4.3.4 Earthquake

Hazard Profile

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

Hazard Description

An earthquake is a shaking of the Earth's surface by energy waves emitted by slow moving tectonic plates overcoming friction with one another underneath the Earth's surface, a volcanic eruption, or by a manmade explosion (FEMA 2023). Most destructive quakes are caused by dislocations of the crust. The crust may first bend and then, when the stress exceeds the strength of the rocks, break, and snap to a new position. In the process of breaking, vibrations called “seismic waves” are generated. These waves travel outward from the source of the earthquake at varying speeds. Most earthquakes occur at the boundaries where the Earth’s tectonic plates meet (faults), whereas less than 10 percent occur within plate interiors.

Faults or Fault Lines

A fault (also known as a fault line) is a fracture or zone of fractures between two blocks of rock. Faults allow the blocks to move relative to each other. This movement may occur rapidly, in the form of an earthquake - or may occur slowly, in the form of creep (USGS 2023). When a fault experiences an earthquake, there is no guarantee that all the stress has been relieved. Another earthquake can still occur. In fact, relieving stress along one part of a fault may increase it in another part.

Tectonic Plates

The State of New York is in an area where the rarer plate interior-related earthquakes occur. As plates continue to move and plate boundaries shift 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 (USGS 2016). As mentioned above, seismic waves are produced when some form of energy stored in Earth’s crust is suddenly released. This is usually when rock masses straining against one another suddenly fracture and slip.

Certain saturated soft soil can take on the characteristics of a fluid when shaken by an earthquake, resulting in a state called liquefaction. Amplified shaking also results in areas of “soft soils” which includes fill, loose sand, waterfront, and lakebed clays.

Seismic Zones

The term “Seismic Zone” is used to describe an area where earthquakes tend to focus. Seismic Zones slightly differ from “Seismic Hazard Zones” in that Seismic Hazard Zones describe areas with a particular level of hazard due to earthquakes (USGS n.d.). The U.S. Geological Survey (USGS) creates Seismic Hazard Maps that reflect these Seismic Zones and Seismic Hazard Zone data across the United States.

According to the U.S. Geological Survey (USGS) Earthquake Hazards Program, an earthquake hazard is any disruption associated with an earthquake that affects residents’ normal activities. The program defines seven different types of earthquake hazards (USGS n.d.) (CRMP 2021):

- **Surface faulting** is when a displacement reaches the Earth's surface during a slip along a fault. Commonly occurs with shallow earthquakes, which are 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 (USGS n.d.). 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 (NOAA 2023).

Location

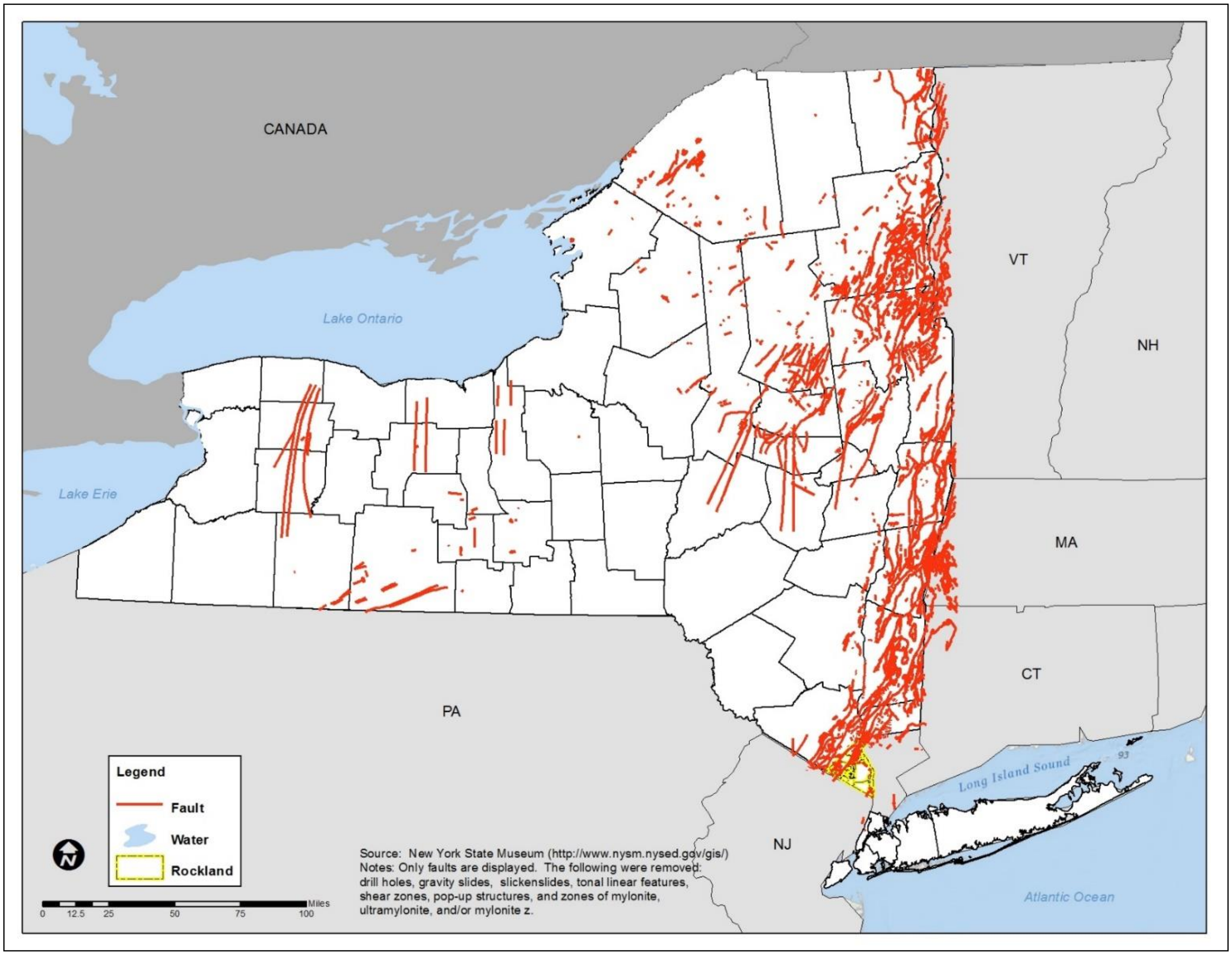
Though less common than other hazards (such as hurricanes or floods), earthquakes can occur throughout the State of New York and the Northeast (MitigateNY 2018). Rockland County has not been identified as an area with increased risk of earthquake events and according to multiple sources, Rockland County faces a low risk of earthquake events (ThinkHazard 2023). Rockland County is not located near any major or especially active fault lines, contributing to the low threat posed by earthquakes. Despite this low earthquake risk, several fault lines run through Rockland County and the surrounding area, as illustrated in Figure 4.3.4-1. No significant geological or topographical features of the County play a role in affecting local earthquake vulnerability.

The Ramapo Seismic Zone is one of the major known fault features that runs from eastern Pennsylvania to the mid-Hudson Valley. This system contains numerous smaller faults that include the 125th Street Fault in Manhattan, the Dyckman Street Fault, the Mosholu Parkway fault, and the Dobbs Ferry fault. The Lamont-Doherty Earth Observatory found evidence of an active seismic zone running at least 25 miles from Stamford, Connecticut to the Hudson Valley's Town of Peekskill (Westchester County), known as the Stamford-Peekskill line. Small clusters of earthquake events are found along the length of the line and to its immediate southwest. Just north of the line, there are no recorded earthquakes. The Stamford-Peekskill line runs parallel to the other faults beginning at 125th Street and researchers believe this fault is in the same family capable of producing at least a magnitude 6.0 earthquake. This fault also intersects the Ramapo seismic zone (USGS 2008).

The Ramapo Fault Line spans more than 185 miles in New York, New Jersey and Pennsylvania. It is one of the best-known fault zones in the mid-Atlantic region. The Ramapo Fault Line crosses the northern and western edge of Rockland County, running approximately parallel to its boundary with Orange County (Guglielmo 2010).

Figure 4.3.4-1 shows the location of the Ramapo and 125th Street fault lines and earthquakes that have occurred in the area.

Figure 4.3.4-1. Faults in Rockland County

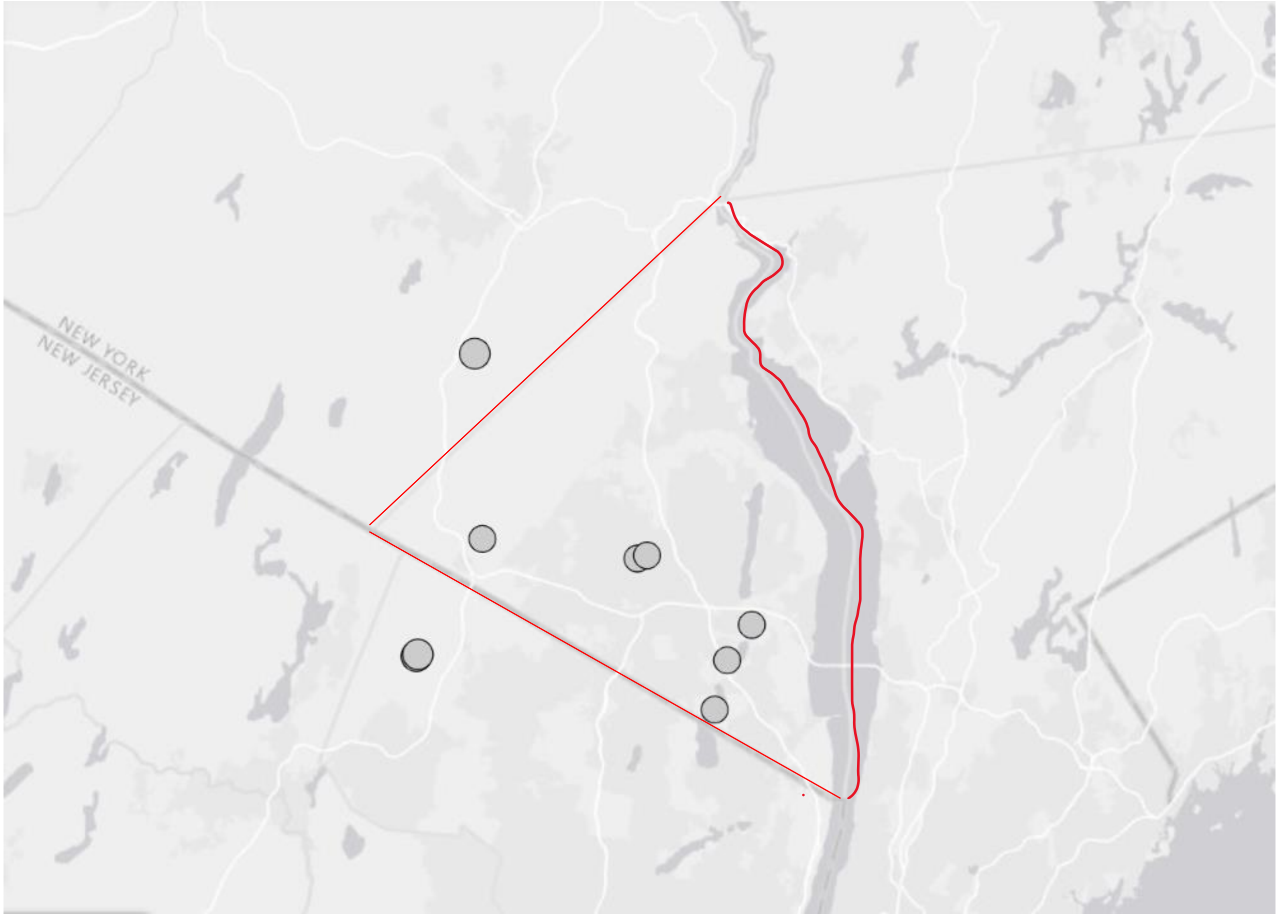


Source: New York State Museum 2023
Note: Rockland County is outlined in yellow.

Figure 4.3.4-2 illustrates historic earthquake epicenters across the southeast region of the State and northern New Jersey between 1950 and 2023. According to this figure, there have been six earthquakes with epicenters in Rockland County (2005, two in 2006, 2018, and two in 2019).

Earthquake epicenters are not the only place at risk to damage during an event. Depending on the scale and type, earthquakes can affect areas far away from their epicenters. Some earthquakes originating outside of the State have had impacts in Rockland County. For details regarding these events between 2017 and 2023, refer to Figure 4.3.4-2.

Figure 4.3.4-2. Earthquake Epicenters in the Rockland County, 1950-2023



Source: USGS 2023
Note: Rockland County is outlined in red.

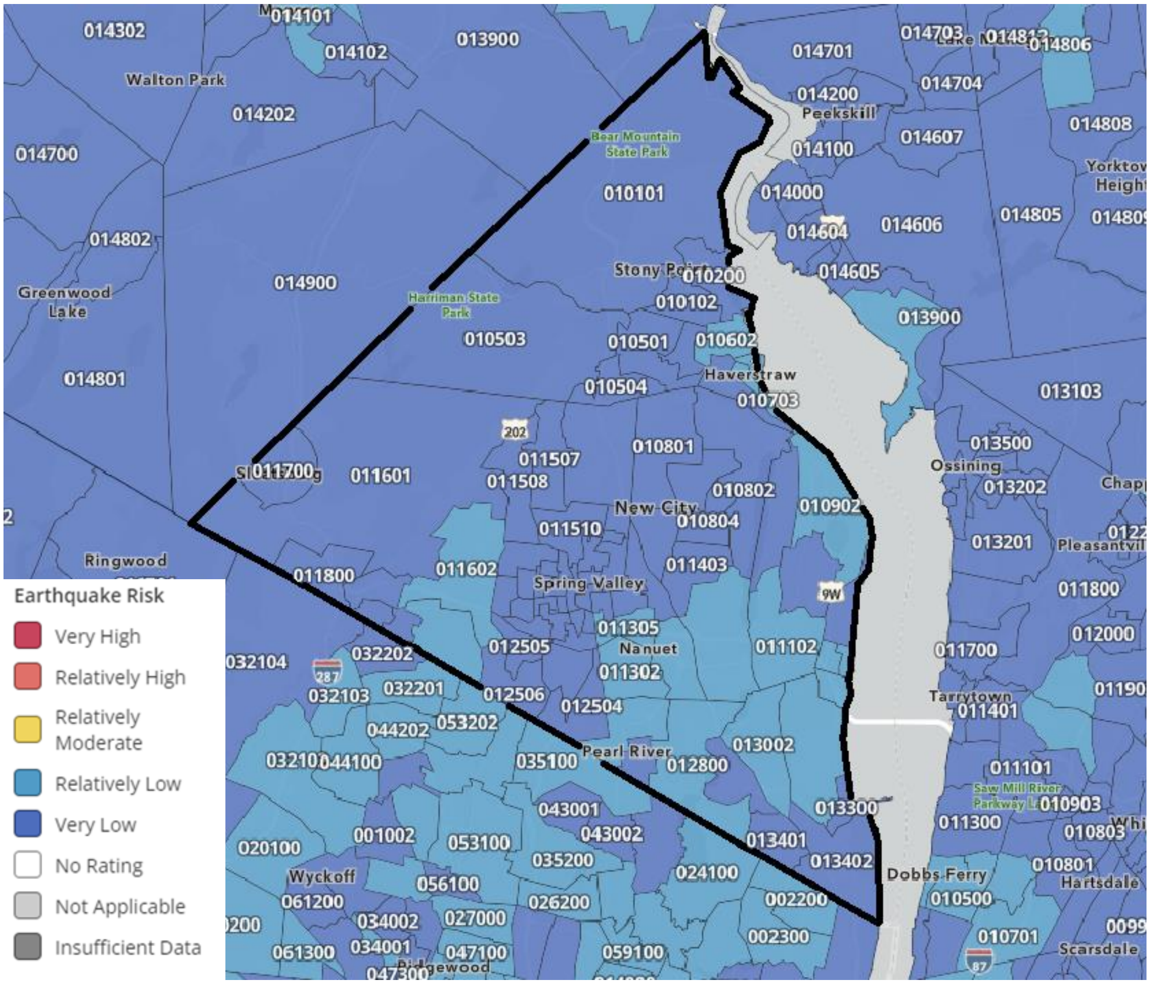
Figure 4.3.4-3 and Figure 4.3.4-4 show the Earthquake Risk Index for Rockland County on the county and census tract scales, respectively. This index helps to understand the susceptibility of the County to earthquakes. According to the National Risk Index, on the county scale, the County has a relatively low risk to earthquakes; on the census tract scale, the County ranges from a very low risk to a relatively low risk (FEMA 2019).

Figure 4.3.4-3. National Risk Index, Earthquake Risk Index Score Using the County Scale

Source: FEMA 2019

Note: Rockland is outlined in a boldened black border.

Figure 4.3.4-4. National Risk Index, Earthquake Index Score Using the Census Tract Scale



Source: FEMA 2019

Note: Rockland is outlined in a boldened black border.

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. Intensity describes the overall severity of shaking felt during the event. The earthquake's magnitude is a measure of the energy released at the source of the earthquake.

Magnitude is expressed by ratings on the Richter scale and/or the moment magnitude scale (MMS). The Richter Scale conveys the shaking felt by an event but does not measure damage (USGS 2023). Table 4.3.4-1. Richter Magnitude Scale presents the Richter scale magnitudes. The Richter Scale is no longer commonly used but is often referred to when discussed past events.

Table 4.3.4-1. Richter Magnitude Scale

Richter Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph
2.5 or 5.4	Often felt, but causes only minor damage
5.5 or 6.0	Slight damage to buildings and other structures
6.1 or 6.9	May cause a lot of damage in very populated areas
7.0 or 7.9	Major earthquake; serious damage
8.0 or greater	Great earthquake, can totally destroy communities near the epicenter

Source: Michigan Tech 2023

The MMS has replaced the Richter Scale as a common measure of earthquake severity. The moment magnitude provides an estimate of earthquake size that is valid over the complete range of magnitudes, a characteristic that was lacking in other magnitude scales. For very large earthquakes, moment magnitude gives the most reliable estimate of earthquake size. Moment is a physical quantity proportional to the slip on the fault multiplied by the area of the fault surface that slips; it is related to the total energy released in the earthquake. The moment can be estimated from seismograms (and also from geodetic measurements). The moment is then converted into a number similar to other earthquake magnitudes by a standard formula. The result is called the moment magnitude (USGS n.d.).

Earthquake intensity is based on the observed effects of ground shaking on people, buildings, and natural features, and varies across affected locations. The Modified Mercalli (MMI) scale expresses how strong a shock was felt at a particular location in values. Table 4.3.4-2 summarizes earthquake intensity as expressed by the Modified Mercalli scale.

Peak ground elevation (PGA) measures how hard the earth shakes, or accelerates, in a given geographic area. PGA is expressed as a percent acceleration force of gravity (%g). For example, 10%g PGA means that the ground is accelerating at a rate that is 10% that of gravity (USGS 2019). Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in Table 4.3.4-3.

Table 4.3.4-2. 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.

Mercalli Intensity	Shaking	Description
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 2023

Table 4.3.4-3. Damage Levels Experienced in Earthquakes (PGA)

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.
< 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: USGS 2005
Note: %g: Peak Ground Acceleration (PGA)

Table 4.3.4-4. Modified Mercalli Intensity and PGA Equivalents

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< .17	Not Felt	None
II	.17 – 1.4	Weak	None
III	.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 2004
Note: PGA: Peak Ground Acceleration

Table 4.3.4-4 describes the MMI scale alongside PGA equivalents to provide a more holistic picture of earthquake extent as it relates to ground acceleration. Building construction, type of structure, building materials, and other factors will play a role in determining the extent of earthquake damage within the planning area.

The USGS updated the National Seismic Hazard Maps in 2022, which superseded the 2014 maps. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps under the National Seismic Hazard Model. The 2022 map represents the best available data as determined by the USGS. According to the data, Rockland County has a PGA between 3%g and 5%g (USGS 2014).

The New York State Geological Survey conducted seismic shear-wave tests of the State's surficial geology (glacial deposits). Surficial materials are those at or near Earth's surface and in the case of New York State, these come in the form of sediment (such as rock, soil, gravel, etc.) that are deposited by glaciers (UC Davis n.d.). Based on these test results, the surficial geologic materials of the State of New York were categorized according to the National Earthquake Hazard Reduction Program's (NEHRP) Soil Site Classifications (Table 4.3.4-5). 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 A to E, as noted in Table 4.3.4-5, 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. 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).

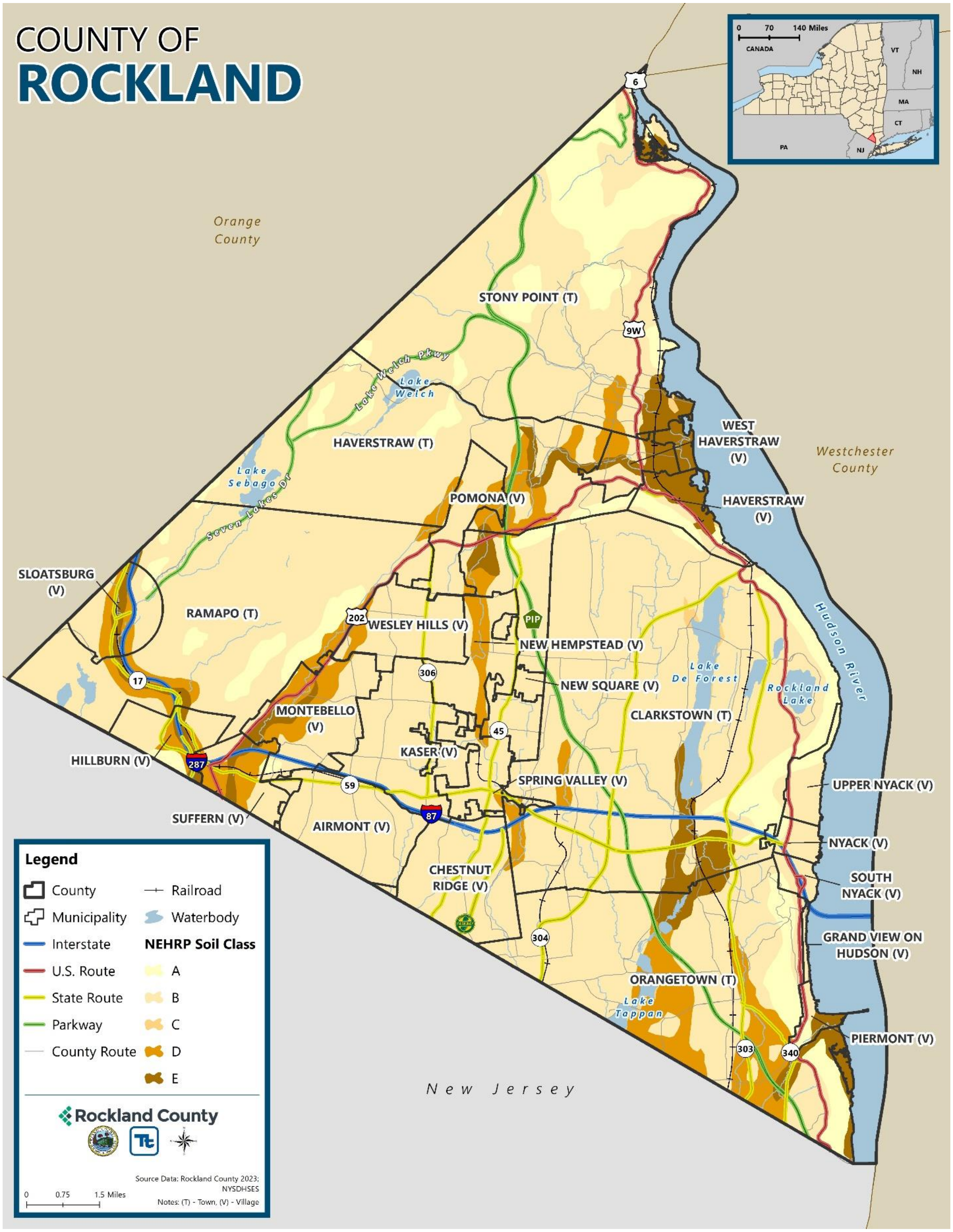
Table 4.3.4-5. NEHRP Soil Classifications

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

Source: FEMA 2016

Figure 4.3.4-5 illustrates the NEHRP soils located throughout Rockland County. The data was available from the NYS DHSES. The available NEHRP soils information is incorporated into the Hazus earthquake model for the risk assessment (discussed in further detail later in this section). According to this figure, Rockland County is predominately underlain by Type B soils.

Figure 4.3.4-5. NEHRP Soils in Rockland County



Previous Occurrences

FEMA Major Disaster and Emergency Declarations

Between 1954 and 2023, Rockland County was not included in any major disaster (DR) or emergency (EM) declarations for earthquake-related events (FEMA 2023). For other earthquake events that occurred between 2017 and 2023, refer to Table 4.3.4-6.

USDA Declarations

The Secretary of Agriculture from the U.S. Department of Agriculture (USDA) is authorized to designate counties as disaster areas to make emergency loans to producers suffering losses in those counties and in counties that are contiguous to a designated county. Between 2018 and 2023, Rockland County was not included in any earthquake-related agricultural disaster declarations.

Previous Events

For this 2024 HMP update, known hazard events that impacted Rockland County between January 2017 and December 2023 are discussed in Table 4.3.4-6. For events prior to 2017, refer to the 2018 Rockland County HMP.

Table 4.3.4-6. Hazard Events in Rockland County (2017 to 2023)

Date(s) of Event	Event Type	FEMA and/or USDA Declaration Number (if applicable)	Rockland County included in declaration?	Location Impacted	Description
November 4, 2019	Earthquake	N/A	N/A	Hillcrest, New York	A magnitude 1.6 earthquake was recorded in Hillcrest, New York. No damages or injuries were reported in this incident.
December 25, 2019	Earthquake	N/A	N/A	Near the New York Thruway in West Nyack, New York	A 1.1 magnitude earthquake was recorded on the Hackensack River near the New York Thruway. The depth of this earthquake was 1.9 miles, and no damage or injuries were reported.
May 25, 2018	Earthquake	N/A	N/A	Hillcrest, New York	A magnitude 1.8 earthquake was recorded in Hillcrest, New York. No damages or injuries were reported an only very weak shaking was experienced by residents.

Sources: USGS 2023

Probability of Future Occurrences

The State of New York intersects with fault lines, but none of which are considered seismically active. Still, earthquake events can impact the region. While the probability of a strong earthquake occurring is moderate, the risk is heightened because of the interdependencies of critical infrastructure systems and the age of New York's built environment (MitigateNY 2018). Rockland County could experience indirect impacts from earthquakes that may affect the general building stock, local economy and may induce secondary hazards such ignite fires and cause utility failure.

For the 2024 HMP update, best available data was used to collect hazard event details. These details were used to calculate the probability of future occurrence of hazard events in the County. Information from NOAA, FEMA, and USGS were used to identify the number of events that occurred between 1954 and 2023. Table 4.3.4-7 provides the calculated probability of future earthquake events in Rockland County.

Table 4.3.4-7. Probability of Future Earthquake Events in Rockland County

Hazard Type	Number of Occurrences Between 1954 and 2023	Percent Chance of Occurring in Any Given Year
Earthquake	11	15.71%

Sources: FEMA 2023; FEMA 2023; NOAA 2023; USGS 2023

Notes: Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected earthquake events since 1968. Due to limitations in data, not all earthquake events occurring between 1954 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.

In Section 4.4, the identified hazards of concern for Rockland County were ranted. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Partnership, the probability of occurrence for earthquake in the County is considered 'rare'

Climate Change Projections

The impacts of global climate change on earthquake probability are still being studied, but earthquakes are known to be affected by climate to some extent. 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 (NASA 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. There are currently no models available to estimate these impacts. Rockland County is expected to experience extreme rises in temperature, increases in precipitation, and increases in sea level rise (NYSERDA 2014). It is unknown how the changing climate in the State of New York and across the country may affect the severity or impacts of earthquake events.

Fracking is another consideration regarding earthquakes. While the State of New York has a low risk of an earthquake event, its neighboring state, the Commonwealth of Pennsylvania, reported its first fracking-related quake in April 2016. Although the State of New York is not participating in fracking activities, it is unclear how to measure the risk of induced earthquake activity due to proximity of activity in surrounding states. Coupled with climate change impacts, the County could potentially face elevated risks related to earthquakes.

Vulnerability Assessment

To assess Rockland County's risk to the earthquake hazard, an exposure analysis was conducted for the County's assets (population, building stock, critical facilities, historic assets, and new development) using the NEHRP soil data. Assets with their centroid areas containing NEHRP Soil Classes Type D and Type E, which are the most susceptible soil type to seismic activity, were totaled to estimate the County's vulnerability to earthquakes.

Impact on Life, Health, and Safety

The degree to which Rockland County residents are affected by potential earthquakes depends on many factors including the age and type of construction people live in, the soil type homes are located on, and 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.

Overall Population

Overall, risk to public safety and loss of life from an earthquake in the County is minimal for low magnitude events. 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. Table 4.3.4-8 presents the estimated population located within the NEHRP Soils Class D and E Hazard Areas. As shown, there are 56,116 persons located within the NEHRP Soils Class D and E Hazard Areas; the Village of Haverstraw has the greatest population in the dam inundation area with 10,160 persons (82.7 percent of total population exposed).

Table 4.3.4-8. Estimated Population Located Within the NEHRP Soils Class D and E Hazard Areas

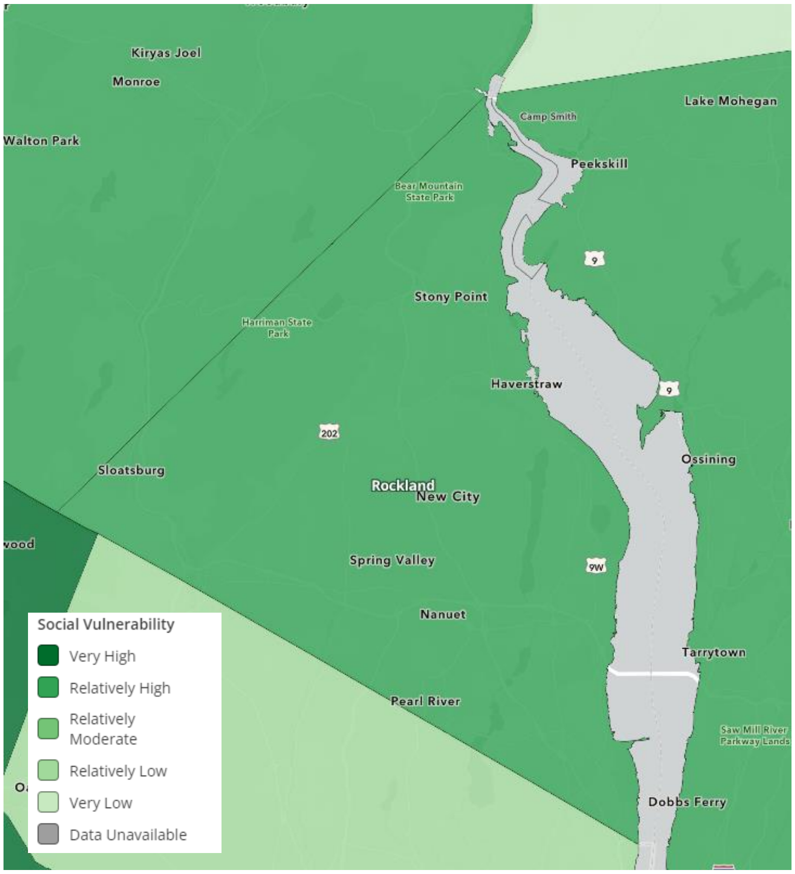
Jurisdiction	Total Population	Estimated Population Located Within the NEHRP Soils Class D and E Hazard Areas	
		Population	Percent of Total
Airmont, Village of	9,964	0	0.0%
Chestnut Ridge, Village of	10,211	75	0.7%
Clarkstown, Town of	81,385	3,173	3.9%
Grand View on Hudson, Village of	241	0	0.0%
Haverstraw, Town of	14,028	7,232	51.6%
Haverstraw, Village of	12,292	10,160	82.7%
Hillburn, Village of	1,110	838	75.5%
Kaser, Village of	5,433	0	0.0%
Montebello, Village of	4,665	2,426	52.0%
New Hempstead, Village of	5,440	1,131	20.8%
New Square, Village of	9,433	0	0.0%
Nyack, Village of	7,303	0	0.0%
Orangetown, Town of	36,127	7,119	19.7%
Piermont, Village of	2,525	958	37.9%
Pomona, Village of	3,306	585	17.7%
Ramapo, Town of	48,846	1,799	3.7%
Sloatsburg, Village of	3,043	1,866	61.3%
South Nyack, Village of	2,803	0	0.0%
Spring Valley, Village of	32,953	1,994	6.1%
Stony Point, Town of	14,876	2,572	17.3%
Suffern, Village of	11,376	8,367	73.5%
Upper Nyack, Village of	2,355	0	0.0%
Wesley Hills, Village of	6,105	356	5.8%
West Haverstraw, Village of	10,665	5,465	51.2%
Rockland County (Total)	**336,485**	**56,116**	**16.7%**

Source: U.S. Census Bureau, American Community Survey 5-year estimates 2017-2021; NYSDHSES
Notes: Values are rounded down

Socially Vulnerable Population

Populations considered most vulnerable to earthquake events are those located in/near the built environment, particularly those near unreinforced masonry construction. Of these most vulnerable populations, socially vulnerable populations, including the elderly (persons over age 65) and individuals living below the poverty threshold, are most susceptible. Factors leadings 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. Refer to Table 4.3.4-9 for details on the total number of vulnerable persons living in areas of Class D and E soils. Figure 4.3.4-6 shows the social vulnerability index for the earthquake hazard, based on FEMA's National Risk Index.

Figure 4.3.4-6. FEMA Social Vulnerability Index for Earthquake



Source: FEMA n.d.

Table 4.3.4-9. Estimated Vulnerable Persons Located Within the NEHRP Soils Class D and E Hazard Areas

Jurisdiction	Estimated Vulnerable Persons Located Within the NEHRP Soils Class D and E Hazard Areas											
	Over 65	Percent of Total	Under 5	Percent of Total	Non-English Speaking	Percent of Total	Disability	Percent of Total	Poverty Level	Percent of Total	Living Below ALICE	Percent of Total
Airmont, Village of	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Chestnut Ridge, Village of	11	0.7%	10	0.7%	4	0.6%	8	0.7%	14	0.7%	14	0.7%
Clarkstown, Town of	653	3.9%	145	3.9%	165	3.9%	314	3.9%	138	3.9%	886	3.9%
Grand View on Hudson, Village of	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Haverstraw, Town of	1,300	51.5%	563	51.5%	513	51.5%	633	51.5%	729	51.6%	2,589	51.5%
Haverstraw, Village of	1,342	82.6%	729	82.7%	1,690	82.6%	1,239	82.6%	1,484	82.6%	3,861	82.7%
Hillburn, Village of	121	75.2%	86	75.4%	36	75.0%	109	75.2%	116	75.3%	273	75.5%
Kaser, Village of	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Montebello, Village of	292	51.9%	100	51.8%	85	51.5%	157	51.8%	268	51.9%	305	51.9%
New Hempstead, Village of	169	20.7%	53	20.5%	13	20.0%	79	20.6%	25	20.7%	91	20.7%
New Square, Village of	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nyack, Village of	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Orangetown, Town of	1,362	19.7%	355	19.7%	208	19.7%	697	19.7%	320	19.7%	2,483	19.7%
Piermont, Village of	204	37.8%	53	37.6%	53	37.3%	68	37.6%	18	37.5%	460	37.9%
Pomona, Village of	108	17.6%	43	17.5%	20	17.2%	51	17.4%	19	17.1%	92	17.7%
Ramapo, Town of	173	3.7%	264	3.7%	46	3.6%	89	3.7%	596	3.7%	696	3.7%
Sloatsburg, Village of	314	61.2%	122	61.0%	41	60.3%	233	61.3%	101	60.8%	881	61.3%
South Nyack, Village of	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Spring Valley, Village of	192	6.0%	225	6.0%	586	6.0%	166	6.0%	481	6.0%	810	6.1%
Stony Point, Town of	458	17.3%	102	17.2%	45	17.0%	279	17.2%	115	17.2%	759	17.3%
Suffern, Village of	1,703	73.5%	360	73.5%	636	73.4%	809	73.5%	519	73.5%	4,007	73.5%
Upper Nyack, Village of	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Wesley Hills, Village of	50	5.8%	36	5.8%	0	0.0%	23	5.7%	29	5.7%	58	5.8%
West Haverstraw, Village of	659	51.2%	483	51.2%	852	51.2%	507	51.2%	701	51.2%	2,300	51.2%
Rockland County (Total)	**9,111**	**17.5%**	**3,729**	**13.5%**	**4,993**	**18.5%**	**5,461**	**18.8%**	**5,673**	**11.5%**	**20,565**	**18.7%**

Source: U.S. Census Bureau, American Community Survey 5-year estimates 2017-2021; NYSDHSES
Notes: Values are Rounded Down

Impact on General Building Stock

Buildings located in areas of Class D or Class E soils are more susceptible to earthquake impacts. The potential damage is the modeled loss that could occur to the exposed inventory measured by the structural and content replacement cost value. There are an estimated 19,585 buildings within the NEHRP Soils Class D and E Hazard Areas, representing approximately 23.3 percent of the County's total general building stock inventory replacement cost value. The Town of Orangetown has the greatest number of its buildings located in areas of Class D and E soils (3,952 buildings or 21.4 percent of its total building stock). Refer to Table 4.3.4-10 for the estimated exposure of the dam inundation area by jurisdiction.

Table 4.3.4-10. Estimated Number and Total Replacement Cost Value of Structures Located in the NEHRP Soils Class D and E Hazard Areas

Jurisdiction	Total Number of Buildings	Total Replacement Cost Value (RCV)	Estimated Number and Total Replacement Cost Value of Structures Located in the NEHRP Soils Class D and E Hazard Areas			
			Number of Buildings in the NEHRP Soils Class D and E Hazard Areas	Percent of Total	Total Replacement Cost Value of Buildings Located in the NEHRP Soils Class D and E Hazard Areas	Percent of Total
Airmont, Village of	4,324	$2,712,726,498	0	0.0%	$0	0.0%
Chestnut Ridge, Village of	3,996	$2,590,102,202	28	0.7%	$13,598,906	0.5%
Clarkstown, Town of	34,094	$22,578,694,610	1,399	4.1%	$1,051,050,770	4.7%
Grand View on Hudson, Village of	219	$123,746,894	0	0.0%	$0	0.0%
Haverstraw, Town of	5,157	$14,687,792,118	2,587	50.2%	$9,200,052,872	62.6%
Haverstraw, Village of	2,232	$1,373,775,543	1,787	80.1%	$1,109,936,463	80.8%
Hillburn, Village of	499	$340,797,550	379	76.0%	$281,044,131	82.5%
Kaser, Village of	197	$434,976,786	0	0.0%	$0	0.0%
Montebello, Village of	2,002	$1,957,771,278	1,014	50.6%	$647,441,315	33.1%
New Hempstead, Village of	2,074	$1,416,579,766	477	23.0%	$324,216,662	22.9%
New Square, Village of	455	$640,979,013	0	0.0%	$0	0.0%
Nyack, Village of	1,830	$1,930,474,072	0	0.0%	$0	0.0%
Orangetown, Town of	18,439	$19,240,363,073	3,952	21.4%	$4,599,187,535	23.9%
Piermont, Village of	841	$520,681,014	334	39.7%	$215,999,239	41.5%
Pomona, Village of	1,437	$947,429,629	258	18.0%	$233,536,228	24.6%
Ramapo, Town of	9,783	$7,401,302,608	403	4.1%	$467,333,659	6.3%
Sloatsburg, Village of	1,776	$780,218,848	1,113	62.7%	$486,241,784	62.3%
South Nyack, Village of	1,009	$628,994,780	0	0.0%	$0	0.0%
Spring Valley, Village of	3,468	$2,977,580,954	229	6.6%	$241,728,972	8.1%
Stony Point, Town of	8,819	$4,492,546,145	1,534	17.4%	$771,098,825	17.2%
Suffern, Village of	3,110	$2,011,976,760	2,314	74.4%	$1,281,373,559	63.7%
Upper Nyack, Village of	1,121	$714,087,836	0	0.0%	$0	0.0%
Wesley Hills, Village of	2,432	$1,597,464,375	143	5.9%	$98,594,574	6.2%
West Haverstraw, Village of	3,171	$1,575,031,545	1,634	51.5%	$833,370,298	52.9%
Rockland County (Total)	**112,485**	**$93,676,093,896**	**19,585**	**17.4%**	**$21,855,805,791**	**23.3%**

Source: Rockland County, NYS Office of Information Technology Services Geospatial Services and NYS Department of Taxation and Finance's Office of Real Property Tax Services (ORPTS) 2022; Center for International Earth Science Information Network, New York State Energy Research and Development Authority 2022; U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2022; NYSDHSES

National maps of earthquake shaking hazards have been produced since 1948, providing crucial information for the development and maintenance of seismic design requirements in building codes, insurance policies, earthquake loss assessments, retrofitting prioritization, and land use planning in the United States. These maps are continuously updated by scientists to incorporate new insights and data. Structures constructed in compliance with modern seismic design standards, such as buildings, bridges, highways, and utilities, are better equipped to endure earthquakes with minimal damage and disruption. Professional engineering organizations review the latest studies to update seismic-risk maps and design standards in building codes (USGS 2008).

Impact on Critical Facilities and Community Lifelines

Critical facilities and community lifelines located in areas of Class D or Class E soils are more susceptible to earthquake impacts. Table 4.3.4-11 summarizes the number of community lifelines exposed to the earthquake hazard. In total, 216 lifelines (22 percent of the total number of lifelines) are vulnerable to earthquakes. Of the 216 community lifelines located in the earthquake hazard area, Safety and Security has the majority of facilities (73 or 33.8 percent of lifelines exposed). Refer to subsection “Critical Facilities and Lifelines” in Section 3 (County Profile) of this HMP for a complete inventory of critical facilities in Rockland County.

Table 4.3.4-11. Number of Lifelines Located in the NEHRP Soils Class D and E Hazard Areas

FEMA Lifeline Category	Number of Lifelines	Number of Lifelines Located in the NEHRP Soils Class D and E Hazard Areas	Percent of Lifelines Exposed
Communications	154	32	14.8%
Energy	0	0	0%
Food, Water, Shelter	71	16	7.4%
Hazardous Material	56	18	8.3%
Health and Medical	195	30	13.9%
Safety and Security	349	73	33.8%
Transportation	8	3	1.4%
Water Systems	148	44	20.4%
Rockland County (Total)	**981**	**216**	**100%**

Impact on the Economy

Earthquakes also have impacts on the economy, including loss of business function, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Hazus 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).

This analysis did not include damage estimates for individual roadway segments and railroad tracks, but it is assumed these features would sustain damage due to ground failure, resulting in interruptions of regional transportation and of distribution of materials.

Earthquake events can also significantly affect 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 building standards in place at times of construction.

Impact on the Environment

According to USGS, earthquakes can cause damage to the surface of the Earth in various forms depending on the magnitude and distribution of the event. Surface faulting is one of the major seismic components to earthquakes that can create wide ruptures in the ground. Ruptures can have a direct impact on the landscape and natural environment because it can disconnect habitats for miles isolating animal species or tear apart plant roots (USGS n.d.).

Furthermore, ground failure as a result of soil liquefaction can have an impact on soil pores and retention of water resources The greater the seismic activity and liquefaction properties of the soil, the more likely drainage of groundwater can occur which depletes groundwater resources. In areas where there is higher pressure of groundwater retention, the pores can build up more pressure and make soil behave more like a fluid rather than a solid increasing risk of localized flooding and deposition or accumulation of silt (USGS n.d.).

Future Changes That May Impact Vulnerability

Understanding future changes that affect vulnerability 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

Potential or Projected Development

As discussed, and illustrated in Section 3 (County Profile), areas targeted for future growth and development have been identified across the County. Development built in areas with softer NEHRP soil classes, liquefaction, and landslide-susceptible areas may experience shifting or cracking in the foundation during earthquakes because of the loose soil characteristics of these soil classes. However, current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts than older, existing construction that may have been built to lower construction standards.

Projected Changes in Population

Rockland County has experienced an increase in its population since 2010. According to the U.S. Census Bureau, the County's population increased by approximately 8.5 percent between 2010 and 2020 (County of Rockland 2021). Cornell University’s Program on Applied Demographics project Rockland County will have a population of 356,758 by 2030 and 372,432 by 2040 (Cornell University 2018).

Persons that move into older buildings may increase their overall vulnerability to earthquakes. As noted earlier, if moving into new construction, current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts.

Other Identified Conditions

Because the impacts of climate change on earthquakes are not well understood, a change in the County’s vulnerability as the climate continues to change 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, 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.

Change of Vulnerability Since 2018 HMP

Overall, the entire County remains vulnerable to earthquakes. For the 2024 HMP, the building inventory was updated using RS Means 2022 values, which is more current and reflects replacement cost versus the building stock improvement values reported in the 2018 HMP. Additional building stock updates include updates to the critical facility inventory provided by Rockland County. Updated hazard areas were used as well; since the 2018 HMP, an updated version of Hazus-MH was released. This updated model includes longer historical records to pull from to generate probabilistic events.