10. GEOLOGICAL HAZARDS

10.1 Hazard Profile

10.1.1 Hazard Description

For the purposes of this HMP update, the Geological Hazards profile discusses earthquakes, landslides, and land subsidence/sinkholes.

EARTHQUAKES

An earthquake is the sudden movement of the Earth's surface caused by the release of stress accumulated within or along the edge of tectonic plates, a volcanic eruption, or by a human-made explosion (FEMA 2001). Most earthquakes occur at the intersection of the Earth's tectonic plates, which are called faults. Less than 10 percent of earthquakes occur in tectonic plate interiors; however, these interior-related earthquakes have occurred in New Jersey in the past. Tectonic plates move slowly over time, sometimes towards or away, or even sliding past one another. These shifts weaken boundary regions, eventually becoming part of the plate interiors. 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).

The location of an earthquake is commonly described by its focal depth and epicenter. Focal depth refers to the depth from the Earth's surface to the region where an earthquake's energy originates, also called the focus or hypocenter. An epicenter is the point on the Earth's surface directly above the hypocenter (USGS n.d.). Earthquakes usually occur without warning and their effects can impact areas of great distance from the epicenter (FEMA 2001).

According to the U.S. Geological Survey (USGS) Earthquake Hazards Program, an earthquake hazard is any disruption associated with an earthquake that may affect residents' normal activities. USGS identifies six types of disruptions, defined as the following, although not all these events affect Hudson County (USGS n.d., NOAA 2023):

- **Surface faulting** results in displacement that reaches the Earth's surface during a slip along a fault. This disruption commonly occurs with "shallow" earthquakes with an epicenter less than 20 kilometers (roughly 12.5 miles).
- **Ground motion** (shaking) is 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** is the movement of surface material down a slope. This type of disruption is examined in more detail later in this section.
- **Liquefaction** is 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.
- **Tectonic deformation** refers to a change in the original shape of a material caused by stress and strain.

- **Tsunami** is 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** is the sloshing of a closed body of water, such as a lake or bay, from earthquake shaking.

LANDSLIDES

The term “landslide” includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Gravity acting on an over-steepened slope is the primary reason for a landslide. Contributing factors include the following (USGS n.d.):

- Erosion by rivers, glaciers, or ocean waves, which creates over-steepened slopes
- Rock and soil slopes weakened by saturation due to snowmelt or heavy rains
- Earthquakes, which generate energy that makes weak slopes fail
- Excess weight from rain/snow accumulation, rock/ore stockpiling, waste piles, or man-made structures.

In New Jersey, there are four main types of landslides: slumps, debris flows, rockfalls, and rockslides.

- Slumps are coherent masses that move downslope by rotational slip-on surfaces that underlie and penetrate the landslide deposit (NJDEP 2009).
- A debris flow, also known as a mudslide, is a form of rapid mass movement in which loose soil, rock, organic matter, air, and water mobilize as slurry that flows downslope. Debris flows are often caused by intense surface water from heavy precipitation or rapid snow melt. This precipitation loosens surface matter, thus triggering the slide.
- Rockfalls are common on roadway cuts and steep cliffs. These landslides are abrupt movements of geological material such as rocks and boulders. Rockfalls happen when these materials become detached.
- Rockslides are the movement of newly detached segments of bedrock sliding on bedrock, joint, or fault surfaces (NPS 2023).

SUBSIDENCE/SINKHOLES

Land subsidence is the sudden sinking or gradual downward settling of the earth’s surface with little or no horizontal motion, owing to the subsurface movement of earth materials (USGS 2018). Subsidence often occurs through the loss of subsurface support in karst terrain, which may result from a number of natural or human-caused occurrences. Karst is a landscape characterized by dissolution of underlying carbonate rocks (limestone and dolomite) by surface water or groundwater over time. The dissolution process causes surface depressions and the development of sinkholes, sinking streams, enlarged bedrock fractures, caves, and underground streams (NJOEM 2019).

Sinkholes, the type of subsidence most frequently seen in New Jersey, are a common geologic feature in areas with underlying limestone, carbonate rock, salt beds, or other rocks that are soluble in water. They can result from natural or human causes:

- Natural sinkholes result when, over thousands of years, carbonate bedrock is dissolved by acidic rainwater moving in fractures or cracks in the bedrock. This creates larger openings in the rock through which water and overlying soil materials travel. Over time the voids enlarge until the roof over the void is unable to support the land above, at which time it collapses, forming a sinkhole.

- Human-caused sinkholes involve changes to the water balance of an area such as over-withdrawing groundwater, diverting surface water from a large area and concentrating it in a single point; artificially creating ponds of surface water; and drilling new water wells. These actions can accelerate the natural processes of creation of soil voids, which can have a direct impact on sinkhole creation (NJOEM 2019).

Both natural and human-made sinkholes can occur without warning. Slumping or falling fence posts, trees, or foundations, sudden formation of small ponds, wilting vegetation, discolored well water, and/or structural cracks in walls and floors are signs that a sinkhole may be forming. Sinkholes can range from steep-walled holes to bowl or cone-shaped depressions. When sinkholes occur in developed areas, they can cause severe property damage, disruption of utilities, damage to roadways, injury, and loss of life (NJOEM 2019).

10.1.2 Location

EARTHQUAKES

Faults

Earthquakes in New Jersey are most likely to occur in the northern parts of the state, which includes Hudson County, where significant faults are concentrated; however, low-magnitude events can and do occur in many other areas of the State (NJDEP 2024). There is no known surface ground displacement along faults in the eastern U.S. from historic earthquakes. Earthquake epicenters in eastern North America and the New Jersey area, in general, do not now occur on known faults. The faults in these areas are from tectonic activity more than 200 million years ago (NJDEP 2024).

There are many faults in New Jersey; however, the Ramapo Fault, which separates the Piedmont and Highlands Physiographic Provinces, is best known. Numerous minor earthquakes have been recorded in the Ramapo Fault zone, a 10- to 20-mile-wide area lying adjacent to, and west, of the actual fault (NJDEP 2024). Figure 10-1 illustrates the proximity of the Ramapo fault line to Hudson County.

Soils Susceptible to Shaking

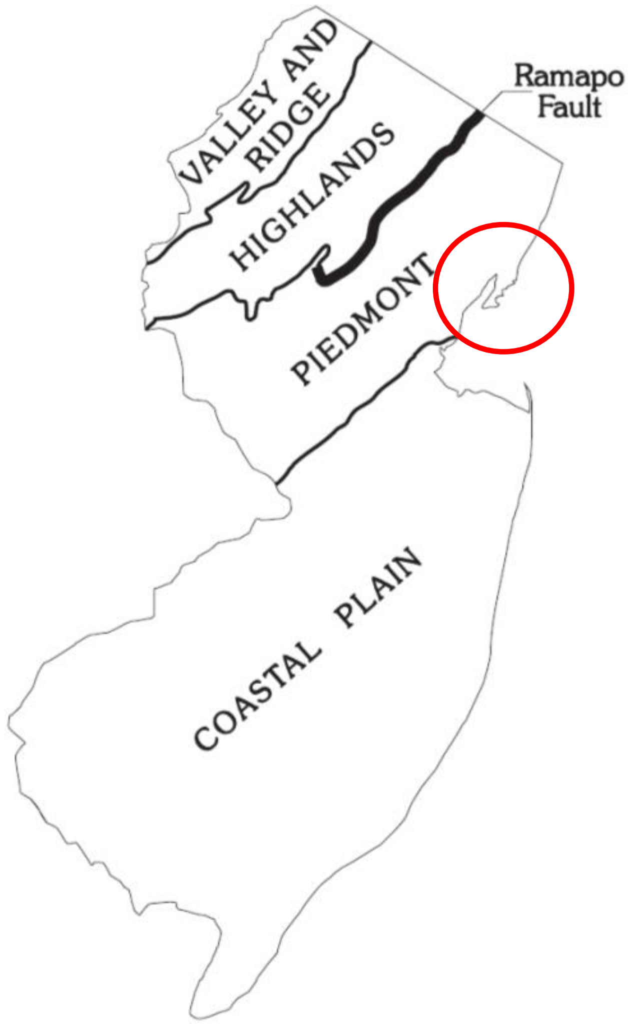
The National Earthquake Hazard Reduction Program (NEHRP) developed five soil classifications that impact the severity of an earthquake. The soil classification system ranges from A to E, as noted in Table 10-1, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses. Figure 10-2 illustrates the most seismically sensitive NEHRP soils (Classes D and E) in Hudson County.

Table 10-1. 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 n.d.

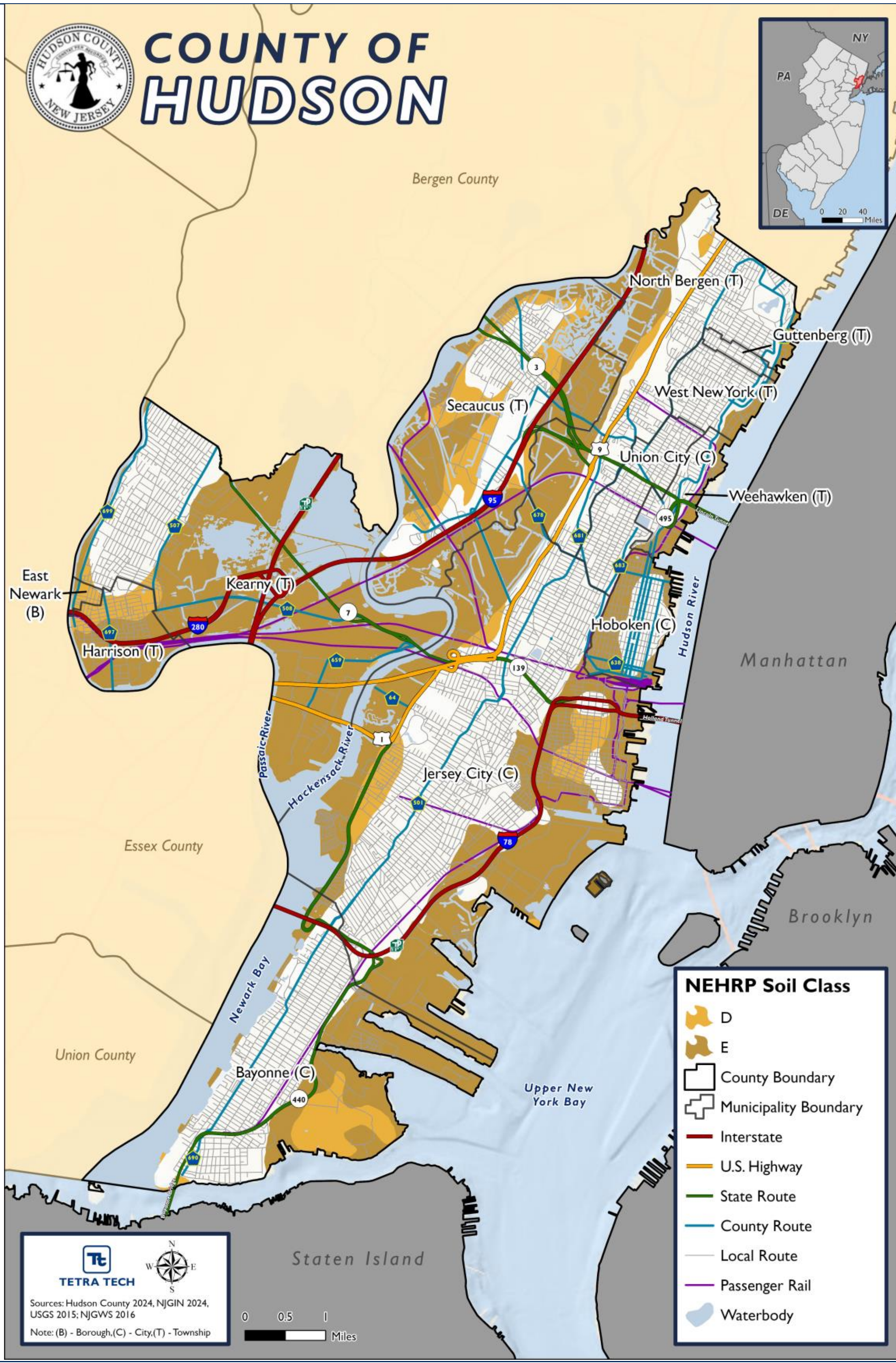
Figure 10-1. Physiographic Provinces of New Jersey and Ramapo Fault Line



Note: The red circle indicates the approximate location of Hudson County.

Source: Dombroski 1998 (Revised in 2005)

Figure 10-2. NEHRP Soils in Hudson County



A New Jersey Department of Transportation (NJDOT) report on seismic design for bridges in the state (Anil Agrawal 2012) classifies soils according to the American Association of State Highway and Transportation Officials Guide Specifications for Bridge Seismic Design. Sites are classified into Soil Classes A, B, C, D, E and F, ranging from hard rock to soft soil and special soils (similar to the NEHRP soil classifications); refer to Table 10-2.

Table 10-2. NJDOT Soil Classifications

Soil Classification	Description
A-B	Rock sites
C	Very dense soil
D	Dense soil
E	Soft soil
F	Special soil requiring site-specific analysis

Source: NJDOT 2012

NJDOT also developed a Geotechnical Database Management System that contains soil boring data across the state. The soil boring logs were then used to classify soil sites. Through this analysis, NJDOT developed a map of soil site classes according to ZIP codes in New Jersey where each ZIP code was assigned a class based on its predominant soil condition. In Hudson County, most ZIP codes were rated as Category C (Anil Agrawal 2012).

LANDSLIDES

Landslides are common in New Jersey, primarily in the northern region of the state. The state has an extensive history of landslides, and the landslides occur for a variety of reasons. Figure 10-3 illustrates the historic landslides in Hudson County. According to this figure, most of the landslide events have occurred in the northeastern section of the County.

The New Jersey Geologic Survey (currently known as the NJGWS) determined landslide susceptibility for the following nine counties in New Jersey: Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union (NJOEM 2024). Areas within these counties are classified into Class A, B, and C landslide susceptible classes based on soil types, with subclasses within these main classifications based on slope. Class A areas consist of strongly cemented rock. Class B consists of weakly cemented rock. Class C includes shale and clayey soil (FEMA 2020). Figure 10-4 shows the landslide susceptibility in Hudson County. There are small areas throughout the County with Class A and Class B landslide susceptibility and no areas of Class C.

Surficial materials in Hudson County include glacial till, glacial-lake sand and gravel deposits, glacial-lake silt and clay deposits, postglacial river sand, peat and organic silt deposited in estuaries and salt marshes, and outcropping bedrock. Areas of potential landsliding in Hudson County include cliffs and steep slopes in diabase bedrock on the east slope of the Palisades Ridge north of Jersey City, several small areas of steep slope on the west slope of the Palisades Ridge, bluffs in serpentinite bedrock at Stevens Point in Hoboken, and the cliffs in diabase on Snake Hill in Secaucus (NJGS 1999). Figure 10-5 illustrates the geological features of Hudson County.

Figure 10-3. Historic Landslide Locations in Hudson County

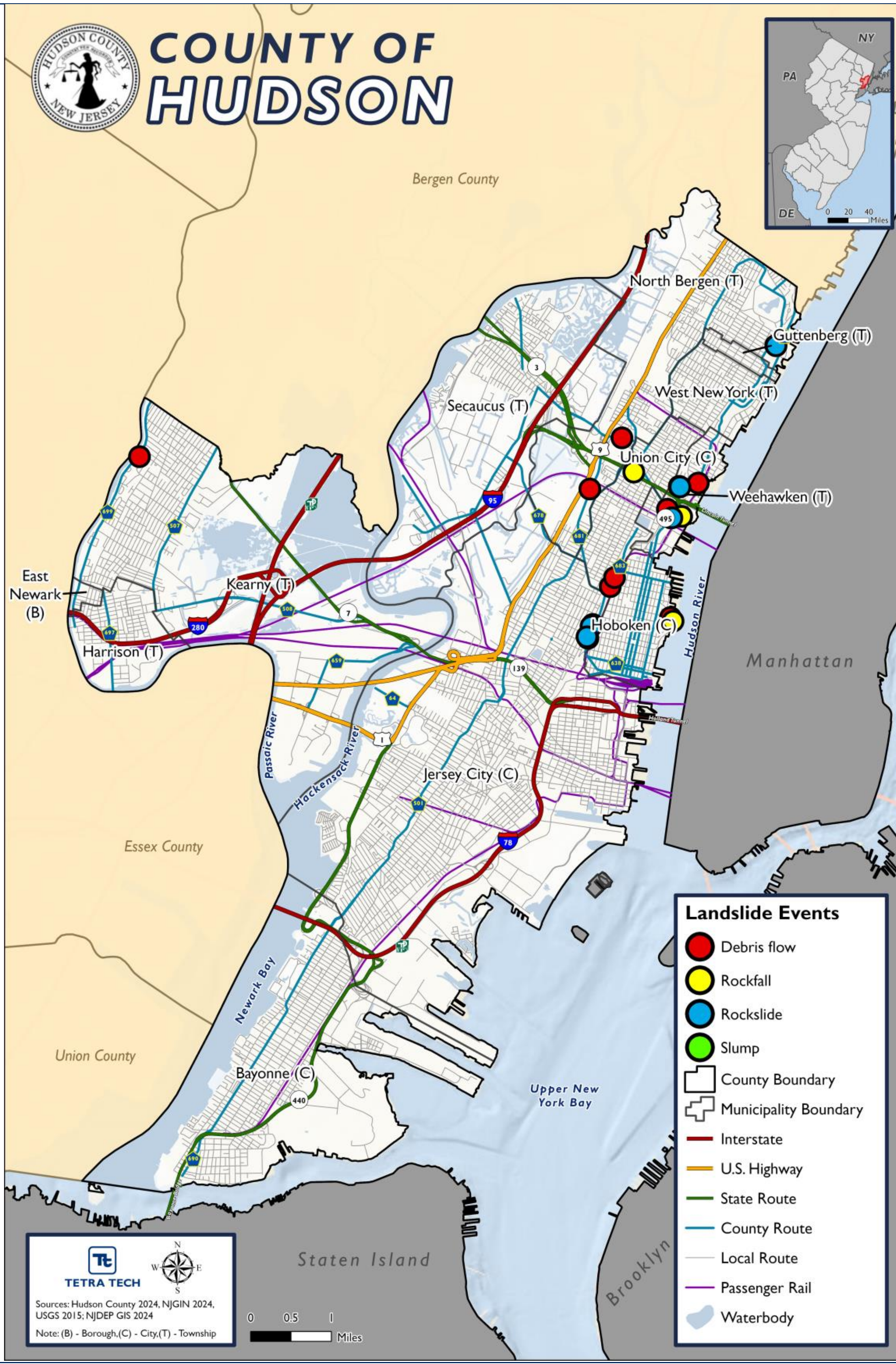
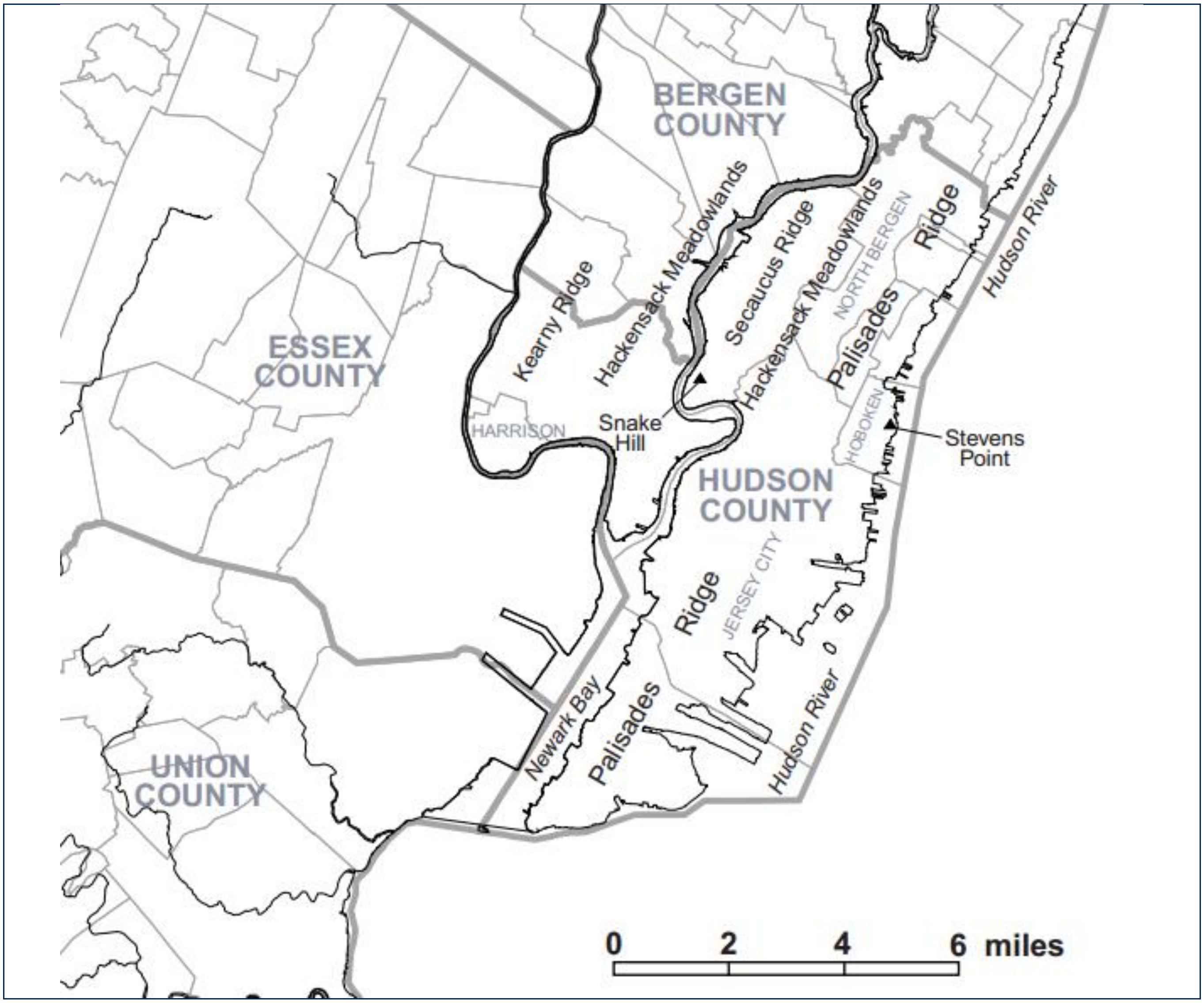


Figure 10-4. Landslide Susceptibility in Hudson County

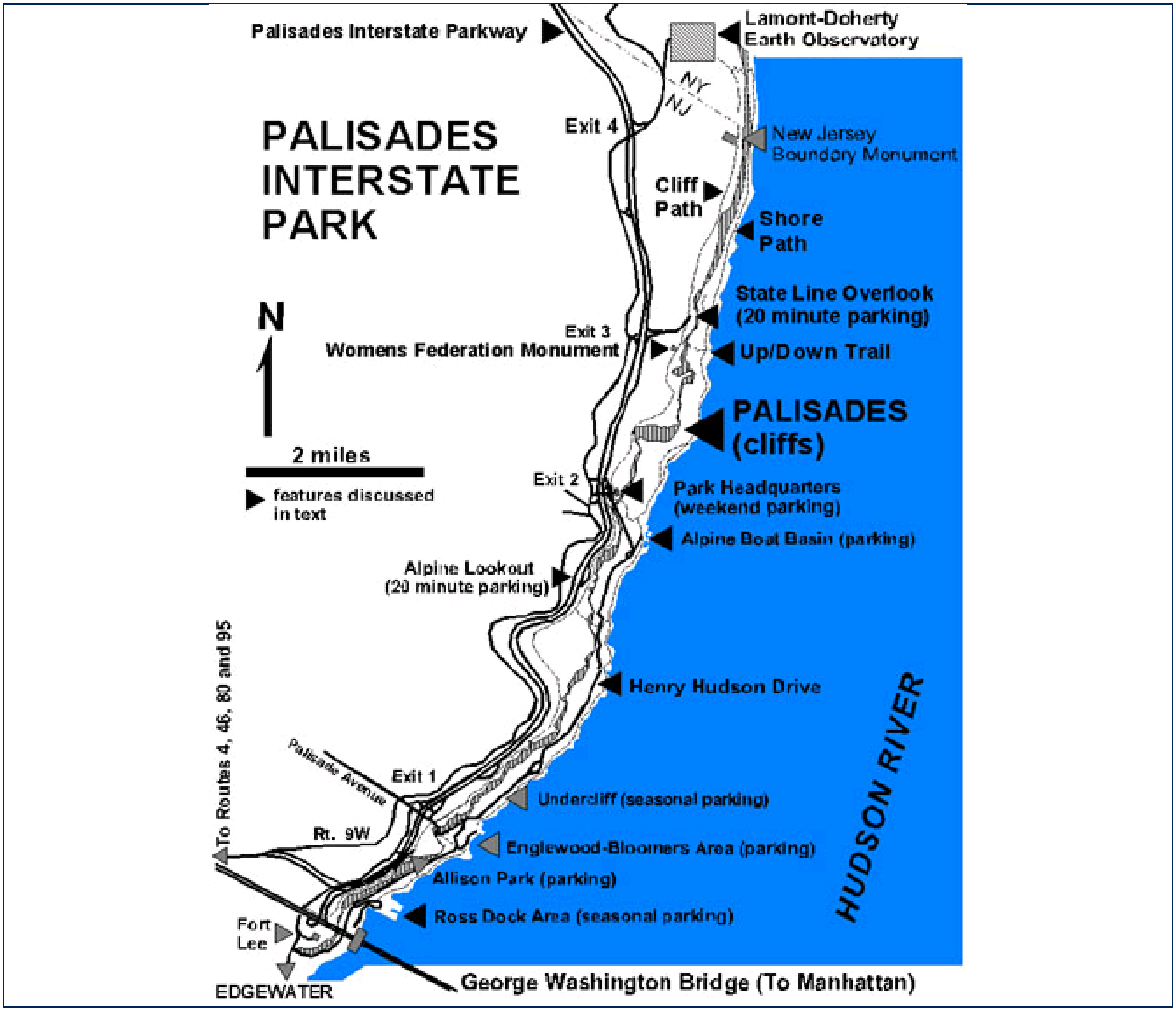
Figure 10-5. Geological Features in Hudson County



Source: NJGS 1999

According to the New Jersey Geological Survey (NJGS), the Palisades are the most active area for landslides in New Jersey (refer to Figure 10-6). The Palisades are cliffs that line the western margin of the Hudson River, from Jersey City to the south, to northward of the Tappan Zee Bridge. The cliffs and forested talus slopes rise more than 600 feet above the river (NJ Palisades Interstate Park Commission 2024). In this region, large rockfalls and rockslides occur along the high cliffs bordering the Hudson River. These landslides are most common in the winter and spring months after freeze-thaw cycles occur and loosen pieces of rock along joints and fractures. Surface water also seeps into joints and cracks along the rock, increasing the weight of the rocks and causing the expansion of joints when it freezes, thus prying blocks away from the main cliff (NJGS 2009).

Figure 10-6. New Jersey Palisades



Source: USGS n.d.

SUBSIDENCE/SINKHOLES

New Jersey is susceptible to the effects of subsidence and sinkholes, primarily in the northern region of the state. Land subsidence and sinkholes have been known to occur as a result of natural geologic phenomenon or as a result of human alteration of surface and underground geology. Naturally occurring subsidence and sinkholes in the State occur within bands of carbonate bedrock. In northern New Jersey, there are more than 225 square miles that are underlain by limestone, dolomite, and marble. In some areas, no sinkholes have appeared, while in others, sinkholes are common. Sinkholes in New Jersey are generally concentrated in the northwestern part of the state.

Areas underlain by carbonate rock may contain surface depressions and open drainage passages making such areas unstable and susceptible to subsidence and surface collapse. As a result, the alteration of drainage patterns, placement of impervious coverage, grade changes or increased loads can result in land subsidence and sinkhole formation (AGI 2001). These formations are areas of potential natural subsidence. These geologic units contain a high enough percentage of carbonate minerals such as calcite and/or dolomite for karst features such as sinkholes to form. Some of these units are more prone to sinkhole development than others due to a greater carbonate content in the rock. Although not every unit listed has documented sinkholes, all are susceptible to dissolution by groundwater so various karst features, including sinkholes, may be found on any of these units. Hudson County does not contain carbonate rock formations.

The region's susceptibility to subsidence is also due in part to the number of abandoned mines throughout the State of New Jersey. There are approximately 450 underground mines in New Jersey, all of which are now abandoned. Although these mines have closed, continued development in the northern part of the State has been problematic because of the extensive mining there which has caused widespread subsidence. One problem is that the mapped locations of some of the abandoned mines are not accurate. Another issue is that many of the surface openings were improperly filled in, and roads and structures have been built adjacent to or on top of these former mine sites. Hudson County does not have any abandoned mines (NJOEM 2019).

10.1.3 Extent

EARTHQUAKES

Event Magnitude

An earthquake's magnitude describes the size at the focal point of an earthquake. Magnitude is 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) (USGS 2012).

Intensity, Shaking, and Peak Ground Acceleration

An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region, depending 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.

The most used intensity scale is the modified Mercalli intensity scale (MMI). Ratings of the scale, as well as the perceived shaking and damage potential for structures, are shown in Table 10-3. The modified Mercalli intensity scale is generally represented visually using maps that show the expected ground shaking at any given location produced by an earthquake with a specified magnitude and epicenter.

The ground experiences acceleration as it shakes during an earthquake. The peak ground acceleration (PGA) is the largest acceleration that occurs during an earthquake. 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 (%g). Horizontal and vertical PGA varies with soil or rock type (UNDRR n.d.). Table 10-4 displays the MMI scale and its relationship to PGA. Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in Table 10-5.

Table 10-3. Modified Mercalli Intensity Scale

Mercalli Intensity	Description
a	Felt by very few people; barely noticeable.
II	Felt by few people, especially on upper floors.
III	Noticeable indoors, especially on upper floors, but may not be recognized as an earthquake.
IV	Felt by many indoors, few outdoors. May feel like passing truck.
V	Felt by almost everyone, some people awakened. Small objects move; trees and poles may shake.
VI	Felt by everyone; people have trouble standing. Heavy furniture can move; plaster can fall off walls. Chimneys may be slightly damaged.
VII	People have difficulty standing. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.
VIII	Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Some walls collapse.
IX	Considerable damage to specially built structures; buildings shift off foundations. The ground cracks. Landslides may occur.
X	Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, and lakes. The ground cracks in large areas.
XI	Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed.
XII	Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.

Source: USGS 2021

Table 10-4. Modified Mercalli Intensity and PGA Equivalents

Modified Mercalli Intensity	Peak Ground Acceleration (%g)	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

Source: USGS 2021

Table 10-5. Damage Levels Experienced in Earthquakes

Ground Motion	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 and more damage in poorly designed buildings. 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 2011

Note: %g = peak ground acceleration as a percent of the acceleration due to gravity.

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. The USGS updated the National Seismic Hazard Maps in 2023 for all 50 states using new science on seismicity, fault ruptures, ground motions, and probabilistic techniques to produce a standard of practice for public policy and other engineering applications (USGS 2023).

A probabilistic assessment was conducted for the 500- and 2,500-year mean return period (MRP) in Hazus 6.1 to analyze the earthquake hazard for Hudson County. In summary, a 500-year MRP is an earthquake with 0.2 percent chance that mapped PGAs will be exceeded in any given year. A 2,500-year MRP is an earthquake with 0.04 percent chance that mapped PGAs will be exceeded in any given year. The Hazus analysis evaluates the statistical likelihood that a specific event will occur and what consequences will occur. Figure 10-7 and Figure 10-8 show the geographic distribution of PGA for the 500- and 2,500-year MRP events.

Liquefaction

Liquefaction occurs in saturated soils and when it occurs, the strength of the soil decreases and the ability of a soil deposit to support foundations for buildings and bridges is reduced. Liquefaction has been responsible for tremendous amounts of damage in historical earthquakes around the world. Shaking behavior and liquefaction susceptibility of soils are determined by their grain size, thickness, compaction, and degree of saturation. These properties, in turn, are determined by the geologic origin of the soils and their topographic position.

In Hudson County, NJGWS classified soils into the Hazus categories using Standard Penetration Test data, which were acquired during the drilling of test borings. Approximately 300 borings in the Hudson County-Newark area contained engineering data usable for Hazus soil classification. The boring logs also reported the water table depth, which marks the upper limit of saturation. This information, along with the grain size and compaction of the soil, was used to map liquefaction susceptibility in Hudson County. The coverage shows the liquefaction susceptibility of natural soils. Man-made fill overlies these soils, particularly those in Category 4, in some areas. Typically, fill has a low liquefaction susceptibility, uncompacted sand, and silt fills may liquefy. The behavior or fill during seismic shaking should be addressed on a site-specific basis. The categories are as follows:

- Category 1 – Very Low
- Category 2 – Low
- Category 3 – Moderate
- Category 4 – High

As shown in Figure 10-9, liquefaction susceptibility varies throughout Hudson County. A central band of the County, from the Town of Guttenberg to the City of Bayonne is shown as having a very low susceptibility. Areas along the Newark Bay and Upper New York Bay and Hudson River are shown as having high liquefaction susceptibility, as shown in Figure 10-10. Parts of Secaucus, East Newark, Hoboken, and Jersey City have areas of low to moderate susceptibility.

Figure 10-7. Peak Ground Acceleration 500-Year Mean Return Period for Hudson County

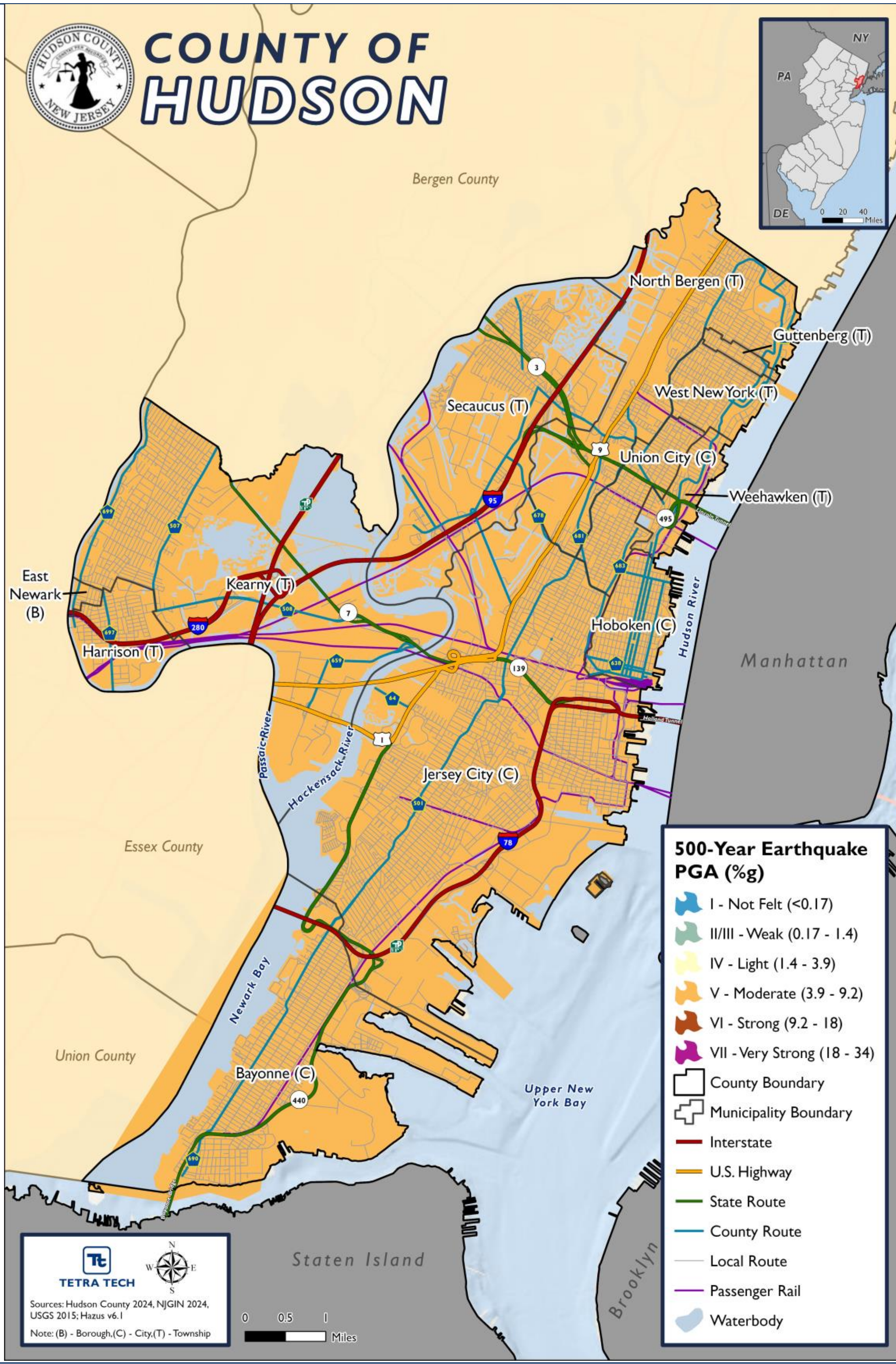


Figure 10-8. Peak Ground Acceleration 2,500-Year Mean Return Period for Hudson County

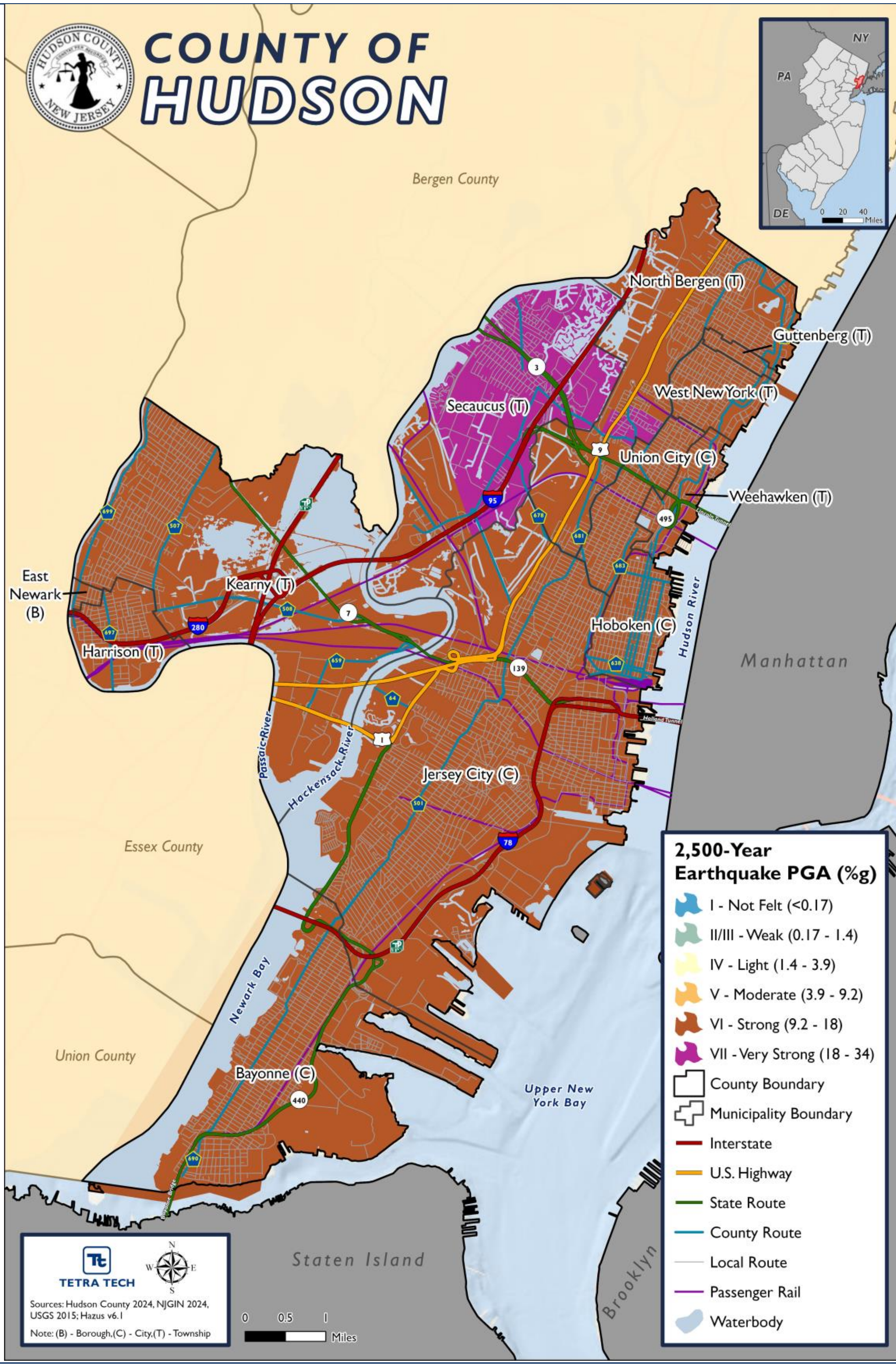


Figure 10-9. Liquefaction Classes in Hudson County

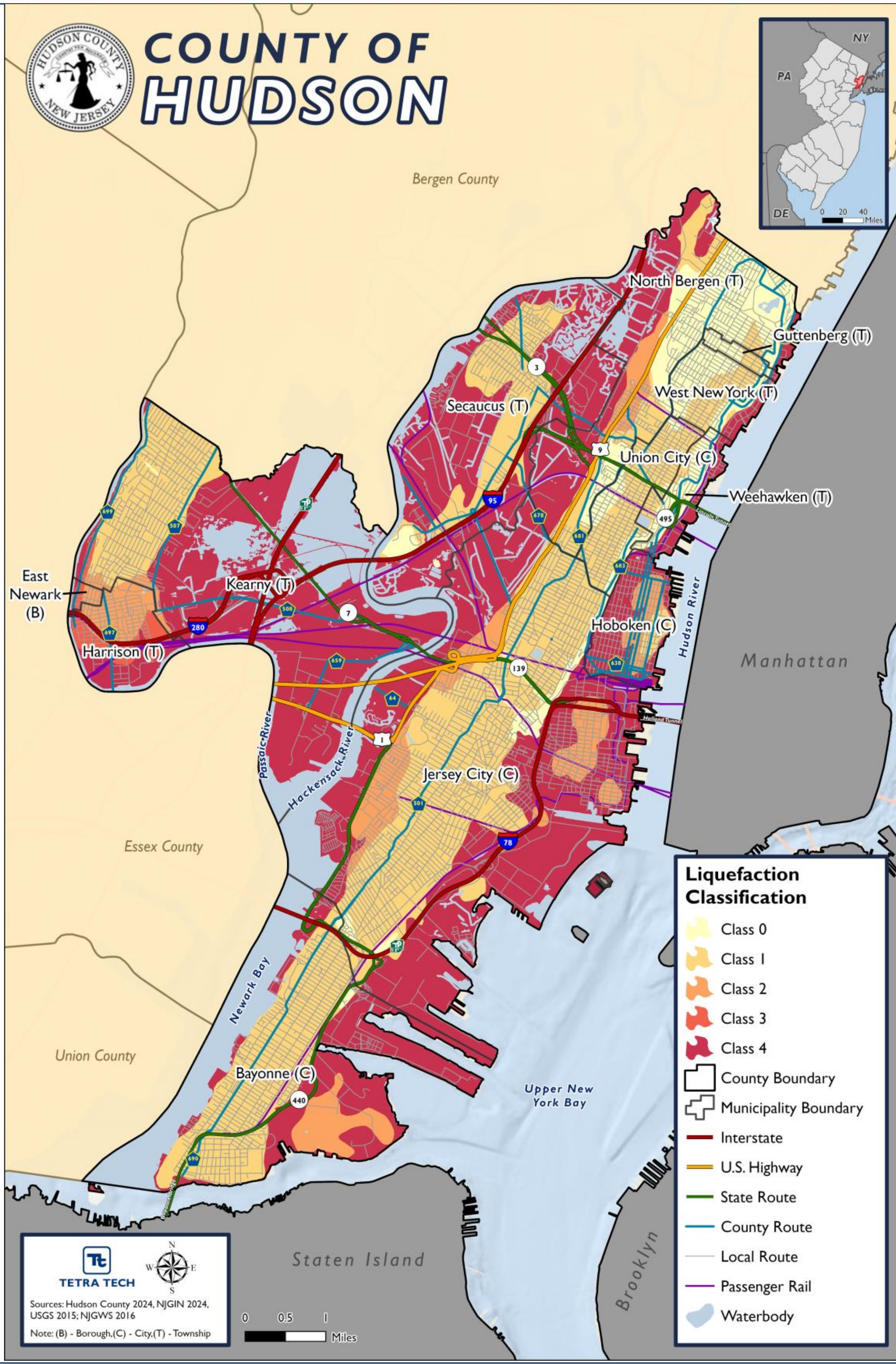
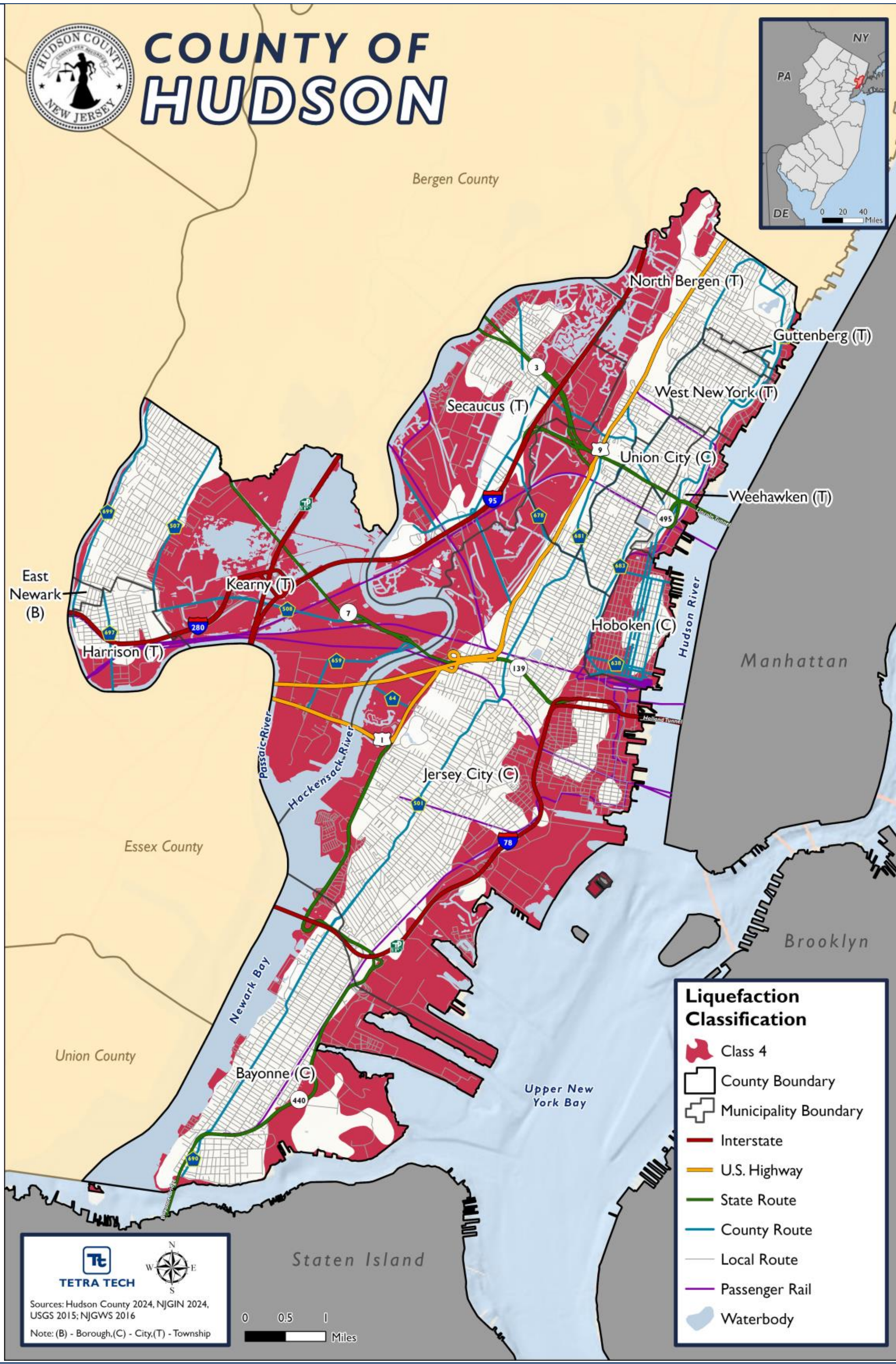


Figure 10-10. Liquefaction, Class 4 Only, in Hudson County



LANDSLIDES

To determine the extent of a landslide hazard, the affected areas need to be identified and the probability of the landslide occurring within some time period needs to be assessed. Natural variables that contribute to the overall extent of potential landslide activity in an area include soil properties, topographic position and slope, and historical incidence. The landslide hazard is often represented by landslide incidence and/or susceptibility, as defined below (NJGWS 2013):

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15 percent of a given area has been involved in landsliding; medium incidence means that 1.5 to 15 percent of an area has been involved; and low incidence means that less than 1.5 percent of an area has been involved.
- Landslide susceptibility is the probable degree of response of geologic formations to natural or artificial cutting, to loading of slopes, or to unusually high precipitation. It can be assumed that unusually high precipitation or changes in existing conditions can initiate landslide movement. Landslide susceptibility depends on slope angle and the geologic material underlying the slope. High, medium, and low susceptibility are delimited by the same percentages used for classifying the incidence of landsliding.

SUBSIDENCE/SINKHOLES

Subsidence in the U.S. has directly affected more than 17,000 square miles in 45 states, and associated annual costs are estimated to be $125 million. Global positioning systems (GPS) are used to monitor subsidence on a regional scale. Benchmarks are commonly spaced approximately 4 miles apart (USGS 2013).

Another method to monitor subsidence is Interferometric Synthetic Aperture Radar (InSAR). InSAR is a remote sensing technique that uses radar signals to interpolate land surface elevation changes. It is a cost-effective solution for measuring land surface deformation for a region while offering a high degree of spatial detail and resolution (USGS 2013).

10.1.4 Previous Occurrences

FEMA MAJOR DISASTER AND EMERGENCY DECLARATIONS

Between 1954 and 2023, Hudson County was not included in any DR or EM declarations for geological hazard-related events (FEMA 2023).

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 contiguous counties. Between 2019 and 2023, Hudson County was not included in any USDA geological hazard-related agricultural disaster declarations (USDA 2024).

PREVIOUS EVENTS

There have been two rockslide events that impacted Hudson County between August 2019 and December 2023, as shown below in Table 10-6. No events prior to 2019 have been recorded in past Hudson County HMP updates.

Table 10-6. Geological Hazard Events sin Hudson County (2019 to 2023)

Date	Hazard Type	FENA Declaration Number	Hudson County Included in Declaration?	Location Impacted	Description
September 2023	Rockslide	N/A	N/A	North Bergen	Minor rockslide reported on the cliffs in back of the Duchess, 7601 River Road.
December 2023	Rockslide	N/A	N/A	North Bergen	Dozens of vehicles parked behind a North Bergen high-rise at the foot of the Palisades were badly damaged in a rockslide at The Duchess at 7601 River Rd. The falling rock even causing some damage to the parking garage.

(NJDEP Bureau of GIS 2024)

10.1.5 Probability of Future Occurrences

PROBABILITY BASED ON PREVIOUS OCCURRENCES

Historically, New Jersey and Hudson County have not experienced a major geological hazard event. However, there have been a number of earthquakes of relatively low intensity. The majority of earthquakes that have occurred in New Jersey have occurred along faults in the central and eastern Highlands, with the Ramapo fault being the most seismically active fault in the region (Volkert 2015). Small earthquakes may occur several times a year and generally do not cause significant damage. Based on historical records, as summarized in Table 10-7, and input from the Steering Committee, the probability of occurrence for Hazard in the County is considered "occasional."

Table 10-7. Probability of Future Geological Hazards

Hazard Type	Number of Occurrences Between 1939 and 2024	Percent Chance of Occurring in Any Given Year
Earthquakes	6	7.0 %
Landslides	0	0 %
Rockslides/Rockfalls	11	12.8 %
Debris Flow	10	11.6 %
Subsidence/Sinkholes	0	0 %
Total	**27**	**31.4 %**

Source: (NJDEP Bureau of GIS 2024); (Hudson County 2020); (NOAA NCEI 2024)

EFFECT OF CLIMATE CHANGE ON FUTURE PROBABILITY

Earthquakes

The potential impacts of global climate change on earthquake probability are unknown. Some scientists feel 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. The National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes (NJOEM 2019). The lack of glaciers in New Jersey and the surrounding area makes it unlikely that glacier retreat will increase the occurrence of earthquake in Hudson County.

Secondary impacts of earthquakes could be magnified by future climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity because of the increased saturation. Dams storing increased volumes of water from changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts (NJOEM 2019).

Landslides

Increase in global temperature could affect the snowpack and its ability to hold and store water, resulting in an increase in the occurrence and duration of droughts. This in turn could increase the probability of wildfire, leading to the reduction in vegetation growth that helps to support steep slopes. Climate change may impact storm patterns, increasing the probability of more frequent, intense storms that could loosen unprotected soils. All these factors would increase the probability for landslide occurrences.

Subsidence/Sinkholes

One of the triggers for subsidence and sinkholes is an abundance of moisture which has the potential to permeate the bedrock causing an event. Climatologists expect an increase in annual precipitation amounts. This increase will coincide with an increased risk in subsidence and sinkholes in vulnerable areas.

Recently, sinkholes have been correlated to land use practices, especially from groundwater pumping and from construction and development practices. Sinkholes may form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The weight of new material can trigger an underground collapse of supporting material, causing a sinkhole. Additionally, the overburden sediments that cover buried cavities in the aquifer systems are balanced by groundwater fluid pressure. Groundwater is helping keep the surface soil in place. Pumping groundwater for urban water supply and irrigation can produce new sinkholes. If pumping results in a lowering of groundwater levels, then underground structural failure, sinkholes may occur as well (USGS 2018).

10.1.6 Cascading Impacts on Other Hazards

Geological hazards, such as earthquakes or landslides, can elevate the risk of a dam failure. Seismic activity can cause slumping or settling of earth-filled dams, especially if the fill is not properly compacted. If the slumping occurs when the dam is full, then overtopping of the dam, with rapid erosion leading to dam failure is possible. Dam failure is also possible if strong ground motions heavily damage concrete dams. Earthquake-induced landslides into reservoirs have also caused dam failures.

10.2 Vulnerability and Impact Assessment

To estimate the County's risk to the geologic hazard, the following hazard datasets were analyzed:

- NEHRP Class D and E Soils (earthquake risk)
- Liquefaction Class 4 (earthquake risk)
- Geological Class A (landslide, sinkhole, subsidence risk)

These datasets were overlaid on the updated asset inventory maps (population, building stock, critical facilities, and new development). Assets with their centroid located in the hazard area were totaled to estimate the totals and values at risk from the impacts of a geologic event.

The risk assessment for earthquake also included a Level 2 probabilistic assessment in Hazus for the 500- and 2,500-year MRP events to estimate injuries and structure damage. The probabilistic method uses information from historic earthquakes and inferred faults, locations and magnitudes, and computes the probable ground shaking levels that may be experienced during a recurrence period.

10.2.1 Life, Health, and Safety

OVERALL POPULATION

Earthquakes

The entire County may experience the impacts of an earthquake. The degree of impact on people is dependent on the age and type of construction people live in, the soil type that homes are located on, and the intensity of the earthquake. 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.

NEHRP Soil Classes D and E amplify ground shaking to damaging levels even during a moderate earthquake and thus increase risk to the population. As shown in Table 10-8, 115,322 persons live within the NEHRP Soils Class D and E hazard areas. The City of Jersey City has the greatest population in the hazard area with 52,524 persons.

Table 10-9 shows that 81,622 persons live in the Liquefaction Class 4 hazard area. The City of Hoboken has the greatest population in the hazard area with 38,311 persons.

Hazus estimated the number of people who might be injured or killed by an earthquake,. The analysis provided casualty estimates for three times of day to reflect peak occupancy in different community sectors. The 2:00 AM estimate represents maximum residential occupancy, the 2:00 PM estimate represents peak occupancy in educational, commercial, and industrial sectors, and the 5:00 PM estimate represents peak commute time. The Hazus analysis was conducted for the 500- and 2,500-year MRP events; results for each are shown in Table 10-10.

Table 10-8. Estimated Population Living in the NEHRP Soils Class D and E Hazard Areas

Jurisdiction	Total Population (2020 Decennial)	Population in the NEHRP Soils (D&E) Hazard Area	
		Number of Persons	% of Jurisdiction Total
Bayonne (C)	71,686	845	1.2%
East Newark (B)	2,594	2,465	95.0%
Guttenberg (T)	12,017	905	7.5%
Harrison (T)	19,450	18,888	97.1%
Hoboken (C)	60,419	33,451	55.4%
Jersey City (C)	292,449	52,524	18.0%
Kearny (T)	41,999	2,234	5.3%
North Bergen (T)	63,361	136	0.2%
Secaucus (T)	22,181	2,792	12.6%
Union City (C)	68,589	0	0.0%
Weehawken (T)	17,197	625	3.6%
West New York (T)	52,912	457	0.9%
Hudson County (Total)	**724,854**	**115,322**	**15.9%**

Source: U.S. Census Bureau 2020; NJGWS 2016

Table 10-9. Population in the Liquefaction Class 4 Hazard Area

Jurisdiction	Total Population (2020 Decennial)	Population in the Liquefaction Class 4 Hazard Area	
		Number of Persons	% of Jurisdiction Total
Bayonne (C)	71,686	2,855	4.0%
East Newark (B)	2,594	0	0.0%
Guttenberg (T)	12,017	611	5.1%
Harrison (T)	19,450	62	0.3%
Hoboken (C)	60,419	38,311	63.4%
Jersey City (C)	292,449	34,337	11.7%
Kearny (T)	41,999	1,662	4.0%
North Bergen (T)	63,361	136	0.2%
Secaucus (T)	22,181	2,941	13.3%
Union City (C)	68,589	0	0.0%
Weehawken (T)	17,197	250	1.5%
West New York (T)	52,912	457	0.9%
Hudson County (Total)	**724,854**	**81,622**	**11.3%**

Source: U.S. Census Bureau 2020; NJGWS 2016

Table 10-10. Estimated Casualties from 500- and 2,500-Year Mean Return Period Earthquake Events

Time of Day Event Occurs	Non-Hospitalized Injuries	Hospitalizations	Casualties
500-Year Mean Return Period			
2:00 a.m.	4	0	0
2:00 p.m.	13	1	0
5:00 p.m.	4	0	0
2,500-Year Mean Return Period			
2:00 a.m.	64	5	0
2:00 p.m.	153	27	5
5:00 p.m.	65	9	1

Source: Hazus v6.1

Residents may be displaced or require temporary to long-term sheltering as a result of the 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 after a disaster event. After running Hazus v6.1 it is estimated that there will be eight displaced households and three persons requiring sheltering for Hudson County for any earthquake event with a 500-Year Mean Return Period and for the 2,500-Year Mean Return Period there will be 400 displaced households, and 171 persons who would require sheltering needs as shown in Table 10-11.

Table 10-11. Person Seeking Sheltering, 500- and 2,500-Year Mean Return Period Earthquake Event

Jurisdiction	500-Year Mean Return Period Earthquake Event		2,500-Year Mean Return Period Earthquake Event	
	Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering
Bayonne (C)	0	0	17	9
East Newark (B)	0	0	0	0
Guttenberg (T)	0	0	1	0
Harrison (T)	0	0	4	2
Hoboken (C)	0	0	14	5
Jersey City (C)	8	3	318	132
Kearny (T)	0	0	10	5
North Bergen (T)	0	0	10	5
Secaucus (T)	0	0	7	3
Union City (C)	0	0	11	7
Weehawken (T)	0	0	2	0
West New York (T)	0	0	6	3
Hudson County (Total)	**8**	**3**	**400**	**171**

Source: Hazus v6.1, US Census Bureau 2020

Landslides and Subsidence/Sinkholes

Generally, a landslide or subsidence event is an isolated incidence, impacting the populations within the immediate area. Specifically, the population located downslope of the landslide hazard areas are vulnerable. In addition to causing damages to residential buildings and displacing residents, landslides and subsidence events can block or damage major roadways and inhibit travel for emergency responders or populations trying to evacuate the area.

Table 10-12 summarizes the population living in the geological class A hazard area. Overall, 7,109 persons are living in this hazard area. The Township of Guttenberg has the highest number of persons, 3,249 (27.0-percent of the jurisdictions total) exposed to the class A hazard area.

Table 10-12. Estimated Population in the Geological Class A Hazard Areas

Jurisdiction	Total Population (2020 Decennial)	Population in the Class A Hazard Area	
		Number of Persons	% of Jurisdiction Total
Bayonne (C)	7,726	0	0.0%
East Newark (B)	89,451	0	0.0%
Guttenberg (T)	8,945	3,249	27.0%
Harrison (T)	19,456	0	0.0%
Hoboken (C)	14,229	917	1.5%
Jersey City (C)	8,801	53	<0.1%
Kearny (T)	70,048	0	0.0%
North Bergen (T)	157,864	754	1.2%
Secaucus (T)	11,052	0	0.0%
Union City (C)	6,299	1,095	1.6%
Weehawken (T)	11,692	982	5.7%
West New York (T)	10,975	59	0.1%
Hudson County (Total)	**11,217**	**7,109**	**1.0%**

Source: U.S. Census Bureau 2020; NJGWS 2016

Socially Vulnerable Population

Populations most vulnerable to geological hazards such as earthquakes, landslides, and subsidence are those living in or near built environments, especially near unreinforced masonry construction. Among these, socially vulnerable groups, including the elderly (over age 65) and individuals living below the poverty threshold, are particularly susceptible. This increased vulnerability is due to factors like decreased mobility, limited financial resources to respond to hazards, and the quality and location of their housing. Research indicates that while some populations may not face higher hazard exposure, they can experience more severe impacts and longer recovery times if affected. For instance, the elderly and those living in poverty are at greater risk during geological events due to potential limited access to mobilization or medical resources.

Earthquakes

Table 10-13 presents the estimated socially vulnerable populations located within the NEHRP Soils Class D and E hazard areas. There are 11,402 persons over the age of 65 years, 7,655 persons under the age of 5 years, 12,061 non-English speakers, 8,021 persons with a disability, and 14,248 living in poverty located in these hazard areas. Table 10-14 presents the estimated socially vulnerable populations located within the Liquefaction Class 4 hazard area. There are 7,534 persons over the age of 65 years, 5,538 persons under the age of 5 years, 6,069 non-English speakers, 5,385 persons with a disability, and 8,803 living in poverty located in this hazard area.

Landslides and Subsidence/Sinkholes

Table 10-15 presents the estimated socially vulnerable populations living in the geological class A hazard areas. There are 878 persons over the age of 65 years, 453 persons under the age of 5 years, 1,070 non-English speakers, 671 persons with a disability, and 967 living in poverty located in this hazard area.

10.2.2 General Building Stock

EARTHQUAKE

Location on Susceptible Soils

There are 21,061 buildings with a replacement cost value of approximately $43 billion built on lands in the NEHRP D and E soils hazard area. The City of Hoboken has the greatest number of buildings built in the NEHRP D and E Soils hazard area; 7,720 buildings (54.0-percent of its total building stock) with an estimated replacement cost of $4.2 billion. Table 10-16 summarizes the number of buildings built on the NEHRP D and E Soils hazard area and the total replacement cost of these buildings by jurisdiction. Table 10-17 displays the buildings by general occupancy located within the NEHRP D and E hazard area. The exposure analysis estimates that the residential occupancy is the most exposed to this hazard area with 16,816 total buildings. The City of Hoboken holds the highest number of resident buildings (7,331) in the hazard area.

There are 16,419 buildings with a replacement cost value of approximately $39 billion built on lands in the Liquefaction Class 4 hazard area. The City of Hoboken has the greatest number of buildings built in the Liquefaction Class 4 hazard area; 8,881 buildings (62.2-percent of its total building stock) with an estimated replacement cost of $4.8 billion. Table 10-18 summarizes the number of buildings built on the Liquefaction Class A hazard area and the total replacement cost of these buildings by jurisdiction. Table 10-19 displays the buildings by general occupancy located in the Liquefaction Class 4 hazard area. The exposure analysis estimates that the residential occupancy is the most exposed to this hazard with a total of 13,420 residential buildings. The City of Hoboken has the highest number of residential buildings (8,396) in this hazard area.

Table 10-13. Estimated Vulnerable Persons Located in the NEHRP D & E Soils Hazard Area

Jurisdiction	Estimated Number of Vulnerable Persons Located in the NEHRP D & E Soils Hazard Area									
	Persons Over 65	Percent of Total	Persons Under 5	Percent of Total	Non-English Speaking Persons	Percent of Total	Persons with a Disability	Percent of Total	Persons in Poverty	Percent of Total
Bayonne (C)	117	1.2%	60	1.2%	66	1.2%	80	1.2%	99	1.2%
East Newark (B)	292	94.8%	100	94.3%	450	95.0%	198	94.7%	606	95.0%
Guttenberg (T)	121	7.5%	61	7.5%	151	7.5%	100	7.5%	141	7.5%
Harrison (T)	2,004	97.1%	1,148	97.0%	3,978	97.1%	1,403	97.1%	2,639	97.1%
Hoboken (C)	2,136	55.4%	2,270	55.4%	1,446	55.4%	1,702	55.3%	2,497	55.4%
Jersey City (C)	5,867	18.0%	3,677	18.0%	5,221	18.0%	4,022	18.0%	7,747	18.0%
Kearny (T)	290	5.3%	143	5.3%	299	5.3%	170	5.3%	226	5.3%
North Bergen (T)	22	0.2%	8	0.2%	23	0.2%	13	0.2%	15	0.2%
Secaucus (T)	422	12.6%	132	12.5%	270	12.6%	245	12.6%	141	12.6%
Union City (C)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Weehawken (T)	74	3.6%	36	3.6%	45	3.6%	38	3.6%	45	3.6%
West New York (T)	57	0.9%	20	0.8%	112	0.9%	50	0.9%	92	0.9%
Hudson County (Total)	**11,402**	**13.2%**	**7,655**	**16.3%**	**12,061**	**12.9%**	**8,021**	**13.1%**	**14,248**	**14.3%**

Source: US Census Bureau, ACS 5-Year Estimates; NJGWS 2016

Table 10-14. Estimated Vulnerable Persons Located in the Liquefaction Class 4 Hazard Area

Jurisdiction	Estimated Number of Vulnerable Persons Located in the Liquefaction Class 4 Hazard Area									
	Persons Over 65	Percent of Total	Persons Under 5	Percent of Total	Non-English Speaking Persons	Percent of Total	Persons with a Disability	Percent of Total	Persons in Poverty	Percent of Total
Bayonne (C)	396	4.0%	203	4.0%	225	4.0%	273	4.0%	335	4.0%
East Newark (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Guttenberg (T)	82	5.1%	41	5.1%	102	5.1%	68	5.1%	95	5.1%
Harrison (T)	6	0.3%	3	0.3%	13	0.3%	4	0.3%	8	0.3%
Hoboken (C)	2,446	63.4%	2,599	63.4%	1,656	63.4%	1,949	63.4%	2,860	63.4%
Jersey City (C)	3,836	11.7%	2,404	11.7%	3,413	11.7%	2,629	11.7%	5,064	11.7%
Kearny (T)	216	3.9%	106	3.9%	222	3.9%	126	3.9%	168	3.9%
North Bergen (T)	22	0.2%	8	0.2%	23	0.2%	13	0.2%	15	0.2%
Secaucus (T)	444	13.2%	140	13.3%	285	13.3%	258	13.2%	148	13.2%
Union City (C)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Weehawken (T)	29	1.4%	14	1.4%	18	1.4%	15	1.4%	18	1.4%
West New York (T)	57	0.9%	20	0.8%	112	0.9%	50	0.9%	92	0.9%
Hudson County (Total)	7,534	8.7%	5,538	11.8%	6,069	6.5%	5,385	8.8%	8,803	8.8%

Source: US Census Bureau, ACS 5-Year Estimates; NJGWS 2016

Table 10-15. Estimated Number of Vulnerable Persons Located in the Geological Class A Hazard Area

Jurisdiction	Estimated Number of Vulnerable Persons Located in the Geological Class A Hazard Area									
	Persons Over 65	Percent of Total	Persons Under 5	Percent of Total	Non-English Speaking Persons	Percent of Total	Persons with a Disability	Percent of Total	Persons in Poverty	Percent of Total
Bayonne (C)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
East Newark (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Guttenberg (T)	437	27.0%	219	27.0%	545	27.0%	361	27.0%	507	27.0%
Harrison (T)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Hoboken (C)	58	1.5%	62	1.5%	39	1.5%	46	1.5%	68	1.5%
Jersey City (C)	5	<0.1%	3	<0.1%	5	<0.1%	4	<0.1%	7	<0.1%
Kearny (T)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
North Bergen (T)	125	1.2%	45	1.2%	130	1.2%	72	1.2%	87	1.2%
Secaucus (T)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Union City (C)	130	1.6%	65	1.6%	265	1.6%	122	1.6%	216	1.6%
Weehawken (T)	116	5.7%	57	5.7%	72	5.7%	60	5.6%	71	5.7%
West New York (T)	7	0.1%	2	0.1%	14	0.1%	6	0.1%	11	0.1%
Hudson County (Total)	**878**	**1.0%**	**453**	**1.0%**	**1,070**	**1.1%**	**671**	**1.1%**	**967**	**1.0%**

Source: US Census Bureau, ACS 5-Year Estimates; NJGWS 2016

Table 10-16. Replacement Cost Values of Buildings in the NEHRP D & E Soils Hazard Area

Jurisdiction	Jurisdiction Total Buildings		Buildings in the NEHRP D&E Soils Hazard Area			
			Number of Buildings		Replacement Cost Value	
	Count	Replacement Cost Value	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Bayonne (C)	9,264	$11,278,964,959	1,084	11.7%	$4,056,799,464	36.0%
East Newark (B)	434	$300,712,303	413	95.2%	$291,565,176	97.0%
Guttenberg (T)	2,574	$1,062,772,505	188	7.3%	$97,070,195	9.1%
Harrison (T)	2,646	$2,812,269,922	2,566	97.0%	$2,773,660,855	98.6%
Hoboken (C)	14,289	$6,922,849,652	7,720	54.0%	$4,231,207,516	61.1%
Jersey City (C)	38,336	$29,829,276,781	7,229	18.9%	$13,187,265,915	44.2%
Kearny (T)	7,207	$9,630,626,567	885	12.3%	$6,244,169,746	64.8%
North Bergen (T)	6,002	$9,906,706,329	112	1.9%	$2,905,836,187	29.3%
Secaucus (T)	3,844	$12,075,088,549	694	18.1%	$8,435,759,036	69.9%
Union City (C)	1,729	$4,009,712,429	0	0.0%	$0	0.0%
Weehawken (T)	2,112	$1,638,112,105	122	5.8%	$643,984,158	39.3%
West New York (T)	4,594	$3,076,856,343	48	1.0%	$298,648,955	9.7%
Hudson County (Total)	**93,031**	**$92,543,948,444**	**21,061**	**22.6%**	**$43,165,967,204**	**46.6%**

Source: NJOIT 2024; Microsoft BING 2019; RS Means 2024; NJGWS 2016

Table 10-17. Buildings in the NEHRP D&E Soils Hazard Area by General Occupancy Class

Jurisdiction	Buildings in the NEHRP D&E Soils Hazard Area by General Occupancy Class			
	Residential	Commercial	Industrial	Other[a]
Bayonne (C)	90	29	907	58
East Newark (B)	364	22	19	8
Guttenberg (T)	176	0	0	12
Harrison (T)	2,121	257	69	119
Hoboken (C)	7,331	227	21	141
Jersey City (C)	5,877	637	315	400
Kearny (T)	332	65	360	128
North Bergen (T)	11	34	41	26
Secaucus (T)	413	100	115	66
Union City (C)	0	0	0	0
Weehawken (T)	70	22	6	24
West New York (T)	31	4	0	13
Hudson County (Total)	**16,816**	**1,397**	**1,853**	**995**

Source: NJOIT 2024; Microsoft BING 2019; NJGWS 2016

a. Other = Government, Religion, Agricultural, Education

Table 10-18. Replacement Cost Values of Buildings in the Liquefaction Class 4 Hazard Area

Jurisdiction	Jurisdiction Total Buildings		Buildings in the Liquefaction Class 4 Hazard Area			
			Number of Buildings		Replacement Cost Value	
	Count	Replacement Cost Value	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Bayonne (C)	9,264	$11,278,964,959	741	8.0%	$3,031,197,238	26.9%
East Newark (B)	434	$300,712,303	2	0.5%	$3,089,311	1.0%
Guttenberg (T)	2,574	$1,062,772,505	131	5.1%	$85,310,463	8.0%
Harrison (T)	2,646	$2,812,269,922	48	1.8%	$788,213,286	28.0%
Hoboken (C)	14,289	$6,922,849,652	8,881	62.2%	$4,795,091,918	69.3%
Jersey City (C)	38,336	$29,829,276,781	4,883	12.7%	$11,861,372,086	39.8%
Kearny (T)	7,207	$9,630,626,567	769	10.7%	$6,118,825,987	63.5%
North Bergen (T)	6,002	$9,906,706,329	137	2.3%	$3,172,230,337	32.0%
Secaucus (T)	3,844	$12,075,088,549	712	18.5%	$8,477,481,795	70.2%
Union City (C)	1,729	$4,009,712,429	0	0.0%	$0	0.0%
Weehawken (T)	2,112	$1,638,112,105	67	3.2%	$513,800,802	31.4%
West New York (T)	4,594	$3,076,856,343	48	1.0%	$298,648,955	9.7%
Hudson County (Total)	**93,031**	**$92,543,948,444**	**16,419**	**17.6%**	**$39,145,262,176**	**42.3%**

Source: NJOIT 2024; Microsoft BING 2019; RS Means 2024; NJGWS 2016

Table 10-19. Buildings in the Liquefaction Class 4 Hazard Area by General Occupancy Class

Jurisdiction	Buildings in the Liquefaction Class 4 Hazard Area by General Occupancy Class			
	Residential	Commercial	Industrial	Other[a]
Bayonne (C)	304	27	351	59
East Newark (B)	0	0	2	0
Guttenberg (T)	119	0	0	12
Harrison (T)	7	5	26	10
Hoboken (C)	8,396	303	26	156
Jersey City (C)	3,842	391	286	364
Kearny (T)	247	40	353	129
North Bergen (T)	11	38	61	27
Secaucus (T)	435	96	115	66
Union City (C)	0	0	0	0
Weehawken (T)	28	15	3	21
West New York (T)	31	4	0	13
Hudson County (Total)	**13,420**	**919**	**1,223**	**857**

Source: NJOIT 2024; Microsoft BING 2019; NJGWS 2016

a. Other = Government, Religion, Agricultural, Education

Level of Damage by Occupancy Class

The entire general building stock of the county is exposed to the earthquake hazard. Table 10-20 provides an analysis of the expected damage to various building types during earthquakes with 500-year and 2,500-year Mean Return Periods. For residential buildings, the majority are expected to sustain no damage, with 99.3 percent undamaged in the 500-year period and 91.1 percent in the 2,500-year period. Minor damage is expected in a small percentage, increasing from 0.7 percent to 7.6 percent as the return period lengthens. Moderate to severe damage and destruction are rare across all building types, with slightly higher percentages in the 2,500-year period. Commercial, industrial, and other buildings show similar trends, with most buildings remaining undamaged, and minor damage percentages increasing with longer return periods. Severe damage and destruction remain minimal across all categories. Another key factor in degree of vulnerability is age of facilities and infrastructure, which correlates with building standards in place at times of construction.

Table 10-20. Damage Severity by Occupancy Class

Total Number of Buildings in Occupancy	Severity of Expected Damage	500-Year Mean Return Period		2,500-Year Mean Return Period	
		Building Count	% Buildings in Occupancy Class	Building Count	% Buildings in Occupancy Class
Residential Exposure (Single and Multi-Family Dwellings)					
79,906	NONE	79,328	99.3%	72,769	91.1%
	MINOR	532	0.7%	6,036	7.6%
	MODERATE	46	0.1%	1,039	1.3%
	SEVERE	0	0.0%	61	0.1%
	DESTRUCTION	0	0.0%	1	<0.1%
Commercial Buildings					
7,174	NONE	7,129	99.4%	6,593	91.9%
	MINOR	36	0.5%	402	5.6%
	MODERATE	8	0.1%	165	2.3%
	SEVERE	0	0.0%	12	0.2%
	DESTRUCTION	0	0.0%	2	<0.1%
Industrial Buildings					
2,746	NONE	2,566	93.5%	1,993	72.6%
	MINOR	124	4.5%	423	15.4%
	MODERATE	48	1.8%	255	9.3%
	SEVERE	7	0.3%	65	2.4%
	DESTRUCTION	0	0.0%	11	0.4%
Other Buildings[a]					
3,205	NONE	3,162	98.7%	2,856	89.1%
	MINOR	33	1.0%	239	7.5%
	MODERATE	9	0.3%	95	3.0%
	SEVERE	1	<0.1%	13	0.4%
	DESTRUCTION	0	0.0%	2	0.1%

Source: Hazus v6.1; NJOIT 2024; Microsoft BING 2019

a. Other = Government, Religion, Agricultural, Education

Estimated Cost of Damage

Table 10-21 and Table 10-22 provide an overview of the estimated damage to structures and contents in various jurisdictions within Hudson County during earthquakes with a 500-Year and 2,500-Year Mean Return Period. The first table shows that the total replacement cost value (RCV) for the County is approximately $93 billion, with estimated damages to residential, commercial, and other buildings totaling around $38 million, which is less than 0.1 percent of the RCV. The second table presents details indicating that the total estimated damage for the 2,500-Year period is about $785 million, or 0.8 percent of the RCV. This includes significant damages across residential, commercial, and other buildings, with the City of Jersey City experiencing the highest total damage at approximately $248 million.

Table 10-21. Estimated Damage Costs Due to the 500-Year Mean Return Period Earthquake Events

Jurisdiction	Total Replacement Cost Value (RCV)	Estimated Damage to Structure and Contents				
		Residential	Commercial	Other[a]	Total	
					Damage	% of RCV
Bayonne (C)	$11,278,964,959	$1,090,766	$505,581	$3,333,091	$4,929,438	<0.1%
East Newark (B)	$300,712,303	$30,519	$3,917	$108,406	$142,842	<0.1%
Guttenberg (T)	$1,062,772,505	$85,370	$7,687	$36,272	$129,329	<0.1%
Harrison (T)	$2,812,269,922	$268,502	$52,069	$508,383	$828,954	<0.1%
Hoboken (C)	$6,922,849,652	$1,034,154	$210,553	$551,707	$1,796,415	<0.1%
Jersey City (C)	$29,829,276,781	$3,573,671	$1,177,206	$7,659,348	$12,410,224	<0.1%
Kearny (T)	$9,630,626,567	$607,385	$161,245	$5,160,319	$5,928,950	0.1%
North Bergen (T)	$9,906,706,329	$508,472	$418,476	$2,440,644	$3,367,591	<0.1%
Secaucus (T)	$12,075,088,549	$753,402	$724,500	$5,009,883	$6,487,784	0.1%
Union City (C)	$4,009,712,429	$473,860	$219,519	$494,003	$1,187,382	<0.1%
Weehawken (T)	$1,638,112,105	$168,695	$59,873	$123,232	$351,800	<0.1%
West New York (T)	$3,076,856,343	$173,556	$63,926	$201,533	$439,015	<0.1%
Hudson County (Total)	**$92,543,948,444**	**$8,768,352**	**$3,604,551**	**$25,626,820**	**$37,999,723**	**<0.1%**

Source: Hazus v6.1; NJOIT 2024; Microsoft BING 2019; RS Means 2024

a. Other = Industrial, Government, Religion, Agricultural, Education

Table 10-22. Estimated Damage Costs Due to 2,500-Year Mean Return Period Earthquake Events

Jurisdiction	Total Replacement Cost Value (RCV)	Estimated Damage to Structure and Contents				
		Residential	Commercial	Other[a]	Total	
					Damage	% of RCV
Bayonne (C)	$11,278,964,959	$28,800,121	$12,255,351	$58,149,892	$99,205,363	0.9%
East Newark (B)	$300,712,303	$783,309	$111,350	$1,999,788	$2,894,447	1.0%
Guttenberg (T)	$1,062,772,505	$3,463,684	$439,203	$1,031,316	$4,934,203	0.5%
Harrison (T)	$2,812,269,922	$6,935,384	$1,505,189	$13,401,278	$21,841,851	0.8%
Hoboken (C)	$6,922,849,652	$28,709,556	$6,180,246	$11,758,655	$46,648,457	0.7%
Jersey City (C)	$29,829,276,781	$84,583,264	$29,825,141	$133,977,061	$248,385,466	0.8%
Kearny (T)	$9,630,626,567	$15,278,578	$4,366,027	$81,127,459	$100,772,064	1.0%
North Bergen (T)	$9,906,706,329	$15,556,628	$12,112,857	$51,441,033	$79,110,518	0.8%

Jurisdiction	Total Replacement Cost Value (RCV)	Estimated Damage to Structure and Contents				
		Residential	Commercial	Other[a]	Total	
					Damage	% of RCV
Secaucus (T)	$12,075,088,549	$14,617,925	$14,467,785	$97,507,511	$126,593,220	1.0%
Union City (C)	$4,009,712,429	$13,839,922	$6,291,474	$9,244,695	$29,376,090	0.7%
Weehawken (T)	$1,638,112,105	$5,346,251	$2,039,053	$2,679,033	$10,064,337	0.6%
West New York (T)	$3,076,856,343	$7,280,262	$3,078,407	$5,101,244	$15,459,913	0.5%
Hudson County (Total)	**$92,543,948,444**	**$225,194,882**	**$92,672,082**	**$467,418,964**	**$785,285,928**	**0.8%**

Source: Hazus v6.1; NJOIT 2024; Microsoft BING 2019; RS Means 2024

a. Other = Industrial, Government, Religion, Agricultural, Education

LANDSLIDES AND SUBSIDENCE/SINKHOLES

In general, the built environment is vulnerable to the geological hazard if built on soils/geology susceptible to land sliding or sinkholes. Geological hazard areas may destabilize the foundation of structures resulting in monetary losses to businesses and residents. There are 1,072 buildings with a replacement cost value of approximately $574 million built on lands within the Geological Class hazard area. The Township of Guttenberg has the greatest number of buildings built in this area; 632 buildings (24.6-percent of its total building stock) with an estimated replacement cost of $216 million. Table 10-23 summarizes the number of buildings built on the Geological Class A hazard area and the total replacement cost of these buildings by jurisdiction.

Table 10-23. Replacement Cost Value of Buildings in the Geological Class A Hazard Area

Jurisdiction	Jurisdiction Total Buildings		Buildings in the Geological Class A Hazard Area			
			Number of Buildings		Replacement Cost Value	
	Count	Replacement Cost Value	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Bayonne (C)	9,264	$11,278,964,959	0	0.0%	$0	0.0%
East Newark (B)	434	$300,712,303	0	0.0%	$0	0.0%
Guttenberg (T)	2,574	$1,062,772,505	632	24.6%	$215,716,005	20.3%
Harrison (T)	2,646	$2,812,269,922	0	0.0%	$0	0.0%
Hoboken (C)	14,289	$6,922,849,652	204	1.4%	$87,308,478	1.3%
Jersey City (C)	38,336	$29,829,276,781	10	<0.1%	$41,898,680	0.1%
Kearny (T)	7,207	$9,630,626,567	0	0.0%	$0	0.0%
North Bergen (T)	6,002	$9,906,706,329	73	1.2%	$68,165,601	0.7%
Secaucus (T)	3,844	$12,075,088,549	0	0.0%	$0	0.0%
Union City (C)	1,729	$4,009,712,429	22	1.3%	$63,307,034	1.6%
Weehawken (T)	2,112	$1,638,112,105	120	5.7%	$55,654,929	3.4%
West New York (T)	4,594	$3,076,856,343	11	0.2%	$41,653,796	1.4%
Hudson County (Total)	**93,031**	**$92,543,948,444**	**1,072**	**1.2%**	**$573,704,523**	**0.6%**

Source: NJOIT 2024; Microsoft BING 2019; RS Means 2024; NJGWS 2016

Table 10-24 displays the buildings by general occupancy located within the Geological Class A hazard area. The exposure analysis estimates that across all subsidence hazard areas, the residential occupancy is the most exposed to the this hazard area with 1,034 total buildings. The Township of Guttenberg holds the highest number of resident buildings (632) in the hazard area.

Table 10-24. Buildings in the Geological Class A Hazard Area by General Occupancy Class

Jurisdiction	Buildings in the Geological Class A Hazard Area by General Occupancy Class			
	Residential	Commercial	Industrial	Other[a]
Bayonne (C)	0	0	0	0
East Newark (B)	0	0	0	0
Guttenberg (T)	632	0	0	0
Harrison (T)	0	0	0	0
Hoboken (C)	201	0	2	1
Jersey City (C)	6	1	2	1
Kearny (T)	0	0	0	0
North Bergen (T)	61	2	0	10
Secaucus (T)	0	0	0	0
Union City (C)	20	0	0	2
Weehawken (T)	110	3	4	3
West New York (T)	4	1	6	0
Hudson County (Total)	**1,034**	**7**	**14**	**17**

a. Other = Government, Religion, Agricultural, Education

10.2.3 Community Lifelines and Other Critical Facilities

EARTHQUAKE

All critical facilities in Hudson County are considered exposed to the earthquake hazard. The Hazus earthquake model was used to assign the range or average probability of each damage state category to the critical facilities in the County for the 500-Year and 2,500-Year Mean Return Period events. In addition, Hazus estimates the time to restore critical facilities to fully functional use. Results are presented as a probability of being functional at specified time increments (days after the event). For example, Hazus 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. For percent probability of sustaining damage, the minimum and maximum damage estimated value for that facility type is presented.

Table 10-25 provides an analysis of the average percent probability of sustaining damage and the average percent functionality of various lifeline systems during a 500-year MRP earthquake. The lifelines assessed include communications, energy, food, hydration, shelter, hazardous materials, health and medical, safety and security, transportation, and water systems.

Table 10-25. Average Percent Probability of Sustaining Damage, 500-Year MRP

Name	Average Percent Probability of Sustaining Damage 500-Year Mean Return Period					Average Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communications	97.0%	2.9%	<0.1%	<0.1%	0.0%	99.9%	99.9%	99.9%	99.9%
Energy	97.4%	1.5%	0.9%	0.1%	0.0%	98.2%	99.9%	99.9%	99.9%
Food, Hydration, Shelter	97.2%	2.1%	0.6%	0.1%	0.0%	97.1%	99.2%	99.9%	99.9%
Hazardous Materials	97.0%	2.3%	0.7%	0.1%	0.0%	96.9%	99.2%	99.9%	99.9%
Health and Medical	99.4%	0.6%	<0.1%	0.0%	0.0%	99.4%	99.9%	99.9%	99.9%
Safety and Security	97.1%	2.2%	0.6%	0.1%	0.0%	97.1%	99.2%	99.9%	99.9%
Transportation	99.8%	0.2%	<0.1%	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%
Water Systems	97.7%	1.3%	0.8%	0.1%	0.0%	98.2%	99.7%	99.8%	99.9%

Source: Hazus v6.1; Hudson County; HIFLD; NJGIN 2024

For most lifelines, the probability of sustaining no damage is very high, ranging from 97.0 percent to 99.8 percent. Slight damage is expected in a small percentage of cases, while moderate, extensive, and complete damage are rare. For instance, the transportation and health and medical systems have over 99 percent chance of sustaining no damage and less than a 0.1 percent chance of moderate damage.

In terms of functionality, most lifelines are expected to recover quickly. By Day 1, functionality ranges from 96.9 percent to 100.0 percent, and by Day 7, it improves to between 99.2 percent and 100.0 percent. By Day 30 and Day 90, nearly all lifelines are expected to be fully functional, with percentages close to or at 100 percent.

Table 10-26 provides an analysis of the average percent probability of sustaining damage and the average percent functionality of various lifeline systems during a 2,500-year MRP earthquake. The lifelines assessed include communications, energy, food, hydration, shelter, hazardous materials, health and medical, safety and security, transportation, and water systems.

Table 10-26. Average Percent Probability of Sustaining Damage, 2,500-Year MRP

Name	Average Percent Probability of Sustaining Damage 2,500-Year Mean Return Period					Average Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communications	58.6%	29.2%	8.9%	3.2%	0.1%	92.7%	98.2%	99.9%	99.9%
Energy	82.5%	8.5%	7.1%	1.9%	<0.1%	87.4%	98.9%	99.9%	99.9%
Food, Hydration, Shelter	80.9%	12.1%	5.8%	1.1%	0.1%	80.9%	93.0%	98.8%	99.8%
Hazardous Materials	80.2%	12.5%	6.1%	1.1%	0.1%	80.1%	92.6%	98.7%	99.8%
Health and Medical	92.8%	6.5%	0.7%	<0.1%	<0.1%	92.7%	99.1%	99.9%	99.9%
Safety and Security	80.9%	12.1%	5.8%	1.1%	0.1%	80.8%	92.7%	98.7%	99.4%
Transportation	97.8%	2.0%	0.2%	<0.1%	<0.1%	99.7%	99.9%	99.9%	99.9%
Water Systems	83.9%	7.9%	6.4%	1.7%	0.0%	87.3%	97.7%	98.5%	99.8%

Source: Hazus v6.1; Hudson County; HIFLD; NJGIN 2024

For most lifelines, the probability of sustaining no damage is relatively high, ranging from 80.2 percent to 97.8 percent, with the exception of communications showing a probability of 58.6 percent of sustaining no damage. Slight damage ranges from 2.0 percent to 29.2 percent, moderate damage ranges from 0.2 percent to 8.9 percent, extensive damage ranges from less than 0.1 percent to 3.2 percent, and complete damage is generally very low, ranging from less than 0.1 percent to 0.1 percent. This indicates that while slight and moderate damage are more common, extensive and complete damage are rare.

In terms of functionality, most lifelines are expected to recover significantly within the first week. By Day 1, functionality ranges from 80.1 percent to 99.7 percent, improving to between 92.6 percent and 99.9 percent by Day 7. By Day 30 and Day 90, nearly all lifelines are expected to be fully functional, with percentages close to 100 percent.

Table 10-27 shows the number of critical facilities located in the NEHRP D and E soils hazard area for Hudson County. There is a total of 455 facilities located in this hazard area with the highest number among the Transportation lifeline (143). The City of Jersey City has the highest number of critical facilities (156) located in the NEHRP D and E soils hazard area.

Table 10-28 outlines the number of critical facilities in the Liquefaction Class 4 Hazard Area across various jurisdictions in Hudson County, categorized by lifeline sectors. Again, the City of Jersey City has the highest number of facilities in this hazard area (145), followed by the City of Hoboken (90). Overall, Hudson County has 405 facilities in the Liquefaction Class 4 hazard area, accounting for 32.7 percent of the jurisdictional total.

LANDSLIDES AND SUBSIDENCE/SINKHOLES

In addition to critical facilities, a significant amount of infrastructure can be exposed to mass movements of geological material (USGS 2023):

- *Roads*—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides and sinkholes can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation. This can result in economic losses for businesses.
- *Bridges*—Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- *Power Lines*—Power lines are generally elevated above steep slopes; but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Sinkholes can swallow utility lines and cause impacts to underground pipes. Power and communication failures due to landslides and sinkholes can create problems for vulnerable populations and businesses.
- *Rail Lines*—Similar to roads, rail lines are important for response and recovery operations after a disaster. Landslides can block travel along the rail lines, which would become especially troublesome, because it would not be as easy to detour a rail line as it is on a local road or highway. Many residents rely on public transport to get to work around the County and into New York City, and a landslide event could prevent travel to and from work.

Table 10-27. Number of Facilities in the NEHRP D & E Soils Hazard Area, by Lifeline Category

Jurisdiction	Number of Facilities in the NEHRP D & E Soils Hazard Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Jurisdiction Total
Bayonne (C)	0	8	0	3	0	2	7	7	2	29	25.0%
East Newark (B)	0	0	2	0	1	2	1	0	0	6	66.7%
Guttenberg (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Harrison (T)	1	4	2	2	2	14	9	1	9	44	97.8%
Hoboken (C)	0	3	15	5	2	12	12	3	27	79	56.4%
Jersey City (C)	1	16	4	20	3	31	52	10	19	156	35.9%
Kearny (T)	3	10	0	7	0	5	25	11	0	61	57.0%
North Bergen (T)	0	3	0	0	2	0	9	3	1	18	18.0%
Secaucus (T)	5	3	1	2	4	1	17	6	2	41	48.8%
Union City (C)	0	0	0	0	0	0	0	0	0	0	0.0%
Weehawken (T)	0	0	1	0	0	1	11	3	2	18	39.1%
West New York (T)	0	0	0	0	0	1	0	2	0	3	6.3%
Hudson County (Total)	**10**	**47**	**25**	**39**	**14**	**69**	**143**	**46**	**62**	**455**	**36.7%**

Source: Hudson County 2024; HIFLD 2024; NJGIN 2024; NJGWS 2016

Table 10-28. Number of Facilities in the Liquefaction Class 4 Hazard Area, by Lifeline Category

Jurisdiction	Number of Facilities in the Liquefaction Class 4 Hazard Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Jurisdiction Total
Bayonne (C)	0	4	0	3	0	0	7	8	2	24	20.7%
East Newark (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Guttenberg (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Harrison (T)	0	1	0	1	0	0	1	0	1	4	8.9%
Hoboken (C)	0	3	17	5	7	14	12	3	29	90	64.3%
Jersey City (C)	1	16	4	18	3	26	54	10	13	145	33.4%
Kearny (T)	3	10	0	7	0	5	25	11	0	61	57.0%
North Bergen (T)	0	3	0	0	2	0	9	4	2	20	20.0%
Secaucus (T)	5	3	1	2	4	2	18	6	3	44	52.4%
Union City (C)	0	0	0	0	0	0	0	0	0	0	0.0%
Weehawken (T)	0	0	1	0	0	0	8	3	2	14	30.4%
West New York (T)	0	0	0	0	0	0	0	3	0	3	6.3%
Hudson County (Total)	**9**	**40**	**23**	**36**	**16**	**47**	**134**	**48**	**52**	**405**	**32.7%**

Source: Hudson County 2024; HIFLD 2024; NJGIN 2024; NJGWS 2016

Several other types of infrastructure may also be exposed to the geological hazards, including water and sewer infrastructure. In addition to impacting buildings and facilities, subsidence can severely impact roads and roadway infrastructure, which are included in the transportation lifeline. Depending upon the size, events can block egress and ingress on roads, causing isolation for residents and potentially neighborhoods, traffic problems and delays for transportation. This can result in economic losses for businesses. Furthermore, mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.

For Hudson County, there are 12 critical facilities located in the Geological Class A hazard area, as show in Table 10-29.

10.2.4 Economy

Geological hazards can impose direct and indirect impacts on society. Direct costs include the actual damage sustained by buildings, property, and infrastructure due to ground failure, which also threatens transportation corridors, fuel and energy conduits, and communication lines (USGS 2020). Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity may also occur, but are difficult to measure. Earthquake impacts on the economy include loss of business function, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Buildings susceptible to landslide events were summarized earlier in this section. Losses to these structures will impact the local tax base and economy. Subsidence and sinkholes can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public, and private transportation.

Estimated Debris Generated

Table 10-30 outlines the estimated debris generated in various jurisdictions within Hudson County during earthquakes with 500- and 2,500-Year Mean Return Periods. For the 500-Year period, the total debris includes 19,463 tons of brick/wood and 3,168 tons of concrete/steel. In the 2,500-Year period, these amounts significantly increase to 130,406 tons of brick/wood and 40,257 tons of concrete/steel.

10.2.5 Natural, Historic and Cultural Resources

Natural

According to the USGS, earthquakes can cause damage to the surface of the Earth in various forms depending on the magnitude and distribution of the event. Ground failure as a result of soil liquefaction can significantly impact soil pores and water retention. The greater the seismic activity and the liquefaction properties of the soil, the more likely it is that groundwater drainage will occur, depleting groundwater resources. In areas with higher groundwater pressure, the soil pores can build up more pressure, causing the soil to behave more like a fluid rather than a solid, increasing the risk of localized flooding and the deposition or accumulation of silt. (USGS n.d.).

Disturbance of areas with unstable soil can trigger erosion and sedimentation, resulting in the loss of topsoil. Silting of wetlands, lakes, ponds, and streams can damage and degrade wetland and aquatic habitats, which are found throughout the region and receive the state's highest water quality protections. Soil liquefaction and erosion can also result in the loss of habitat quality, degradation of surface water quality, and alteration of drainage patterns.

Table 10-29. Number of Facilities in Geological Class A Hazard Area, by Lifeline Category

Jurisdiction	Number of Facilities in the Geological Class A Hazard Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Jurisdiction Total
Bayonne (C)	0	0	0	0	0	0	0	0	0	0	0.0%
East Newark (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Guttenberg (T)	0	0	0	0	0	0	1	0	0	1	5.3%
Harrison (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Hoboken (C)	0	0	0	0	0	0	0	1	0	1	0.7%
Jersey City (C)	0	0	0	0	0	0	4	1	0	5	1.2%
Kearny (T)	0	0	0	0	0	0	0	0	0	0	0.0%
North Bergen (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Secaucus (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Union City (C)	0	0	1	0	0	0	2	0	1	4	4.4%
Weehawken (T)	0	1	0	0	0	0	0	0	0	1	2.2%
West New York (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Hudson County (Total)	**0**	**1**	**1**	**0**	**0**	**0**	**7**	**2**	**1**	**12**	**1.0%**

Source: Hudson County 2024; HIFLD 2024; NJGIN 2024; NJGWS 2016

Table 10-30. 500- and 2,500-Year Mean Return Period Earthquake Event Debris

Jurisdiction	Debris Generated (tons)			
	500-Year Mean Return Period		2,500-Year Mean Return Period	
	Brick/Wood	Concrete/Steel	Brick/Wood	Concrete/Steel
Bayonne (C)	3,038	532	18,247	5,950
East Newark (B)	114	19	704	209
Guttenberg (T)	38	5	326	74
Harrison (T)	278	33	2,903	666
Hoboken (C)	366	57	3,074	948
Jersey City (C)	5,806	980	38,526	13,670
Kearny (T)	4,210	738	23,806	7,217
North Bergen (T)	1,958	295	14,400	3,814
Secaucus (T)	3,008	413	23,465	6,259
Union City (C)	349	57	2,595	831
Weehawken (T)	101	17	746	244
West New York (T)	199	23	1,614	374
Hudson County (Total)	**19,463**	**3,168**	**130,406**	**40,257**

Source: Hazus v6.1; NJOIT 2024; Microsoft BING 2019; RS Means 2024

HISTORIC

In Hudson County, the primary concern for historic resources in the event of an earthquake is the potential damage from ground shaking and soil liquefaction. The County's historic landmarks and older buildings, many of which may not be built to modern seismic standards, are particularly vulnerable to earthquake damage. These structures are more susceptible to damage compared to newer infrastructure designed to withstand seismic activity.

While landslides are not a significant risk in the County due to its relatively flat terrain, the effects of earthquakes can still pose a threat to the integrity of historical buildings. Ground shaking can cause structural damage, and soil liquefaction can undermine foundations, leading to potential collapse or severe damage. Protecting these historic resources requires careful planning and retrofitting to enhance their resilience against seismic events.

CULTURAL

Earthquake impacts on cultural resources within Hudson County are primarily related to ground shaking and soil liquefaction. Cultural landmarks in the county, many of which are older structures not built to modern seismic standards, are particularly vulnerable to these effects. Depending on the magnitude, earthquake events could cause significant damage to properties in and around cultural landmarks, undermining foundations and leading to structural damage.

10.3 Future Changes That May Affect Risk

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

10.3.1 Potential or Planned Development

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

Any areas of growth could potentially be impacted by geological hazards if located within the identified hazard zones. In general, development on slopes is not recommended due to the increased risk of erosion, stormwater runoff, and flooding potential. Additional runoff can result in sedimentation of downstream surface waters, which damages habitats and has the potential to damage property. Geological make-up should also be considered for future development; certain soils, such as those prone to liquefaction, require careful planning and mitigation measures.

10.3.2 Projected Changes in Population

The New Jersey Department of Labor and Workforce Development produced populations projections by County from 2014 to 2019, 2024, 2029, and 2034. According to these projections, Hudson County is projected to have an increase in population in the upcoming years. These projection totals include a population of 747,400 by 2029, and 766,500 by 2034 (State of New Jersey 2017). An increase in population density can impact the number of persons exposed to geological hazard areas. Changes in density can not only create issues for local residents during evacuation of a landslide or ground failure event but can also have an effect on commuters that travel into and out of the County for work, particularly during a geologic event (such as a sinkhole) that breaches major transportation corridors, which are also major commuter roads.

10.3.3 Climate Change

The County is expected to experience an increase in average annual temperatures and precipitation due to climate change. Severe storms and heavy rainfall events may elevate the likelihood of landslides in steep sloped areas, as precipitation may exceed the soil's absorption capacity. These changes depend on the development of steep slopes and other climate trends, such as seasonal precipitation and drought, which affect vegetation growth.

Higher temperatures and potentially more intense, less frequent summer rainfall may alter water resource availability and increase the frequency of droughts. Drought periods can intensify sinkhole activity in some karst areas, potentially increasing the number of sinkholes. Changes to the water balance, including over-withdrawal of groundwater, diverting surface water, creating artificial ponds, and drilling new wells, can accelerate bedrock degradation and sinkhole formation.

The impacts of climate change on earthquakes are not well understood, making it difficult to determine changes in the County's vulnerability. However, climate change may magnify secondary impacts of earthquakes. Consequently, the County's assets located on saturated soils and at the base of steep slopes are at higher risk of landslides and mudslides due to seismic activity.

10.3.4 Other Identified Conditions

The impacts of climate change on earthquakes are not well understood, making it difficult to determine changes in the County's vulnerability. However, climate change has the potential to magnify secondary impacts of earthquakes. As a result, the County's assets located on saturated soils and at the base of steep slopes are at higher risk of landslides and mudslides due to seismic activity.

The County is expected to experience an increase in average annual temperatures and precipitation due to climate change. Severe storms and heavy rainfall events may elevate the likelihood of landslides in steep sloped areas, as precipitation may exceed the soil's absorption capacity. These changes depend on the development of steep slopes and other climate trends, such as seasonal precipitation and drought, which affect vegetation growth.