9. Earthquakes

A. Hazard Profile

i. Hazard Description

The infrequency of major earthquakes, coupled with the relatively more frequent occurrence of moderate-magnitude events in the recent past, has led to a public perception that New York City is not vulnerable to damaging earthquakes. While the city does not sit on a seismically active plate boundary like California or Alaska do, it is nonetheless susceptible to earthquakes that originate in or near the city. Population density, the sheer volume of built and critical assets, the lack of seismic design provisions prior to the first seismic code in 1995, and the interdependency of sometimes aged infrastructure amplify the city's risk.

An earthquake is a sudden, rapid shaking of the earth caused by the breaking and shifting of rock beneath the surface. Most earthquakes originate from pre-existing faults, or from a new break in the rocks that make up the earth's crust, along which rocks on either side of faults move past each other. As the rock is strained from geological processes over long periods of time, there is a buildup of potential energy. Eventually, this accumulated energy becomes so great that it is abruptly released in the form of seismic waves. These waves travel away from the earthquake's source, or “focus,” deep underground, causing the shaking at the earth's surface that geologists call “ground acceleration.” The point on the earth's surface that is directly above the focus is called the epicenter.

Ground acceleration caused by earthquakes has the potential to damage or destroy buildings and infrastructure and can result in loss of life. Earthquakes can also trigger landslides and liquefaction of soils under certain conditions. Liquefaction occurs when unconsolidated, water-saturated soils exhibit fluid-like or significantly softened properties due to the intense shaking and vibrations during an earthquake. Together, ground shaking, landslides, and liquefaction can damage or destroy buildings, disrupt utilities, trigger fires, and endanger public safety.

Aftershocks are earthquakes that follow the largest shock of an earthquake sequence. They are typically less intense than the main shock, and can continue over weeks, months, or years after the initial earthquake is felt.

ii. Severity

The term “magnitude” is used to describe the size (released strain energy) at the focus of an earthquake, and “intensity” is used to describe the overall felt severity of shaking during an earthquake. An earthquake's magnitude is a measurement of the energy released at the source of the earthquake expressed by ratings on the Richter or more recent magnitude scales; one such recent scale is the moment magnitude scale, which is now uniformly used by the United States Geological Survey (USGS) unless otherwise specified. Magnitude is determined from measurements on seismographs, and expressed in decimal fractions. Magnitude scales have theoretically no upper limit, but no observed magnitude has ever reached or exceeded a magnitude of 10.

While the Magnitude scale measures the size of an earthquake at its source, the Modified Mercalli Intensity (MMI) scale is empirical and measures the shaking damages of an earthquake on people, animals, objects, buildings, and, in most severe cases, seismic effects on the landscape. As shown in Table 3.9.36, MMI ratings range from I to XII. One of the strongest earthquakes to occur near New York City was on August 10, 1884. It had an estimated magnitude of 5.2 on the Richter scale, based on correlations to the reported maximum intensities of VI to VII on the MMI scale.

In addition to the *qualitative* measure of damage from seismic shaking by intensity—the MMI rating—there are also *quantitative* measures of ground shaking. One such measure is the “peak ground acceleration” (PGA). PGA is the maximum acceleration experienced by the ground during the course of the earthquake motion and can be described by its changing velocity as a function of time. Acceleration is measured because many seismic building codes stipulate how much horizontal inertial force (or mass times the acceleration) a building should be able to withstand during an earthquake without life-threatening damage. PGA is expressed as a percentage of acceleration force of the earth's gravity

Table 3.9.36: MMI Scale Rating (Source: USGS Earthquake Hazards Program, 2013)

MMI	Damage/Perception
I	• Not felt except by a very few under especially favorable conditions
II	• Felt only by a few people at rest, especially on upper floors of buildings
III	• Felt quite noticeably by people 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
IV	• 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 rock noticeably
V	• Felt by nearly everyone; many awakened • Some dishes, windows broken • Unstable objects overturned • Pendulum clocks may stop
VI	• Felt by all; many frightened • Some heavy furniture moved • Few instances of fallen plaster • Damage slight
VII	• Damage negligible in buildings of good design and construction • Slight to moderate damage in well-built ordinary structures • Considerable damage in poorly built or badly designed structures • Some chimneys broken
VIII	• Damage slight in specially designed structures • Considerable damage in ordinary substantial buildings, with partial collapse • Damage great in poorly built structures • Fall of chimneys, factory stacks, columns, monuments, walls • Heavy furniture overturned
IX	• 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	• Some well-built wooden structures destroyed • Most masonry and frame structures destroyed with foundations • Rails bent
XI	• Few, if any, masonry or frame structures remain standing • Bridges destroyed • Rails bent greatly
XII	• Total damage • Lines of sight and level are distorted • Objects thrown into the air

(%g). Table 3.9.37 shows the approximate relationship between MMI and PGA near an earthquake epicenter.

While PGA is an important measure for ground acceleration, Spectral Acceleration (SA) is now more commonly used as the measure of ground motion in modern seismic building codes because it more closely relates to what a building of a certain mass, height, and structural stiffness (and related natural response period) experiences during an earthquake. It can be used as a better indicator of damage to specific building types and heights. SA for a building is modeled by replacing the building with an inverted pendulum of a certain mass on a mass-less vertical rod having the same natural period of vibration and the same mechanical damping as the building. A very approximate rule for the natural spectral period T_b (seconds) of a building as function of the number of stories *n* in the building is: T_b (sec) = 0.1*n*. For example, a 2-story building tends to have a natural period of about 0.2 seconds (frequency of 5Hz), while a 10 story building tends to have a natural period near T_b=1 second (frequency of 1 Hz).

Soil and rock type can also impact the severity of earthquake shaking at a given location. As the earthquake's waves move into the soils, the softness of the ground and the total thickness of sediments above hard bedrock affect the wave speed and velocity. In stiff or hard soil, the wave generally will travel at a higher velocity. With soft soils, the wave will slow, traveling at lower velocities. With slower waves, the seismic energy is modified, resulting in waves with greater amplitude. This amplification tends to result in greater earthquake damage unless the building is designed to take this soil effect into account. Thick soil sediments tend to increase the amount of shaking at long spectral periods (affecting tall buildings), while they can reduce the ground motions at very short periods (high frequencies). The combination of softer and thicker soil can increase the shaking of waves produced by an earthquake at certain spectral ground motion periods. The greatest amplification of the spectral ground acceleration SA tends to occur at the ground motion periods of T_o = 4H / V_s where H (feet) is the thickness of the near-surface soil layer that has a seismic shear wave velocity of V_s (feet/seconds).

There are unique geologic characteristics in the NYC metropolitan area that can create significant soil amplification effects. The two main characteristics are: (a) the sharp stiffness contrast of overburden soils with very hard regional bedrock, and (b) the bedrock mo-

Table 3.9.37: Approximate Relationship between MMI and PGA (Source: USGS Earthquakes Hazard Program, 2013)

MMI	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
XI	> 124	Extreme	Very heavy
XII	> 124	Extreme	Very heavy

tions, expected to be of relatively short duration, high frequency, and moderate intensity. Hence, if the soil is soft above the bedrock at shallow depths (say less than 100 feet), there will be resonance in the short period range, affecting mostly "short" or "stiff" structures. There are some NYC-specific modifications in the upcoming (2014) NYC code that try to address this issue in a simplified manner, since this condition is not typically encountered in the seismically more active west coast.

The National Earthquake Hazard Reduction Program (NEHRP) soil classification system describes how soils affect seismic waves as they propagate from the bedrock to the ground surface. A map of the NERP soil classifications for New York State is shown below in Figure 3.9.61. As indicated on the map, Class A soils (pink on the map) tend to reduce ground motions, whereas Class E soils (shown in blue) tend to further amplify and magnify seismic waves. New York City has a variety of NEHRP soil site classes, ranging from hard rock to soft soil. Most of New York City is classified as class B (rock) and class D (stiff soil).

The New York State Office of Emergency Manage-

Figure 3.9.61: New York State Soil Classifications (Source: NYS OEM 2014)

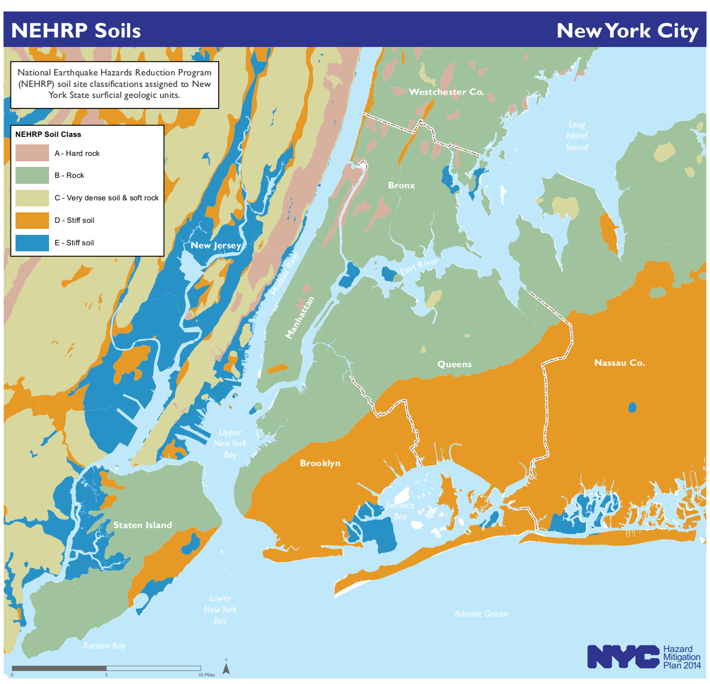
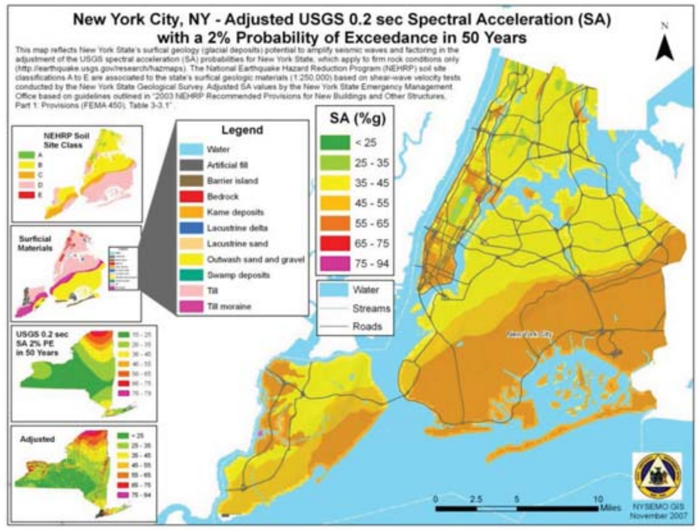


Figure 3.9.62: Adjusted USGS 0.2 Sec SA for New York City (Source: NYS OEM, 2011)

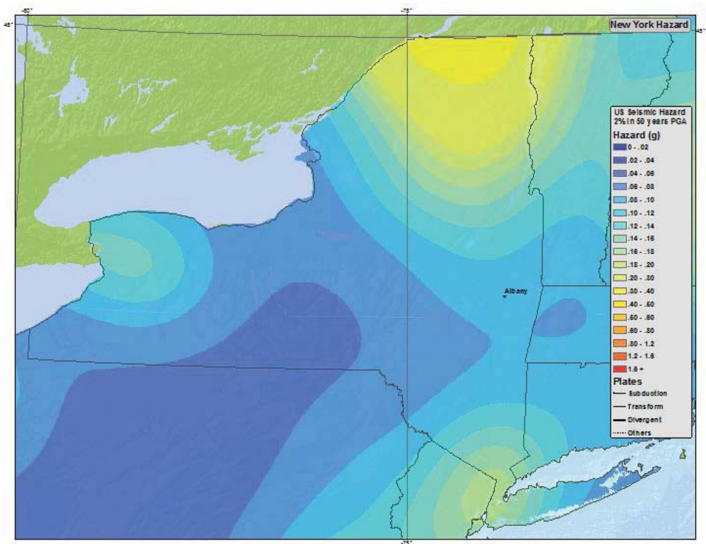


ment (NYS OEM) created county-specific seismic hazard maps that reflect the soil's ability to affect seismic waves and the resulting SA that may be experienced by a building. The maps are based on USGS data and the New York State Geological Survey shear-wave tests of the surficial soils. These maps facilitate a better understanding of local seismic hazards by identifying areas of higher vulnerability within the city. The seismic hazard map for New York City shown below (Figure 3.9.62) indicates that SA values of 25% to 75% of gravity have the potential to occur in New York City. It presents the adjusted USGS 0.2 sec SA with a 2% probability of exceedance within 50 years.

iii. Probability

PGA can not only be used to measure severity, it can also be used as a measure for the probabilistic assessment of earthquake hazards. Probabilistic seismic hazard maps, whether for PGA or another measure, project the likelihood of a certain level of ground shaking to be reached or exceeded at a certain location over a given period. As shown in the seismic hazard map for New York City (see Figure 3.9.63), a PGA value of 16% to 18% g (1g=earth gravity) has a 2% chance of being exceeded over 50 years. Such earthquake ground motions would likely produce strong to very strong perceived shaking and light to moderate physical damage. The probabilistic seismic hazard maps are for a given stiff soil condition, and the ground motions must be

Figure 3.9.63: **Earthquake Peak Ground Acceleration (% gravity) 2% Probability of Exceedance in 50 years (Source: http://earthquake.usgs.gov/earthquakes/states/new_york/hazards.php)**



further modified for the specific soil conditions at any given site.

Although New York City has a low risk of large magnitude earthquakes, overall seismic risk is higher because of the city's tremendous assets, concentration of buildings, and construction types (most buildings have not been seismically designed). A 2008 analysis by the Federal Emergency Management Agency (FEMA 366b, 2008) ranks New York State as the fourth most at-risk U.S. state for annualized building-related earthquake losses. The analysis also ranks the New York City/New Jersey/Long Island metropolitan region as the 21st most at-risk metropolitan region.

The risk of earthquakes in the New York City area might be greater than once believed. According to a 2008 study by Columbia University's Lamont-Doherty Earth Observatory, there are subtle but seismically active faults in the area. Although New York City is not located along a major fault, according to seismologists the existence of these many smaller active faults may increase the probability of a large earthquake.

The Lamont-Doherty Earth Observatory located hundreds of small events; including magnitude 3 earthquakes that occurred from 1677 to 2007. The smaller earthquakes tended to occur along a series of small, old faults in harder rocky soil. The study asserts that these faults are still active and capable of producing severe earthquakes. According to the study, the probabilities of occurrence in a 50-year period would be 7% (magnitude 6) and 1.5% (magnitude 7).

iv. Location

According to the USGS Earthquake Hazards Program, around 90% of earthquakes occur at the boundaries where the earth's tectonic plates meet, although it is possible for earthquakes to occur entirely within plates. New York City is situated well within the North American plate, far from the plate boundary, which is located approximately 2,000 miles east in the Atlantic Ocean. Seismic research is being conducted into the causes of earthquakes in regions far from plate margins.

Regardless of where they are centered, earthquakes can affect locations beyond their point of origin. For example, two earthquakes that recently occurred (one in Virginia in 2011 and one in Canada in 2013) were felt in New York City. Figure 3.9.64 shows the distribution of historical earthquake epicenters for areas of New York, Connecticut, and New Jersey.

Earthquakes are possible in any of New York City's counties. However, the risk of earthquakes is not the same throughout the city, as evidenced by higher SA values in certain areas as shown in Figure 3.9.62. These areas would likely experience more damage depending on their proximity to an earthquake's epicenter.

Areas with large numbers of unreinforced masonry buildings are also at greater risk from earthquakes. This building type is not as sturdy and does not absorb energy as well as other structure types such as wood, steel, or reinforced concrete (see Built Environment, below). Brooklyn has the largest number of unreinforced masonry buildings. According to the New York City Area Consortium for Earthquake Loss Mitigation (NYCEM), 79% of all buildings in Manhattan are unreinforced masonry buildings. Neighborhoods in Lower Manhattan—such as Soho, Greenwich Village, Chinatown, Little Italy, and Noho—have many unreinforced masonry buildings. In addition, both the Upper West Side and Upper East Side have many unreinforced masonry buildings. The 125th Street fault runs from 125th Street and Broadway east, crossing the East River and extending through Randall's Island. The area around

125th Street has a large number of unreinforced masonry buildings.

v. Historic Occurrences

More than 400 earthquakes with a magnitude greater than 2.0 are on record in New York State between 1700 and 1986, but many more have occurred. Stronger earthquakes are rarer. From 1973 to 2012 there were only two damaging earthquakes in the state with magnitude of 5.0 or greater.

Many smaller earthquakes have been felt in New York City, as shown in Table 3.9.38. For example, in 2001 an earthquake with a 2.4 magnitude occurred in the Upper East Side near the 125th Street fault. The earthquake caused only minor damage, but it was the first one on record in Manhattan.

Figure 3.9.64: Location of Earthquakes in New York City and Surrounding Areas 1973 to 2012 (Source: NYS HMP 2014)

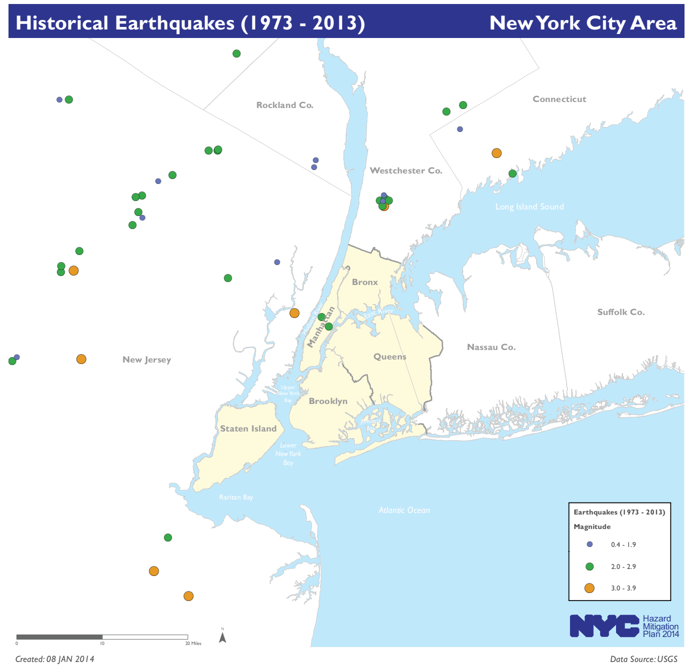


Table 3.9.38: Earthquakes Felt in New York City 1737 to 2013 (Source: Lamont-Doherty Earth Observatory of Columbia University and USGS Historic World Earthquakes, 2013)

Date	Location	Mag-nitude (ML)**	Max. Intensity (MM)	Description
December 19, 1737	New York City	5.2	VII	• Bells ring, several chimneys fall
October 26, 1845	Greater NYC area*	3.8	VI	• No information
1847	Greater NYC area*	4.5	V	• Most likely offshore
September 9, 1848	Greater NYC area*	4.4	V	• Felt by many people in New York City
August 10, 1884	Citywide	5.2	VII	• Chimneys and bricks fall, walls crack. • Felt from Virginia to Maine
July 19, 1937	Western Long Island	3.5	IV	• One or a few earthquakes occur beneath Long Island
March 10, 1979	Central New Jersey	3.2	V-VI	• Felt in some locations in Manhattan • Referred to as the "Chelsea earthquake"
October 19, 1985	Ardsley, NY	4.0	IV	• Felt by many people in New York City
January 17, 2001	Manhattan	2.4	IV	• Felt in Upper East Side of Manhattan and Long Island City, Queens
October 27, 2001	Manhattan	2.6	IV	• Felt in the following locations: Upper West Side of Manhattan and Astoria, Queens
April 20, 2002	Au Sable Forks, NY	Mw 5.1	VII	• Vibrations felt in New York City
August 23, 2011	Virginia	Mw 5.8	VIII	• Vibrations felt in New York City
May 17, 2013	Quebec	Mw 5.0	N/A	• Vibrations felt in New York City

*Location is poorly determined; may be uncertain by 50 miles.

** All magnitudes are local Richter magnitude Ml, except for the three most recent listed earthquakes, which are moment magnitudes.

B. Vulnerability Assessment

i. Social Environment

Unlike some other natural hazards, earthquakes often occur with little or no warning, placing the population at immediate risk. Moreover, since earthquakes have not occurred as frequently as other natural hazard events, the risk to public safety may be higher because the general public may not be as prepared or know how to respond.

Earthquakes can have enormous impact on public safety and health. A high-magnitude earthquake could cause significant injuries and casualties. Earthquakes can also disrupt emergency and medical services, putting individuals that depend on these services at even greater risk. Some of the long-term health risks that earthquakes pose include post-traumatic stress disorder and other mental health problems such as depression and anxiety.

Earthquakes can also impact the economy, causing significant losses of many types. They can displace and disrupt businesses and utility operations, and they can impair people's ability to generate income due to disruptions brought on by the event. Property owners may incur losses due to repairs and lost rental income. The effects of downtime in the city that is a major financial center can potentially affect the world's economy.

Several monuments and landmarks of our nation are hosted in this city and they could be damaged in an earthquake, having a cultural impact in our nation.

ii. Built Environment

Earthquakes can significantly affect both buildings and infrastructure.

Buildings

As mentioned above, a building's construction is a key factor in determining how well it can withstand the forces produced by earthquakes. Structures designed with consideration to seismic loads and that follow the NYC Building Code are expected to provide a minimum of life safety under a very rare earthquake and general occupancy conditions for less severe earthquakes. Structures not designed for earthquake loads are inherently vulnerable to seismic events. In particular, unreinforced masonry buildings are most at risk because the walls are prone to collapse outward. Steel and wood buildings have a greater ability to absorb the energy from an earthquake. In addition, proper foundation ties on wood buildings are important for reducing the risk of collapse during an earthquake.

Masonry buildings make up roughly 48% of the all buildings in New York City. The greatest number of masonry buildings are in Brooklyn (178,920), followed by Queens (115,062), the Bronx (54,434), Manhattan (28,762), and Staten Island (8,870). This estimation is refined further in the HAZUS-MH analysis described below.

The first seismic provisions in the New York City Building Code were signed into law in 1995 (Local Law 17/19). These provisions impose design and construction regulations that resist the effects of earthquakes. Since then, the Department of Buildings (DOB) has further addressed structural vulnerability for earthquakes in the revised 2008 New York City Construction Codes. The 2008 code requirements are based on the 2003 International Building Code requirements with local modifications for buildings constructed after July 1, 2009.

The 2008 Construction Codes not only make buildings stronger, but also more flexible and resilient. For example, the soil type and building foundation are taken into account, and seismic detailing is required to ensure the joints and connections of a building hold up during an earthquake. Unreinforced masonry is no longer allowed for new buildings. Inspections are also required during construction to ensure seismic features are built correctly. Furthermore, just as they were under the old code, critical facilities such as firehouses and hospitals will be designed under the revised code to not only survive an earthquake, but remain open and functional afterwards (see section 4. New York City's Hazard Environment). In fall of 2014, DOB will be revising the Building Code and moving towards a new concept: the risk-based approach, following the model of the American Civil Engineers (ASCE) Standard 7-2010. The new seismic standard presents risk-based requirements, and enhanced design requirements for liquefaction.

HAZUS-MH Earthquake-Impact Building Summary:
HAZUS-MH was used to estimate losses and structural vulnerability for earthquakes in New York City. NEHRP soils data was loaded to further improve the accuracy of the results. No modifications were made to the existing HAZUS-MH damage functions relating to earthquake building damage.

For the hazard definition, a set of probabilistic scenarios were modeled to focus on damage to buildings (see section 3. Hazard Risk Assessment Organization). The probabilistic earthquake model in HAZUS-MH also allows for the output of annualized dollar losses. Potential damages were calculated for return periods of 100, 250, 500, 1,000, and 2,500 years (see Table 3.9.39). As is the case with every HAZUS-MH model, there are limitations to the data generated.

The overall damage state categories for the HAZUS-MH earthquake module are None, Slight, Moderate, Extensive, and Complete. Included below is a graphic depiction of structural damage states (Figure 3.9.65).

Definitions of structural damage states for a single building class (in this case, Type W1-wood, light frame) are included here for reference:

Figure 3.9.65: HAZUS-MH Earthquake Damage States (Source: HAZUS-MH Earthquake User Manual Figure 9.17)

Slight: Small plaster or gypsum board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.

Moderate: Large plaster or gypsum board cracks at corners of door and window openings; small diagonal cracks across shear wall panels (stucco and gypsum); large cracks in brick chimneys; toppling of tall masonry chimneys.

Extensive: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations; small foundation cracks.

Complete: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to wall failure or the failure of the lateral load resisting system; some structures may have slipped off foundations; large foundation cracks.

Table 3.9.39: Number of Buildings Damaged from Earthquakes by Return Period for New York City (Source: NYC OEM 2013)

Recurrence Interval	Construction Type	Slight	Moderate	Extensive	Complete	Total Damaged	% of Buildings Damaged
100-year	Unreinforced Masonry	0	0	0	0	0	0.00%
	Total	**0**	**0**	**0**	**0**	**0**	**0.00%**
250-year	Unreinforced Masonry	3,100	1,100	100	0	4,300	2.27%
	Total	**5,800**	**1,500**	**200**	**0**	**7,500**	**0.70%**
500-year	Unreinforced Masonry	11,300	4,800	800	100	17,000	8.98%
	Total	**26,000**	**7,500**	**1,000**	**100**	**34,600**	**3.22%**
1,000-year	Unreinforced Masonry	21,300	11,100	2,500	400	35,300	18.64%
	Total	**66,600**	**22,000**	**3,600**	**400**	**92,600**	**8.63%**
2,500-year	Unreinforced Masonry	35,600	25,900	8,500	2,100	72,100	38.08%
	Total	**159,300**	**69,600**	**15,900**	**2,600**	**247,400**	**23.05%**

Notes: Output rounded to the nearest hundred buildings to minimize potential errors in precision.

Table 3.9.40 and Table 3.9.41 describe the potential impact of a variety of hypothetical earthquake scenarios with the epicenter located at the epicenter of the August 10, 1884 earthquake in New York City. This model, which also utilized HAZUS-MH software, was adapted from the NYCEM study, published in 2003.

Table 3.9.40: Summary of Deterministic Results of NYCEM Study (Source: NYCEM, 2003)

Richter Scale	Building Damage (billion)	Income Loss (billion)	Total (billion)	Hospitalization (people)	Shelter Required (people)	Fires	Buildings Completely Damaged	Debris (million tons)
5	$4.4	$0.4	**$4.8**	24	2800	500	45	1.6
6	$28.5	$10.8	**$39.3**	2,296	197,705	900	2,600	31.9
7	$139.8	$57.1	**$196.8**	13,171	766,746	1,200	12,800	132.1

Table 3.9.41: Summary of Probabilistic Results of NYCEM Study (Source: NYCEM, 2003)

Return Period	Building Damage (billion)	Income Loss (billion)	Total (billion)	Hospitalization (people)	Shelter Required (people)	Fires	Debris (million tons)
100-year	$0.1	$0.1	**$0.2**	0	0	0	0.2
500-year	$6.1	$2.0	**$8.1**	28	575	50	3.1
2,500-year	$64.3	$20.4	**$84.8**	1,430	84,626	900	34.0
Annualized Losses	$0.1	$0.1	**$0.2**	N/A	N/A	N/A	N/A

Infrastructure
Earthquakes can also compromise infrastructure including bridges, tunnels, utility systems, dams, and highways. Some existing bridges in New York City have been partially retrofitted to improve seismic performance as part of other capital improvements. But the seismic vulnerability of the city's interlinked infrastructure networks is still poorly understood and remains of concern, even as this infrastructure undergoes changes, upgrades and renewal.

Upstate dams, reservoirs, and aqueducts also could incur serious damage from an earthquake, affecting the water supply to New York City. In addition, the Indian Point nuclear facility is located 24 miles north of the city and according to seismologists sits above two active seismic zones. These zones are capable of generating a magnitude 6 earthquake, which may increase the risk of harmful radiation exposure. According to the operators of Indian Point (Entergy Corporation), the nuclear plant is “designed with a margin of safety beyond the strongest earthquake anticipated for the area.”

iii. Natural Environment

Earthquakes can severely damage the natural environment. They can destroy trees and parks, for example, and diminish the aesthetic value of natural features. Earthquakes can also have secondary impacts that could harm the natural environment; these include fires caused by gas pipe explosions, broken water pipes, hazardous waste releases, and landslides. Should earthquakes affect nearby nuclear power plants and/or used-nuclear-fuel onsite-storage facilities and cause the release of substantial amounts of radioactive materials into the air and water, such release would not only affect the population and economy, but also could have long-term effects on water, land, the biosphere, and the general ecology of the region including in and around New York City.

iv. Future Environment

As New York City's substantial stock of seismically vulnerable (pre-seismic code) buildings gets gradually replaced with new structures that conform to seismic building code specifications, the per-dollar-of-asset vulnerability tends to gradually decline. On the other hand, as the value and volume of built assets increase, the total seismic exposure, and hence risk, may still increase.

As for New York City's infrastructure, aging components of infrastructure may amplify the structural impacts of earthquakes in the future. However, the City has invested in the retrofit of existing bridges to improve seismic performance, and these investments should reduce the impacts of an earthquake in the future.

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