during a slip along a fault. Commonly occurs with shallow earthquakes—those with an epicenter less than 20 kilometers.
- *Ground motion (shaking):* The movement of the earth's surface from earthquakes or explosions. Ground motion or shaking is produced by waves that are generated by a sudden slip on a fault or sudden pressure at the explosive source and travel through the Earth and along its surface.
- *Landslide*: A movement of surface material down a slope.
- *Liquefaction*: A process by which water-saturated sediment temporarily loses strength and acts as a fluid, like the wet sand near the water at the beach. Earthquake shaking can cause this effect. Liquefaction susceptibility is determined by the geological history, depositional setting, and topographic position of the soil. Liquefaction effects may occur along the shorelines of the ocean, rivers, and lakes and they can also happen in low-lying areas away from water bodies in locations where the ground water is near the earth's surface.
- *Tectonic Deformation*: A change in the original shape of a material caused by stress and strain.
- *Tsunami*: A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major sub-marine slides, or exploding volcanic islands.
- *Seiche*: The sloshing of a closed body of water, such as a lake or bay, from earthquake shaking (USGS 2012a).

Extent

An earthquake's magnitude and intensity are used to describe the size and severity of the event. Magnitude describes the size at the focus of an earthquake and intensity describes the overall felt severity of shaking during the event. The earthquake's magnitude is a measure of the energy released at the source of the earthquake. Magnitude was formerly expressed by ratings on the Richter scale but is now most commonly expressed using the moment magnitude (Mw) scale. This scale is based on the total moment release of the earthquake (the product of the distance a fault moved, and the force required to move it). The scale is as follows:

- Great Mw > 8
- Major Mw = 7.0 – 7.9
- Strong Mw = 6.0 – 6.9
- Moderate Mw = 5.0 – 5.9
- Light Mw = 4.0 – 4.9
- Minor Mw = 3.0 – 3.9
- Micro Mw = 3.0 – 3.9

The most commonly used intensity scale is the modified Mercalli intensity scale. Ratings of the scale, as well as the perceived shaking and damage potential for structures, are shown in Table 5.4.2-1. The modified Mercalli intensity scale is generally represented visually using shake maps, which show the expected ground shaking at any given location produced by an earthquake with a specified magnitude and epicenter. An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region. This shaking depends on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. A USGS shake map shows the variation of ground shaking in a region immediately following significant earthquakes. Table 5.4.2-2 displays the MMI scale and its relationship to the area's peak ground acceleration.

Table 5.4.2-1. Modified Mercalli Intensity Scale

Mercalli Intensity	Shaking	Description
I	Not Felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very Strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Source: USGS 2016c

Table 5.4.2-2 Modified Mercalli Intensity and PGA Equivalents

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< 0.17	Not Felt	None
II	0.17–1.4	Weak	None
III	0.17–1.4	Weak	None
IV	1.4–3.9	Light	None
V	3.9–9.2	Moderate	Very Light
VI	9.2–18	Strong	Light
VII	18–34	Very Strong	Moderate
VIII	34–65	Severe	Moderate to Heavy
IX	65–124	Violent	Heavy
X	>124	Extreme	Very Heavy

Source: Freeman et al. (Purdue University) 2004
Note: PGA Peak Ground Acceleration

The ground experiences acceleration as it shakes during an earthquake. The peak ground acceleration (PGA) is a measure of how hard the earth shakes in a given geographic area. It is expressed as a percentage of the acceleration due to gravity (percent g). Horizontal and vertical PGA varies with soil or rock type. An earthquake hazard assessment involves estimating the annual probability that certain ground accelerations will be exceeded, and then summing the annual probabilities over a period of interest. Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in **Table 5.4.2-3**.

Table 5.4.2-3. Damage Levels Experienced in Earthquakes

Ground Motion Percentage	Explanation of Damages
1-2%g	Motions are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
Below 10%g	Usually causes only slight damage, except in unusually vulnerable facilities.
10 - 20%g	May cause minor-to-moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse.
20 - 50%g	May cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
≥50%g	May causes higher levels of damage in many buildings, even those designed to resist seismic forces.

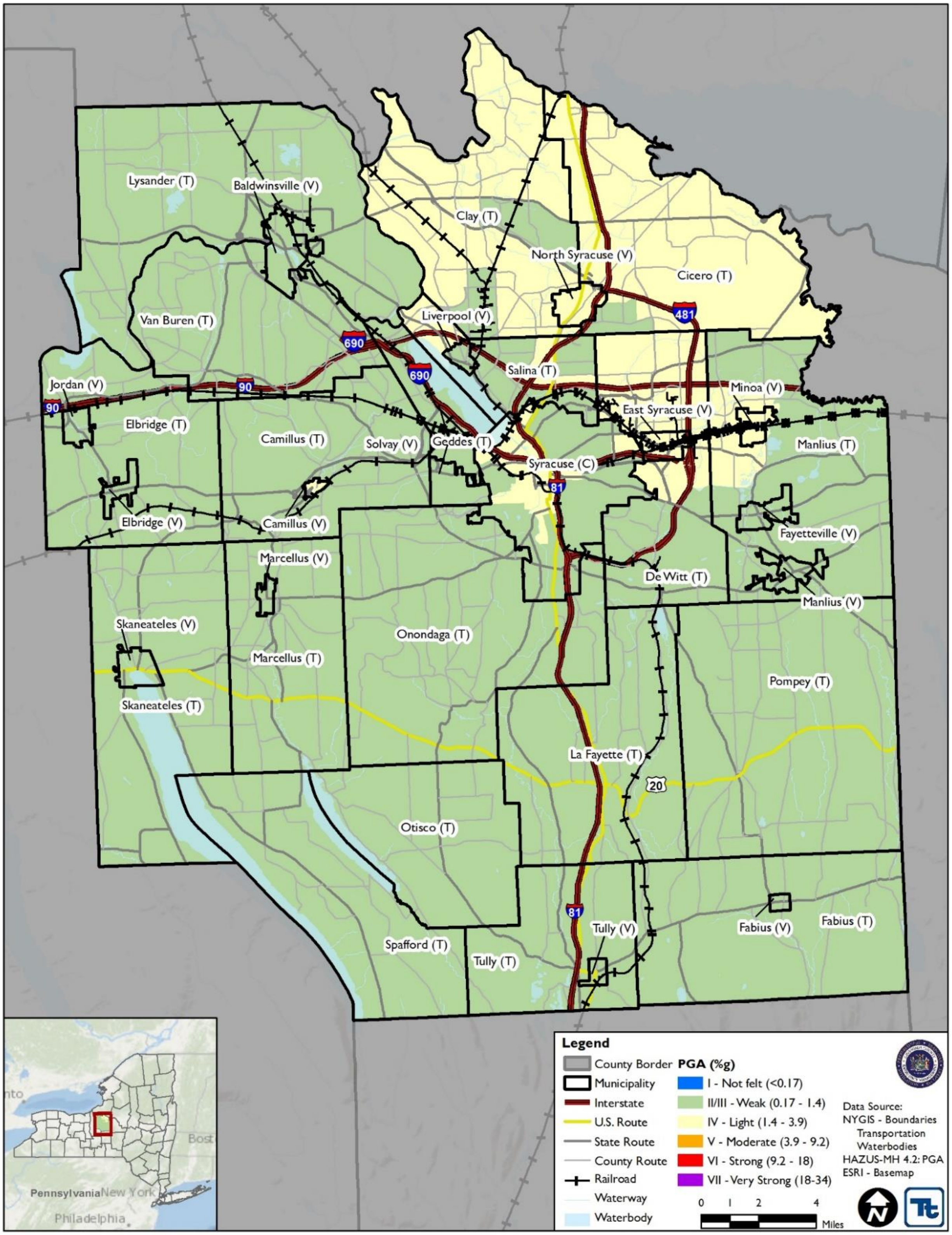
Source: NJOEM 2014
Note: %g Peak Ground Acceleration

National maps of earthquake shaking hazards provide information for creating and updating seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities, and land use planning. After thorough review of the studies, professional organizations of engineers update the seismic-risk maps and seismic design requirements contained in building codes (Brown et al. 2001). The USGS updated the National Seismic Hazard Maps in 2014. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps. The 2014 map represents the best available data, as determined by the USGS.

The USGS updated the National Seismic Hazard Maps in 2014, which superseded the 2008 maps. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps. The 2014 map represents the best available data as determined by the USGS. According to the data, Onondaga County has a PGA between 2%g and 3%g (USGS 2014). The 2014 PGA map can be found at http://pubs.usgs.gov/of/2014/1091/pdf/ofr2014-1091.pdf.

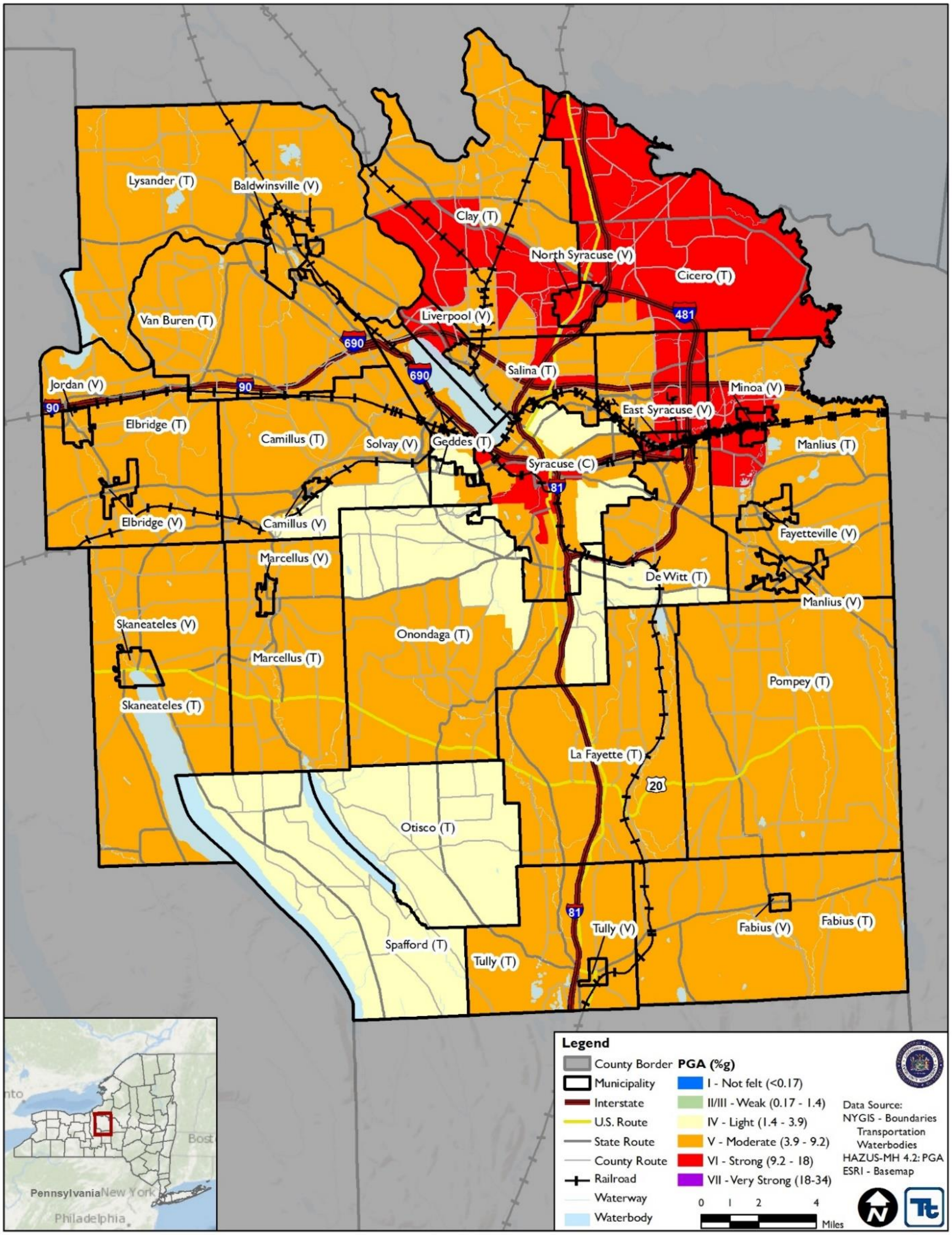
A probabilistic assessment was conducted for the 250- and 1,000-year mean return periods (MRP) in HAZUS-MH v4.2 to analyze the earthquake hazard for Onondaga County. The HAZUS-MH v4.2 analysis evaluates the statistical likelihood that a specific event will occur and what consequences will occur. Figure 5.4.2-1 and Figure 5.4.2-2 illustrate the geographic distribution of PGA (%*g*) across the county for the 250- and 1,000-year MRP events by census-tract. HAZUS-MH v4.2 estimates that the northeast portion of Onondaga County will experience light shaking during the 250-year event and strong shaking during the 1,000-year event. The municipalities in this area that are most likely to experience strong shaking impacts as a result of these probabilistic events are the Town of Clay, the Town of Cicero, the Town of Manlius, the Town of Salina, the Village of East Syracuse, the Village of North Syracuse, the Village of Minoa, and the City of Syracuse. This is due to the distribution of primarily NEHRP Type E soils throughout this region.

Figure 5.4.2-1. Peak Ground Acceleration 250-Year Mean Return Period for Onondaga County



Source: HAZUS-MH v4.2

Figure 5.4.2-2. Peak Ground Acceleration 1,000-Year Mean Return Period for Onondaga County



Source: HAZUS-MH v4.2

The New York State Geological Survey conducted seismic shear-wave tests of the state's surficial geology (glacial deposits). Based on these test results, the surficial geologic materials of New York State were categorized according to the National Earthquake Hazard Reduction Program's (NEHRP) Soil Site Classifications (Table 5.4.2-4). The NEHRP developed five soil classifications defined by their shear-wave velocity that impact the severity of an earthquake. The soil classification system ranges from Class A to Class E, as noted in Table 5.4.2-5, where Class A represents hard rock that reduces ground motions from an earthquake and Class E represents soft soils that amplify and magnify ground shaking and increase building damage and losses. Class E soils include water-saturated mud and artificial fill. The strongest amplification of shaking due is expected for this soil type. Seismic waves travel faster through hard rock than through softer rock and sediments. As the waves pass from harder to softer rocks, the waves slow down and their amplitude increases. Shaking tends to be stronger at locations with softer surface layers where seismic waves move more slowly. Ground motion above an unconsolidated landfill or soft soils can be more than 10 times stronger than at neighboring locations on rock for small ground motions (FEMA 2016).

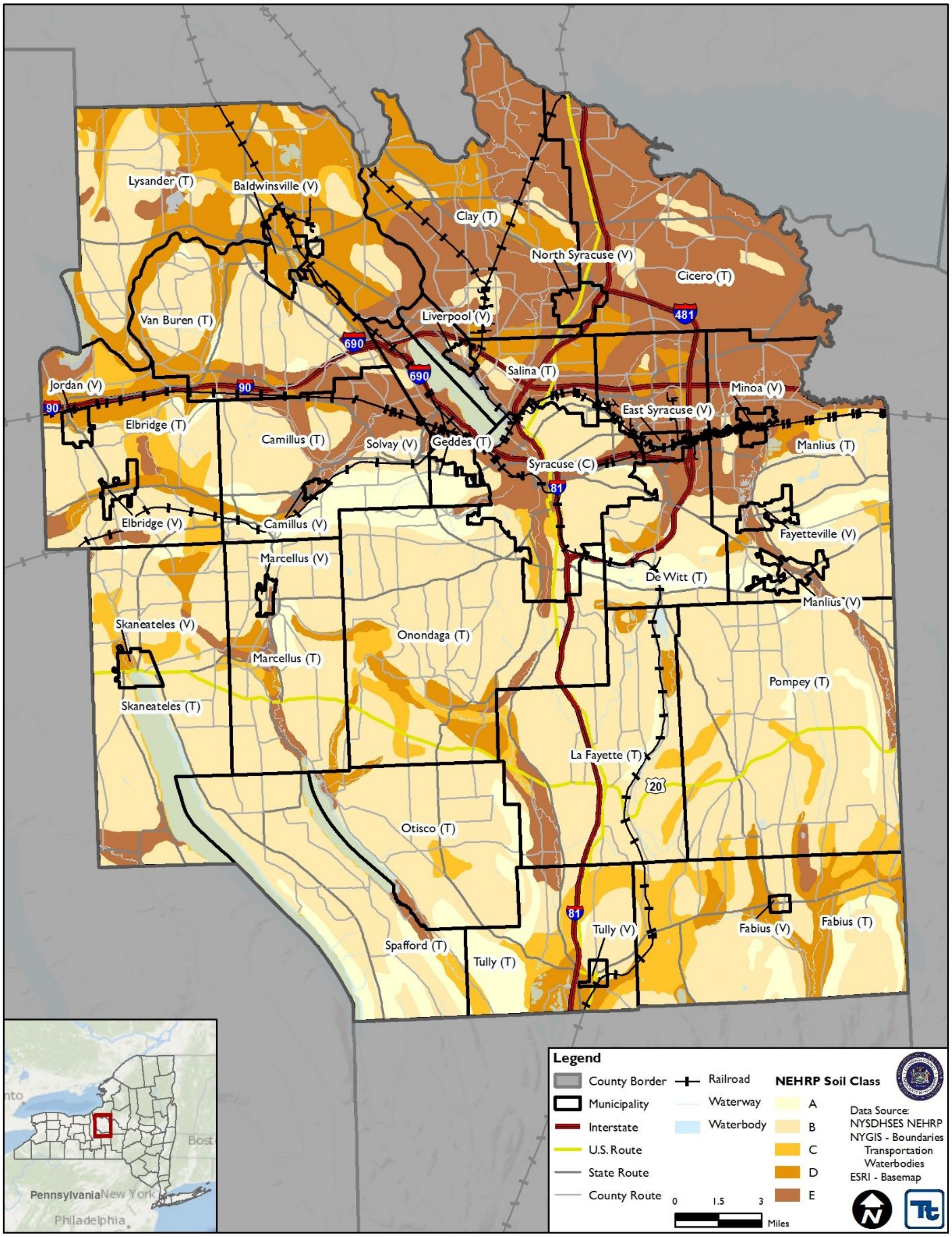
Table 5.4.2-4. NEHRP Soil Classifications

Soil Classification	Description
A	Hard rock
B	Rock
C	Very dense soil and soft rock
D	Stiff soils
E	Soft soils

Source: FEMA 2013

As illustrated in Figure 5.4.2-3, Onondaga County is predominately underlain by NEHRP Soil Class B soils with Class C soils interspersed throughout the county, A large concentration of Class D and E soils are located in the northern region of the county.

Figure 5.4.2-3. NEHRP Soil Classification in Onondaga County



Source: NYSDHSES 2008

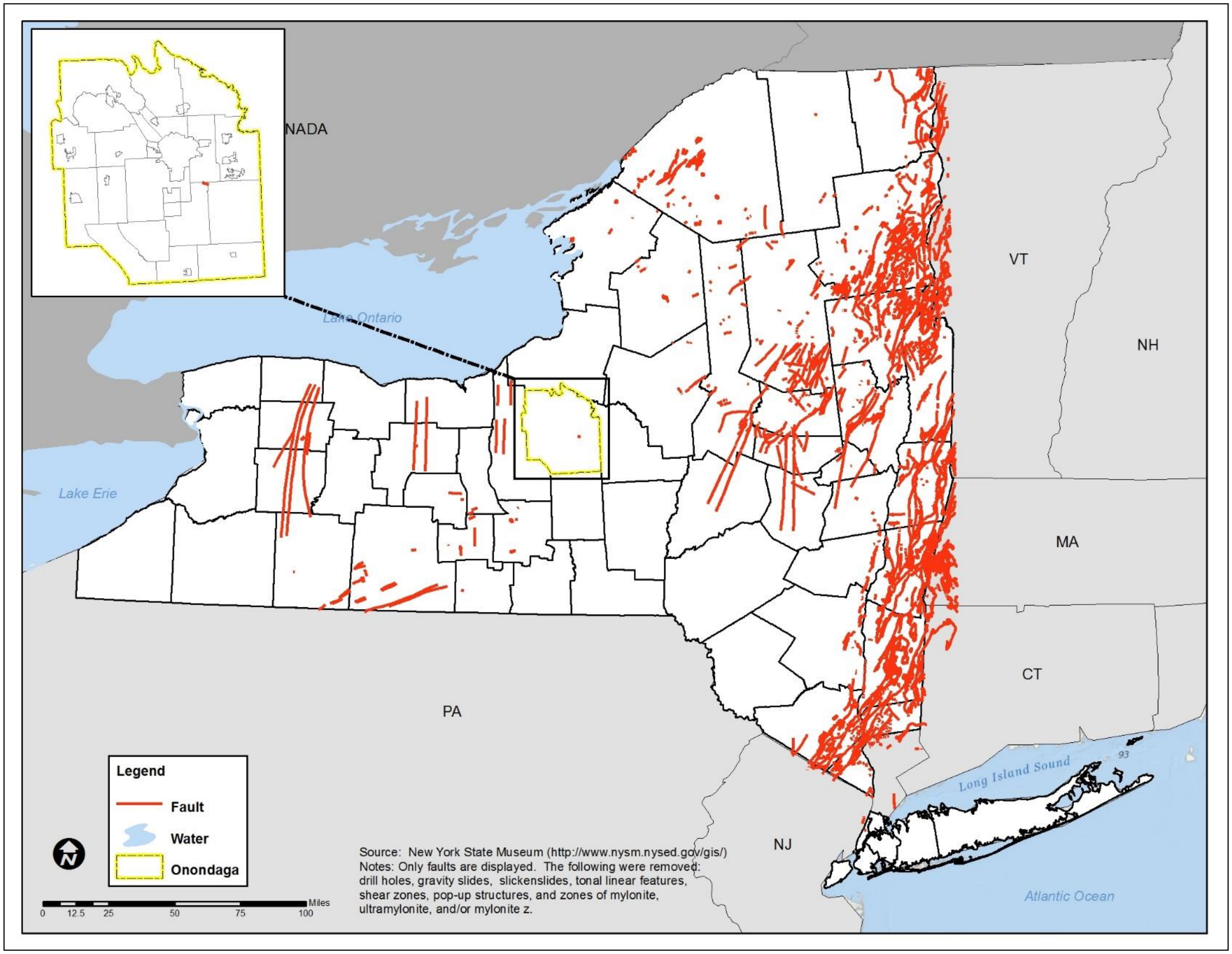
Location

There are three general regions in New York State that have a higher seismic risk compared to other parts of the state including the following:

1. The north and northeast third of the state, which includes the North Country/Adirondack region and a portion of the greater Albany-Saratoga region.
2. The southeast corner, which includes the greater New York City area and western Long Island.
3. The northwest corner, which includes Buffalo and its surrounding area.

Onondaga County is not located in a region identified as having high seismic risk (NYS DHSES 2014). Figure 5.4.2-4 illustrates the faults relative to Onondaga County (New York State Museum 2016). According to this figure, there is one small fault line within and surrounding the county.

Figure 5.4.2-4. Faults in Onondaga County



Source: New York State Museum 2012
Note: Onondaga County is outlined in yellow

The Lamont-Doherty Cooperative Seismographic Network (LCSN) monitors earthquakes that occur primarily in the northeastern United States. The goal of the project is to compile a complete earthquake catalog for this region, to assess the earthquake hazards, and to study the causes of the earthquakes in the region. The LCSN operates 52 seismographic stations in the following seven states: Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania, and Vermont. There are no seismic stations in Onondaga County; however, there are several that service the county (LCSN 2014). In addition to the Lamont-Doherty Seismic Stations, the USGS operates a global network of seismic stations (GSN) to monitor seismic activity. While no seismic stations are located in New York State, nearby stations are positioned in State College, Pennsylvania and Oak Ridge, Massachusetts.

The Advanced National Seismic System (ANSS) is run by USGS. When earthquakes strike, ANSS delivers real-time information, providing situational awareness for emergency-response personnel. In regions with sufficient seismic stations, that information includes –within minutes–a ShakeMap showing the distribution of potentially damaging ground shaking, information used to target post-earthquake response efforts. ANSS stations are operated within the state at Lake Ozonia (St. Lawrence County) and the City of Binghamton (Broome County) (USGS 2018).

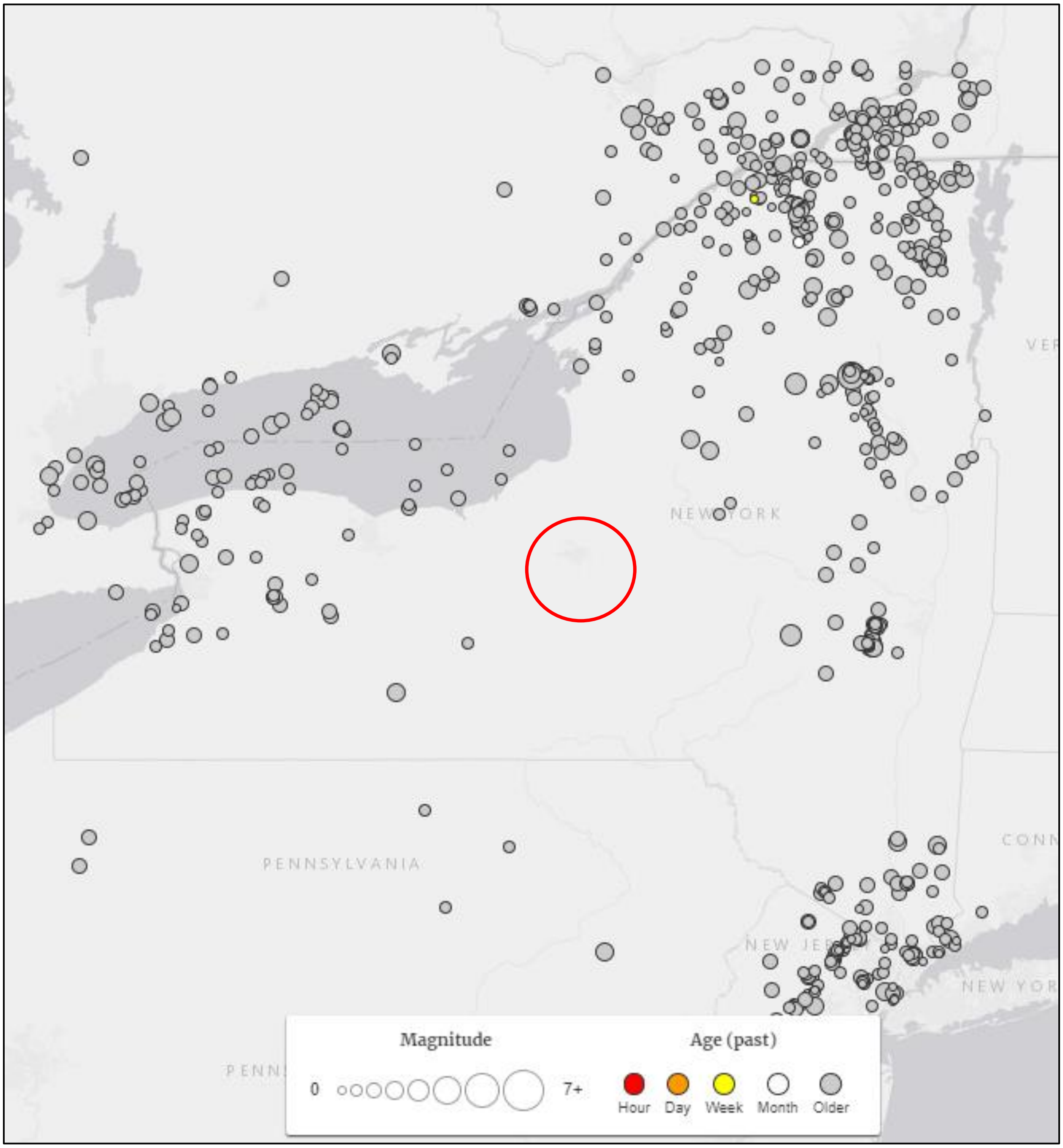
Previous Occurrences and Losses

New York State has a history of earthquake occurrences. According to the USGS earthquake catalog search, between 1950 and January 2019, the state has experienced over 450 earthquakes. Of those events, no earthquake epicenters were recorded in Onondaga County (USGS 2019). Figure 5.4.2-5 illustrates the epicenters of earthquakes with epicenters in the northeast. The earthquakes originating outside of the state have also been felt within the state. According to the NYS HMP, these events are considered significant for hazard mitigation planning because earthquakes such as those could inflict damage within the state in certain situations (NYS DHSES 2014).

Between 1954 and 2018, New York State was included in one earthquake-related major disaster (DR) or emergency (EM) declaration (DR-1415). Generally, these disasters cover a wide region of the state; therefore, they may have impacted many counties. However, not all counties were included in the disaster declaration. Onondaga County was not included in any earthquake DRs or EMs (FEMA 2018).

Known earthquake events that have impacted New York State and Onondaga County between 2005 and 2018 are identified in Table 5.4.2-5. For events prior to 2005, refer to Appendix E (Supplemental Data). Please note that many sources were researched for historical information regarding earthquake events in Onondaga County; therefore, Table 5.4.2-5 might not include all earthquake events that impacted the county.

Figure 5.4.2-5. Earthquake Epicenters in the Northeast United States, January 1950 to January 2019



Source: USGS 2019
Note: The red oval indicates the approximate location of Onondaga County.

Table 5.4.2-5. Earthquake Events Impacting Onondaga County, 2005 to 2018

Dates of Event	Event Type	Location	FEMA Declaration Number (if applicable)	County Designated?	Event Details
June 23, 2010	Earthquake	Ontario-Quebec border, Canada	N/A	N/A	A magnitude 5.4 earthquake at the Ontario-Quebec border region in Canada was felt throughout the northeast, including Onondaga County. Shaking was felt throughout the county.
August 23, 2011	Earthquake	Richmond, Virginia	N/A	N/A	A magnitude 5.8 earthquake centered northwest of Richmond, Virginia was felt throughout the East Coast. Shaking was felt throughout the county.
May 17, 2013	Earthquake	Shawville, Canada	N/A	N/A	A magnitude 5.1 earthquake in Shawville, Canada was felt in portions of New York, including Onondaga County. Shaking was felt throughout the county with some reports of items falling off shelves.

Source(s): *NYS DHSES, 2014; USGS 2018d; FEMA 2018; CNYCentral.com 2010, 2011, 2013*
DR *Major Disaster Declaration (FEMA)*
FEMA *Federal Emergency Management Agency*
N/A *Not Applicable*
NY *New York*
USGS *U.S. Geological Survey*

Climate Change Projections

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (Andersen et al. 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events.

Probability of Future Events

The New York City Area Consortium for Earthquake Loss Mitigation (NYCEM) ranks New York State as having the third highest earthquake activity level east of the Mississippi River (Tantala et al. 2003). The New York State Disaster Preparedness Commission (NYS DPC) and probabilistic maps for Onondaga County indicate that the potential for earthquakes does exist in Onondaga County (NYS DHSES 2014). Based on historical records and input from the Planning Partnership the probability of occurrence for earthquakes in the county is considered 'rare' (having between a 1 and 10 percent annual probability). Section 5.3 (Hazard Ranking) contains additional information on the hazard ranking methodology and probability criteria.

5.4.2.2 Vulnerability Assessment

A probabilistic assessment was conducted for the 250- and 1,000-year MRPs through a Level 2 analysis in HAZUS-MH v4.2 to analyze the earthquake hazard and provide a range of loss estimates.

Impacts on Life, Health, and Safety

The entire population of Onondaga County is exposed to the direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors including the age and type of construction people live in, the soil types their homes are located on, the intensity of the earthquake. Whether directly or indirectly impacted, residents could be faced with business closures, road closures that could isolate populations, and loss of function of critical facilities and utilities.

According to the 2017 American Community Survey annual estimate, Onondaga County had a population of 467,669 people. Overall, risk to public safety and loss of life from an earthquake in the county is minimal. However, there is a higher risk to public safety for those inside buildings due to structural damage or people walking below building ornamentations and chimneys that may be shaken loose and fall because of an earthquake.

An exposure analysis was performed using the NEHRP soils data and 2010 U.S. Census population data. As noted earlier, NEHRP soil classes D and E can amplify ground shaking to damaging levels even during a moderate earthquake, and thus increase risk to the population. Populations within municipalities residing on NEHRP Class D and E soils were estimated and are listed in Table 5.4.2-6 below. Overall, approximately 21.2-percent of the county's population is located on NEHRP Class D and E soils. The Villages of East Syracuse, Minoa, and North Syracuse have 100 percent of their population located on NEHRP Class D and E soils and represent areas within Onondaga County having higher vulnerability to this hazard.

Table 5.4.2-6. Approximate Populations on NEHRP "D" and "E" Soils

Municipality	Total Population (2010 U.S. Census)	Population NEHRP Class "D" and "E" Soils	
		Total Population Exposed	Percent of Population Exposed
Baldwinsville (V)	7,378	6,415	86.9%
Camillus (T)	22,954	2,803	12.2%
Camillus (V)	1,213	1,043	86.0%
Cicero (T)	29,641	26,243	88.5%
Clay (T)	53,397	48,876	91.5%
De Witt (T)	22,754	10,281	45.2%
East Syracuse (V)	3,084	3,084	100.0%
Elbridge (T)	3,496	1,367	39.1%
Elbridge (V)	1,058	254	24.0%
Fabius (T)	1,612	260	16.1%
Fabius (V)	352	147	41.8%
Fayetteville (V)	4,373	1,277	29.2%
Geddes (T)	10,534	2,320	22.0%
Jordan (V)	1,368	668	48.8%
La Fayette (T)	4,952	589	11.9%
Liverpool (V)	2,347	1,599	68.1%
Lysander (T)	17,175	10,911	63.5%
Manlius (T)	19,844	8,024	40.4%
Manlius (V)	4,704	876	18.6%
Marcellus (T)	4,397	516	11.7%
Marcellus (V)	1,813	884	48.8%
Minoa (V)	3,449	3,449	100.0%
North Syracuse (V)	6,800	6,800	100.0%
Onondaga (T)	23,101	1,583	6.9%
Onondaga Nation Reservation	468	99	21.2%
Otisco (T)	2,541	253	10.0%
Pompey (T)	7,080	276	3.9%
Salina (T)	31,363	24,250	77.3%
Skaneateles (T)	4,669	364	7.8%
Skaneateles (V)	2,540	880	34.6%
Solvay (V)	6,584	340	5.2%
Spafford (T)	1,686	25	1.5%
Syracuse (C)	145,170	41,273	28.4%
Tully (T)	1,865	607	32.5%
Tully (V)	873	333	38.1%

Municipality	Total Population (2010 U.S. Census)	Population NEHRP Class "D" and "E" Soils	
		Total Population Exposed	Percent of Population Exposed
Van Buren (T)	10,391	3,575	34.4%
Onondaga County	**467,026**	**212,544**	**45.5%**

Sources: NYS DHSES 2008, U.S. Census 2010
Note: The NEHRP boundaries were overlaid on the U.S. Census blocks; the blocks with their centroids within hazard areas were totaled for each municipality.
NEHRP National Earthquake Hazard Reduction Program

Populations considered most vulnerable are those located in/near the built environment, particularly those near unreinforced masonry structures. Of these most vulnerable populations, socially vulnerable populations, including the elderly (persons over age 65) and individuals living below the census poverty threshold, are most susceptible. Factors leading to this higher susceptibility include decreased mobility and financial ability to react or respond during a hazard, and the location and construction quality of their housing. Within the NEHRP Class D and E soils, there are 36,062 people over the age of 65 and 46,634 people considered low-income populations.

Residents could be displaced or require temporary to long-term sheltering because of an earthquake event. The number of people requiring shelter is generally less than the number displaced, as some displaced persons use hotels or stay with family or friends following a disaster event. Table 5.4.2-7 estimates the number of households displaced and population that may require short-term sheltering as a result of the 250- and 1,000-year MRP earthquake events.

Table 5.4.2-7. Summary of Estimated Sheltering Needs for Onondaga County

Scenario	Displaced Households	Persons Seeking Short-Term Shelter
250-Year Earthquake	31	21
1,000- Year Earthquake	192	129

Source: HAZUS-MH 4.2

According to the 1999-2003 NYCEM Summary Report (Earthquake Risks and Mitigation in the New York / New Jersey / Connecticut Region), a strong correlation exists between structural building damage and number of injuries and casualties from an earthquake event. Further, time of day also exposes different sectors of the community to the hazard. For example, HAZUS-MH v4.2 considers residential occupancy at its maximum at 2:00 AM, whereas educational, commercial, and industrial sectors are at their maximum at 2:00 PM, and peak commute time is at 5:00 PM. Whether directly impacted or indirectly impacted, the entire population will be affected to some degree. Business interruption could prevent people from working, road closures could isolate populations, and loss of utilities could impact populations that suffered no direct damage from an event.

Table 5.4.2-8 summarizes countywide injuries and casualties estimated for the 250- and 1,000-year MRP earthquake events.

Table 5.4.2-8. Estimated Number of Injuries and Casualties from the 250-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
250-year			
Injuries	8	10	8
Hospitalization	1	1	1
Casualties	0	0	0

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
1,000-Year			
Injuries	43	53	42
Hospitalization	7	9	7
Casualties	1	1	1

Source: HAZUS-MH v4.2.

Impact on General Building Stock

The entire county's general building stock is considered at risk and exposed to this hazard. As stated earlier, soft soils (NEHRP Soil Classes D and E) can amplify ground shaking to damaging levels even during a moderate earthquake (NYCEM 2003). Therefore, buildings located on NEHRP Classes D and E soils are at increased risk of damage from an earthquake. Table 5.4.2-9 summarizes the number and replacement cost value of buildings in Onondaga County located on NEHRP Soils Classes D and E.

Table 5.4.2-9. Number and Replacement Cost Value of Buildings within NEHRP Classes D and E Soils

Municipality	Total Number of Buildings	Total Replacement Cost Value (Structure and Contents)	Buildings NEHRP Classes D and E Soils		
			Number of Buildings	RCV	Percent (%) of Total RCV
Village of Baldwinsville	3,321	$1,504,827,309	2,946	$1,348,736,210	89.6%
Town of Camillus	11,611	$4,945,293,987	1,870	$660,074,838	13.3%
Village of Camillus	490	$182,330,235	441	$154,860,497	84.9%
Town of Cicero	15,558	$7,104,912,499	14,322	$6,545,822,506	92.1%
Town of Clay	22,004	$13,377,871,396	20,508	$11,781,223,015	88.1%
Town of DeWitt	11,191	$11,163,898,629	5,945	$7,787,299,529	69.8%
Village of East Syracuse	1,662	$901,239,284	1,662	$901,239,284	100.0%
Town of Elbridge	3,020	$1,214,372,973	1,101	$411,081,876	33.9%
Village of Elbridge	654	$243,606,959	265	$110,103,604	45.2%
Town of Fabius	1,717	$873,582,692	417	$304,184,696	34.8%
Village of Fabius	245	$100,916,840	132	$58,113,579	57.6%
Village of Fayetteville	1,999	$1,065,416,400	620	$290,012,051	27.2%
Town of Geddes	6,048	$3,940,020,462	1,800	$2,268,949,783	57.6%
Village of Jordan	754	$324,416,761	407	$221,770,082	68.4%
Town of Lafayette	3,742	$1,385,373,038	359	$120,868,668	8.7%
Village of Liverpool	1,379	$585,988,259	896	$415,454,299	70.9%
Town of Lysander	9,513	$5,511,947,365	6,363	$3,372,938,371	61.2%
Town of Manlius	10,101	$5,931,420,911	4,074	$2,279,333,870	38.4%
Village of Manlius	1,724	$1,225,609,003	374	$265,337,519	21.6%
Town of Marcellus	3,442	$1,592,818,810	537	$274,083,885	17.2%
Village of Marcellus	790	$446,005,634	161	$86,669,584	19.4%
Village of Minoa	1,579	$677,670,815	1,579	$677,670,815	100.0%
Village of North Syracuse	3,297	$1,347,498,685	3,297	$1,347,498,685	100.0%
Town of Onondaga	11,826	$5,889,094,715	966	$393,345,713	6.7%
Onondaga Nation Territory	638	$182,143,705	52	$12,718,369	7.0%
Town of Otisco	2,567	$1,070,059,196	311	$116,277,315	10.9%
Town of Pompey	5,096	$2,547,562,317	212	$84,719,679	3.3%
Town of Salina	14,486	$8,140,248,129	10,384	$6,022,056,356	74.0%
Town of Skaneateles	4,439	$2,334,223,245	401	$238,144,123	10.2%
Village of Skaneateles	1,583	$871,003,682	670	$343,438,571	39.4%
Village of Solvay	3,003	$1,402,099,960	137	$271,840,499	19.4%
Town of Spafford	2,302	$826,800,666	43	$10,045,226	1.2%
City of Syracuse	51,837	$25,010,023,305	13,671	$9,908,096,347	39.6%
Town of Tully	1,585	$882,534,759	651	$461,672,999	52.3%

Table 5.4.2-9. Number and Replacement Cost Value of Buildings within NEHRP Classes D and E Soils

Municipality	Total Number of Buildings	Total Replacement Cost Value (Structure and Contents)	Buildings NEHRP Classes D and E Soils		
			Number of Buildings	RCV	Percent (%) of Total RCV
Village of Tully	511	$314,789,328	121	$139,369,647	44.3%
Town of Van Buren	5,971	$3,347,767,581	2,646	$1,382,931,871	41.3%
Onondaga County	**221,685**	**$118,465,389,533**	**100,341**	**$61,067,983,960**	**51.5%**

Sources: NYS DHSES 2008, HAZUS v4.2
Note: RCV is the estimated replacement cost value of both structure and contents.
Note: The NEHRP boundaries were overlaid on the custom general building stock inventory; the structures with their centroids within hazard areas were totaled for each municipality.

There is a strong correlation between PGA and damage a building might undergo (NYCEM 2003). The HAZUS-MH model is based on best available earthquake science and aligns with these statements. The HAZUS-MH probabilistic earthquake model was applied to analyze effects from the earthquake hazard on general building stock in Onondaga County. See Figure 5.4.2-1 and Figure 5.4.2-2 earlier in this profile which illustrate the geographic distribution of PGA (%g) across the county for 250- and 1,000-year MRP events.

A building's construction determines how well it can withstand the force of an earthquake. The NYCEM report indicates that unreinforced masonry buildings are most at risk during an earthquake because the walls are prone to collapse outward, whereas steel and wood buildings absorb more of the earthquake's energy. Additional attributes that affect a building's capability to withstand an earthquake's force include its age, number of stories, and quality of construction. HAZUS-MH v4.2 considers building construction and age of building as part of the analysis. Because a custom general building stock was used for this HAZUS-MH v4.2 analysis, the building ages and building types from the inventory were incorporated into the HAZUS-MH v4.2 model.

Potential building damage was evaluated using HAZUS-MH v4.2 across the following damage categories: none, slight, moderate, extensive, and complete. Table 5.4.2-10 lists definitions of these five categories of damage to a light wood-framed building; definitions of categories of damage to other building types appear in HAZUS-MH technical manual documentation.

Table 5.4.2-10. Example of Structural Damage State Definitions for a Light Wood-Framed Building

Damage Category	Description
None	No damage recorded.
Slight	Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations.
Complete	Structure might have large permanent lateral displacement, can collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures can slip and fall off the foundations; large foundation cracks.

Source: HAZUS-MH Technical Manual

Building damage as a result of the 250- and 1,000-year MRP earthquake events was estimated using HAZUS-MH v4.2. In addition, annualized losses were calculated. Table 5.4.2-11 lists the estimated numbers of buildings damaged (within general occupancy categories) from each event. Damage loss estimates include structural and non-structural damage to the building and loss of contents. Table 5.4.2-12 lists estimated replacement cost values

(RCVs) of buildings and contents damaged by the 250- and 1,000-year MRP earthquake events. The total countywide estimated damages are less than 1 percent of the total building replacement cost value for all municipalities.

Table 5.4.2-11. Estimated Buildings Damaged by General Occupancy for 250-year and 1,000-year MRP Earthquake Events

Category	Expected Building Damage by Occupancy									
	250-Year MRP					1,000-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Residential	200,903 (90.6%)	1,453 (<1%)	111 (<1%)	40 (<1%)	4 (<1%)	193,880 (87.5%)	6,795 (3.1%)	1,800 (<1%)	259 (<1%)	28 (<1%)
Commercial	8,252 (3.7%)	148 <1%)	45 <1%)	5 (<1%)	0 (0%)	7,634 (3.4%)	542 (<1%)	236 (<1%)	35 (<1%)	3 (<1%)
Industrial	1,412 (<1%)	20 (<1%)	6 (<1%)	1 (<1%)	0 (0%)	1,317 (<1%)	81 (<1%)	35 (<1%)	4 (<1%)	0 (0%)
Education, Government, Religious and Agricultural	8,929 (4.0%)	80 (<1%)	23 (<1%)	3 <1%)	0 (0%)	8,525 (3.8%)	358 (<1%)	131 (<1%)	19 (<1%)	2 (<1%)

Source: HAZUS-MH v4.2

Table 5.4.2-12. Estimated Replacement Cost Values of Building and Contents Damaged by 250- and 1,000-Year MRP Earthquake Events

Municipality	Total Replacement Cost Value (Structure and Contents)	Estimated Total Damages*		
		Annualized Loss	250-Year	1,000-Year
Village of Baldwinsville	$1,504,827,309	$8,343	$261,265	$2,053,672
Town of Camillus	$4,945,293,987	$14,779	$394,835	$3,698,662
Village of Camillus	$182,330,235	$2,708	$87,722	$610,799
Town of Cicero	$7,104,912,499	$147,884	$4,566,207	$30,900,896
Town of Clay	$13,377,871,396	$210,744	$6,607,614	$45,902,728
Town of DeWitt	$11,163,898,629	$191,929	$5,266,683	$37,280,043
Village of East Syracuse	$901,239,284	$25,113	$701,930	$4,726,408
Town of Elbridge	$1,214,372,973	$4,220	$127,867	$1,040,651
Village of Elbridge	$243,606,959	$875	$26,505	$215,714
Town of Fabius	$873,582,692	$2,150	$69,624	$535,499
Village of Fabius	$100,916,840	$236	$7,651	$58,849
Village of Fayetteville	$1,065,416,400	$3,632	$117,092	$912,512
Town of Geddes	$3,940,020,462	$33,794	$918,217	$7,304,102
Village of Jordan	$324,416,761	$1,124	$34,047	$277,095
Town of Lafayette	$1,385,373,038	$2,339	$0	$671,610
Village of Liverpool	$585,988,259	$6,735	$210,630	$1,562,633
Town of Lysander	$5,511,947,365	$29,499	$943,463	$7,346,485
Town of Manlius	$5,931,420,911	$37,851	$1,198,460	$9,045,215
Village of Manlius	$1,225,609,003	$2,562	$46,065	$680,554
Town of Marcellus	$1,592,818,810	$2,674	$0	$749,500

Municipality	Total Replacement Cost Value (Structure and Contents)	Estimated Total Damages*		
		Annualized Loss	250-Year	1,000-Year
Village of Marcellus	$446,005,634	$730	$0	$203,275
Village of Minoa	$677,670,815	$13,042	$422,223	$2,845,725
Village of North Syracuse	$1,347,498,685	$28,079	$905,801	$6,023,155
Town of Onondaga	$5,889,094,715	$7,834	$37,039	$2,172,570
Onondaga Nation Territory	$182,143,705	$273	$0	$78,995
Town of Otisco	$1,070,059,196	$1,390	$0	$389,739
Town of Pompey	$2,547,562,317	$3,667	$0	$1,032,537
Town of Salina	$8,140,248,129	$95,068	$2,981,973	$21,200,649
Town of Skaneateles	$2,334,223,245	$4,142	$0	$1,166,830
Village of Skaneateles	$871,003,682	$1,658	$0	$466,581
Village of Solvay	$1,402,099,960	$6,844	$192,483	$1,679,673
Town of Spafford	$826,800,666	$975	$0	$273,710
City of Syracuse	$25,010,023,305	$232,360	$6,511,148	$48,942,635
Town of Tully	$882,534,759	$1,990	$56,070	$507,178
Village of Tully	$314,789,328	$721	$20,325	$183,852
Town of Van Buren	$3,347,767,581	$14,721	$465,051	$3,657,809
Onondaga County	**$118,465,389,533**	**$1,142,681**	**$33,177,991**	**$246,398,540**

Source: HAZUS-MH v4.2
**Total Damages is sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious, and government).*

HAZUS-MH v4.2 estimated approximately $33 million in damages due to a 250-year MRP earthquake event. This includes structural damage, non-structural damage and loss of contents, representing less than 1 percent of the total replacement value for general building stock in Onondaga County. HAZUS-MH v4.2 estimates over $246 million in building damage (less than 1 percent of total general building stock RCV) due to a 1,000-year MRP earthquake event. Residential and commercial buildings account for greatest damage as a result of these earthquake events. Residential buildings account for 52.5 percent and 52.1 percent of the total losses for the 250- and 1,000-year MRP events, respectively and commercial losses account for approximately 33.1 percent and 32.7 percent of the total losses for the 250- and 1,000-year MRP events, respectively.

Historically, Building Officials Code Administration (BOCA) regulations in the northeast states were developed to address local concerns, including heavy snow loads and wind. Seismic requirements for design criteria are not as stringent as those of the west coast of the United States, which rely on the more seismically focused Uniform Building Code. As such, a smaller earthquake in the northeast can cause more structural damage than if it would occur in the west.

Impact on Critical Facilities

All critical facilities in Onondaga County are considered exposed and vulnerable to the earthquake hazard. Refer to subsection "Critical Facilities" in Section 4 (County Profile) of this HMP for a complete inventory of critical facilities in Onondaga County. Table F-2 in Appendix F (Critical Facilities) summarizes the number of critical facilities, by type, located on NEHRP Soil Classes D or E. Of the 2,008 critical facilities exposed countywide, the City of Syracuse has the greatest number of critical facilities located on Classes D or E soils (438 facilities), followed by the Town of DeWitt with 232 facilities. Of the 438 facilities in the City of Syracuse, 233 are bulk chemical storage facilities, and of the 261 facilities in DeWitt, 181 are bulk chemical storage facilities. Damage to these bulk chemical storage facilities may result in release of the stored chemicals.

The HAZUS-MH v4.2 earthquake model was used to assign a probability of each damage state category defined in Table 5.4.2-10, to every critical facility in the planning area, which was then averaged across the facility category. In addition, HAZUS-MH v4.2 estimates the time to restore critical facilities to fully functional use. Results are presented as probability of being functional at specified time increments (days after the event). For example, HAZUS-MH v4.2 might estimate that a facility has 5 percent chance of being fully functional at Day 3, and a 95-percent chance of being fully functional at Day 90. Results for the 500- and 1,000-year events are summarized in Table 5.4.2-13 and Table 5.4.2-14. For percent probability of sustaining damage, the minimum and maximum damage estimated value for that facility type is presented.

Table 5.4.2-13. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities for the 250-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	90-99	1-7	0-3	<1	<1	90-98	96-100	99-100	100
Police	89-99	1-7	0-3	<1	<1	89-99	96-100	99-100	100
Fire	89-99	1-7	0-3	<1	<1	89-99	96-100	99-100	100
EOC	89.9	6.7	2.9	<1	<1	90	96	99	100
School	89-99	1-7	0-3	<1	<1	89-99	96-100	99-100	100
Utilities									
Potable Water	98-100	0-1	<1	0	0	99-100	100	100	100
Wastewater	98-100	0-1	<1	0	0	99-100	100	100	100
Electric Power	98-100	0-1	<1	0	0	99-100	100	100	100
Communication	98-100	0-1	<1	0	0	99-100	100	100	100
Natural Gas	98-100	0-1	<1	0	0	99-100	100	100	100

Source: HAZUS-MH 4.2

Table 5.4.2-14. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities for the 1,000-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	74-94	5-15	2-9	0-2	<1	74-94	89-98	98-100	99-100
Police	73-95	4-15	1-9	0-2	<1	73-95	88-98	97-100	98-100
Fire	73-95	4-15	1-9	0-2	<1	73-95	89-98	97-100	98-100
EOC	74.3	14.7	8.6	2.1	<1	74	89	98	99
School	73-95	4-15	1-9	0-2	<1	73-95	89-98	97-100	98-100
Utilities									
Potable Water	88-100	0-8	0-4	<1	0	92-100	100	100	100
Wastewater	88-100	0-8	0-4	<1	0	90-100	100	100	100
Electric Power	88-100	0-8	0-4	<1	0	92-100	99-100	100	100
Communication	89-100	0-8	0-4	0-1	0	98-100	100	100	100
Natural Gas	89-100	0-8	0-4	<1	0	94-100	100	100	100

Source: HAZUS-MH 4.2

Levees

According to EC 1110-2-6067 *USACE Process for the National Flood Insurance Program Levee System Evaluation*, if the PGA is less than 0.10g (10 percent g) for a seismic event with a 100-year MRP, then a seismic evaluation is not required for a levee. HAZUS-MH v4.2 was used to generate the PGA in Onondaga County for a 100-year MRP event. The PGA for Onondaga County ranges from 0.0083g to 0.0272g and is well below the 0.10g standard in EC 1110-2-6067. Based on this guidance, no seismic evaluations are required for the levee system accreditation in the county, and no levees are at an increased risk of structural failure due to a 100-year MRP seismic event.

Impact on Economy

Earthquakes also impact the economy, including loss of business function, damage to inventory (buildings, transportation, and utility systems), relocation costs, wage loss, and rental loss due to repair and replacement of buildings. HAZUS-MH v4.2 estimates building-related economic losses, including income losses (wage, rental, relocation, and capital-related losses) and capital stock losses (structural, non-structural, content, and inventory losses). Economic losses estimated by HAZUS-MH v4.2 are summarized in Table 5.4.2-15.

Table 5.4.2-15. Building-Related Economic Losses from the 250 and 1,000-Year MRP Earthquake Event

Level of Severity	Mean Return Period	
	250-year	1,000-year
Income Losses		
Wage	$2,706,300	$15,082,900
Capital Related	$2,094,700	$11,828,700
Rental	$2,990,800	$15,434,200
Relocation	$5,863,600	$32,090,600
Subtotal	**$13,655,400**	**$74,436,400**
Capital Stock Losses		
Structural	$10,459,800	$55,777,400
Non-Structural	$18,261,900	$140,208,700
Content	$4,455,500	$50,411,700
Inventory	$106,200	$1,170,200
Subtotal	**$33,283,400**	**$247,568,000**

Source: HAZUS-MH v4.2.

Although the HAZUS-MH v4.2 analysis did not compute estimates of damage to roadway segments and railroad tracks, assumedly these features would undergo damage due to ground failure—resulting in interruptions of regional transportation and of distribution of materials. Losses to the community that would result from damage to lifelines could exceed costs of repair (FEMA 2012).

Earthquake events can significantly affect road bridges, many of which provide the only access to certain neighborhoods. Because softer soils generally follow floodplain boundaries, bridges that cross watercourses should be considered vulnerable. Another key factor in degree of vulnerability is age of facilities and infrastructure, which correlates with standards in place at times of construction of these. HAZUS-MH v4.2 estimated economic impacts to Onondaga County for 15-years after the earthquake event, including impacts to transportation infrastructure. $1.3 million in damages were estimated as a result of a 250-year event and $35 million as a result of a 1,000-year event for damages to highway bridges.

HAZUS-MH v4.2 estimates volume of debris that may be generated as a result of an earthquake event to enable the study region to prepare for and rapidly and efficiently manage debris removal and disposal. Debris estimates were divided into two categories: (1) reinforced concrete and steel that require special equipment to break up before transport can occur, and (2) brick, wood, and other debris that can be loaded directly onto trucks by use of bulldozers (HAZUS-MH Earthquake User's Manual).

HAZUS-MH v4.2 estimated the generation of approximately 22,000 tons of total debris during the 250-year MRP event, and over 105,000 tons of debris during the 1,000-year MRP event. Table 5.4.2-16 below lists estimated debris generated by the 250- and 1,000-year MRP events.

Table 5.4.2-16. Estimated Debris Generated by the 250- and 1,000-year MRP Earthquake Events

Mean Return Period	Brick/Wood (tons)	Concrete/Steel (tons)
250-Year	17,022.6	5,232.3
1,000-Year	72,507.4	32,570.9

Source: HAZUS-MH 4.2

5.4.2.3 Future Changes that May Impact Vulnerability

Understanding future changes that affect vulnerability in the county can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The county considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Projected Development

Generally, new development will be more resistant to damage from earthquake events than older construction as building code seismic design standards have improved over time and modern codes, such as the International Building Code, include provisions for classifying soils.

Any areas of growth could be affected by an earthquake, especially those located on NEHRP Class D and E soils. Each municipality identified areas of recent development and proposed development in their community. Developments that could be located using an address or Parcel ID were geocoded and overlain with the NEHRP Class D and E soils to determine vulnerability. There are 46 developments located on these soils; this represents approximately 59.7 percent of the 77 identified developments. Of these 46 developments, 30 are recent developments and 16 are proposed developments. The Town of Geddes has most developments located on these soils (7). As stated above, these buildings will be more resistant to damage from earthquakes due to updated building codes. Specific areas of development are indicated in tabular form in the jurisdictional annexes in Volume II, Section 9 of this plan update.

Projected Changes in Population

According to population projections from the Cornell Program on Applied Demographics, Onondaga County will experience a slight population decrease through 2040 (less than 10,000 people in total by 2040). Population change is not expected to have a measurable effect on the overall vulnerability of the county's population over time. As discussed in *Long Range Transportation Plan 2050: Moving Towards a Greater Syracuse*, the population of Syracuse has decreased as the other municipalities in the county have seen an increase, which has led to an increased reliance on motor vehicles to travel around the county (Syracuse Metropolitan Transportation Council, 2015). The areas that are most susceptible to ground shaking are outside of Syracuse and in the northern region of the county (underlain by NEHRP Class D and E soils). Those moving to from areas of lower vulnerability to higher will increase their vulnerability, though not in a dramatic fashion. Refer to Section 4.4.2 (Population Trends) in the County Profile for a discussion on trends for the county.

Climate Change

Because the impacts of climate change on the earthquakes are not well understood, an increase or decrease in the county's vulnerability is difficult to determine. However, climate change has the potential to magnify secondary impacts of earthquakes. As a result of the climate change projections discussed above, the county's assets located on areas of saturated soils and on or at the base of steep slopes, are at a higher risk of landslides/mudslides because of seismic activity. Steep slope areas are identified in Figure 5.4.4-9 "Geological Hazard Areas in Onondaga County" in this plan. Failure of a dam storing increased volumes of water would result in flooding of the county's assets located in the inundation area.

Changes in Vulnerability Since the 2013 HMP

The 2013 HMP conducted a HAZUS-MH analysis using version MR3 for the 100-, 500-, and 2,500-year MRP events. HAZUS-MH 2.1 used 2000 U.S. Census data for its loss estimations. This HMP update used HAZUS-MH v4.2 for the 250- and 1,000-year MRP events. The analysis relied on 2010 U.S. Census data and was updated with the current custom-building stock and critical facilities. Due to differences in vulnerability assessment methodologies, a direct comparison could not be conducted to determine if there has been a change in vulnerability since the last HMP. Overall, the county continues to be vulnerable to earthquake events.

Issues Identified

Important issues associated with an earthquake in Onondaga County include the following:

- Critical facility owners should be encouraged to create or enhance a continuity of operations plan using the information on risk and vulnerability contained in this plan update.
- A number of levees/earthen dams are found within Onondaga County. Dam failure warning and evacuation plans, and procedures should be reviewed and updated to reflect the dams' risk potential associated with earthquake activity in the region.
- Earthquakes could trigger other natural hazard events, such as levee/dam failures and landslides, which could impact Onondaga County.
- The number of unreinforced masonry structures in Onondaga County is currently unknown. An inventory is needed to identify the number and location of these structures, and then the structure owners should be notified to educate them about retrofitting their structures.
- Over 45 percent of the county's population lives in Class D and E soils. These soils are more susceptible to earthquake damages. The population living in these areas need to be educated on taking appropriate action when earthquakes occur. The current Syracuse-Onondaga County GIS portal does not have NEHRP soil layer option. This layer would provide guidance for communities as to where to limit development in these areas or require more stringent seismic requirements for new buildings.