5.4.3 EARTHQUAKE

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

HAZARD PROFILE

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

Description

An earthquake is the sudden movement of the Earth's surface caused by the release of stress accumulated within or along the edge of the Earth's tectonic plates, a volcanic eruption or by a manmade explosion (FEMA, 2001; Shedlock and Pakiser, 1997). Most earthquakes occur at the boundaries where the Earth's tectonic plates meet (faults); however, less than 10 percent of earthquakes occur within plate interiors. New Jersey is in an area where plate interior-related earthquakes occur. As plates continue to move and plate boundaries change over geologic time, weakened boundary regions become part of the interiors of the plates. These zones of weakness within the continents can cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust (Shedlock and Pakiser, 1997).

According to the USGS Earthquake Hazards Program, most earthquakes occur at the boundaries where the plates meet (roughly 90%), although it is possible for earthquakes to occur entirely within plates. The State of New Jersey and Burlington County are both far from any plate boundaries. Regardless of where they are centered, earthquakes can impact locations at – and well beyond – their point of origin. They are often accompanied by "aftershocks" – secondary quakes in the earthquake sequence. Aftershocks are typically smaller than the main shock, and can continue over a period of weeks, months, or years from the main shock (Burlington County HMP, 2008).

In addition to the effects of ground shaking, earthquakes can also cause landslides and liquefaction under certain conditions. Liquefaction occurs when unconsolidated, saturated soils exhibit fluid-like properties due to intense shaking and vibrations experienced during an earthquake. Together, ground shaking, landslides, and liquefaction can damage or destroy buildings, disrupt utilities (i.e., gas, electric, phone, water), and sometimes trigger fires (Burlington County HMP, 2008).

Extent

The severity of an earthquake at a given location depends on the amount of energy released at the epicenter, and the location's distance from the epicenter. The terms "magnitude" and "intensity" are two terms used to describe the severity of an earthquake. An earthquake's "magnitude" is a measurement of the total amount of energy released while its "intensity" is a measure of the effects of an earthquake at a particular place (Burlington County HMP, 2008).

Seismic waves are the vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude or extent of an earthquake is a measured value of the earthquake size, or amplitude of the seismic waves, using a seismograph. The Richter magnitude scale (Richter Scale) was developed in 1932 as a mathematical device to compare the sizes of earthquakes (USGS, 1989). The Richter Scale is the most widely-known scale that measures the magnitude of earthquakes (Shedlock and Pakiser, 1997; USGS, 2004). It has no upper limit and is not used to express damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, may have the same magnitude and shock in a remote area that did not cause any damage (USGS, 1989). Table 5.4.3-1 presents the Richter Scale magnitudes and corresponding earthquake effects.

Table 5.4.3-1. Richter Scale

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

Source: USGS, 2006

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and varies with location. Intensity is expressed by the Modified Mercalli Scale; a subjective measure that describes how strong a shock was felt at a particular location (Shedlock and Pakiser, 1997; USGS, 2004). The Modified Mercalli Scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII. Table 5.4.3-2 summarizes earthquake intensity as expressed by the Modified Mercalli Scale.

Table 5.4.3-2. Modified Mercalli Intensity Scale

Mercalli Intensity	Description
I	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 moves, 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 their 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, 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(s): Michigan Tech University, 2007; Nevada Seismological Laboratory, 1996

Another way to express an earthquake's severity is to compare its acceleration to the normal acceleration due to gravity. Peak Ground Acceleration (PGA) measures the rate of change in motion of the earth's surface and expresses it as a percent of the established rate of acceleration due to gravity (9.8 m/sec^2) (Burlington County HMP, 2008). PGA is expressed as a percent acceleration force of gravity (%g). For example, 1.0 g PGA in an earthquake (an extremely strong ground motion) means that objects accelerate sideways at the same rate as if they had been dropped from the ceiling. 10% g PGA means that the ground acceleration is 10% that of gravity (NJOEM, 2011). Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures as noted in Table 5.4.3-3.

Table 5.4.3-3. Damage Levels Experienced in Earthquakes

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

Source: NJOEM, 2011

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures as noted in Table 5.4.3-4, which shows an approximated relationship between PGA, magnitude, and intensity of an earthquake. Using this table, one can approximate that, for an earthquake of expected severity for Burlington County and its participating municipalities (PGA values of 2 to 4%g), perceived shaking would be light to moderate (depending upon the distance from the epicenter) and potential damage could range from none to very light (also depending upon the distance from the epicenter).

Table 5.4.3-4. Earthquake Magnitude/Intensity Comparison

PGA	Magnitude	Intensity	Perceived Shaking	Potential Damage
< 0.17	1.0 - 3.0	I	Not Felt	None
0.17 – 1.4	3.0 – 3.9	II - III	Weak	None
1.4 – 9.2	4.0 – 4.9	IV – V	IV. Light V. Moderate	IV. None V. Very Light
9.2 - 34	5.0 – 5.9	VI – VII	VI. Strong VII. Very Strong	VI. Light VII. Moderate
34 - 124	6.0 – 6.9	VIII - IX	VIII. Severe IX. Violent	VIII. Moderate/Heavy IX. Heavy
> 124	7.0 and higher	X and higher	Extreme	Very Heavy

Sources: (1) FEMA Mitigation Planning "How-To" Guide 386-2, 2001; (2) Wald, D., et al., 1999, Relationship between Peak Ground Acceleration, Peak Ground Motion, and Modified Mercalli Intensity in California", Earthquake Spectra, V. 15, p. 557-564

An earthquake with a 10 percent chance of exceedance over 50 years in Burlington County would have a PGA of 2 to 4%g and an intensity ranging from only IV to V, which would result in light to moderate perceived shaking, and damages ranging from none to very light. For comparison purposes, an earthquake of intensity IV on the Modified Mercalli Scale would most likely cause vibrations similar to heavy trucks driving over roads, or the sensation of a jolt. Hanging objects would swing; standing cars would rock; windows, dishes and doors would rattle; and, in the upper ranges of intensity IV, wooden walls and frames would creak. An earthquake of intensity V on the Modified Mercalli Scale would be felt outdoors, awaken sleepers, disturb or spill liquids, displace small unstable objects, swing doors, and cause shutters and pictures to move.

As noted in the New Jersey State Hazard Mitigation Plan, soil type can have an impact on the severity of an earthquake at a given location. For example, soft soils (i.e., fill, sand) are more likely to amplify ground motion during an earthquake. Liquefaction is also more likely to occur in areas of soft soils. In contrast, harder soils (i.e., granite) tend to reduce ground motion during an earthquake. 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, 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 [Tantala et al. (NYCEM), 2003].

Computer software (HAZUS, for Hazards U.S.) developed under the direction of the Federal Emergency Management Agency (FEMA) was developed to simulate ground-shaking, building damage, and estimate economic loss, for potential earthquakes (http://www.fema.gov/hazus). The simulations take into account the magnitude and location of the earthquake, the physical properties of the soil and bedrock, and the type of building construction in the study area. Results of these simulations are used to guide the strengthening of structures built on vulnerable soils and to plan emergency response.

The New Jersey Department of Environmental Protection (NJDEP), Geological and Water Survey Division is currently undertaking a study titled *Earthquake Loss Estimation Study For New Jersey: Geologic Component*. The Survey, with partial funding from the New Jersey State Police Office of Emergency Management (NJOEM), maps seismic soil properties by county, including shaking behavior, liquefaction susceptibility, and tendency to landslide. The mapping shows soil types in five basic categories with varying degrees in likelihood of amplifying the effects of an earthquake. At this time, the Survey is progressing at a rate of one county per year – mapping is currently not available for Burlington County but if it should become available in the future, the data can be incorporated into this section of the plan.

At the time of publication of the 2008 Burlington County HMP, the following jurisdictions expressed specific concerns about the seismic risk in their communities:

- Moorestown Township expressed a particular concern with the vulnerability of public buildings, especially schools that are not earthquake resistant.

- Florence Township indicated a concern that earthquakes could cause significant damage, even though their team was not aware of historic events in their area.

- Cinnaminson Township notes that, while a damaging earthquake has not occurred in their area, a slight tremor was noted in the late 1960s.

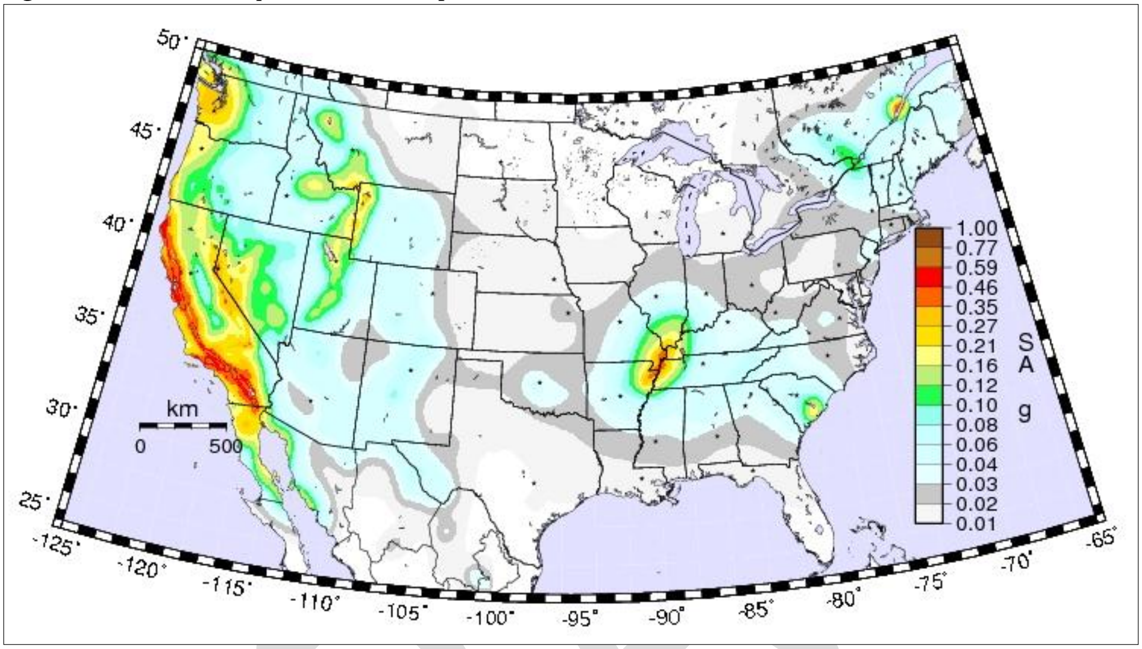
- Mansfield Township reported that the 1999 earthquake was felt in their municipality, but no damages were incurred.

Location

Earthquakes are possible within any of Burlington County's communities. Figure 5.4.3-X is an earthquake hazard map for the conterminous U.S. prepared by the USGS Earthquake Hazards Program. It shows that the earthquake hazard is low in Burlington County relative to other parts of the country (the west coast of the U.S.) but the possibility does exist in the State of New Jersey. Figure 5.4.3-1 shows the same hazard map in more detail, focused on the State of New Jersey, with Burlington County circled.

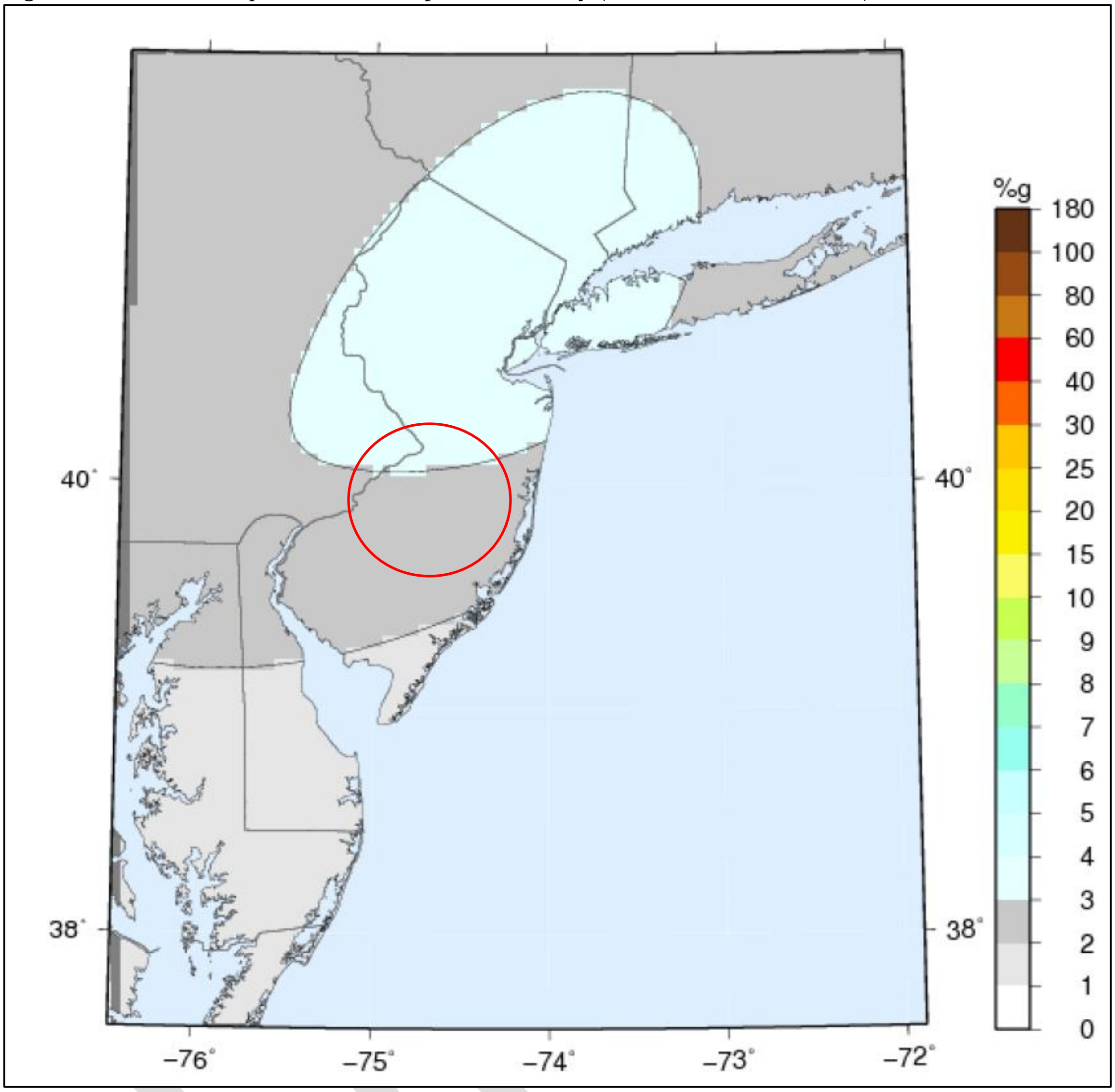
As Figure 5.4.3-1 shows, the earthquake hazard is relatively uniform but shows some degree of variation across the county, with higher hazard areas being in the northern portion of the county and lower hazard areas being toward the southeastern portion of the county.

Figure 5.4.3-1. Earthquake Hazard Map of the Conterminous United States



Source: USGS, 2008
Note: This map shows a PGA of 10% in 50 years.

Figure 5.4.3-2. Earthquake Hazard Map of New Jersey (PGA of 10% in 50 Years)



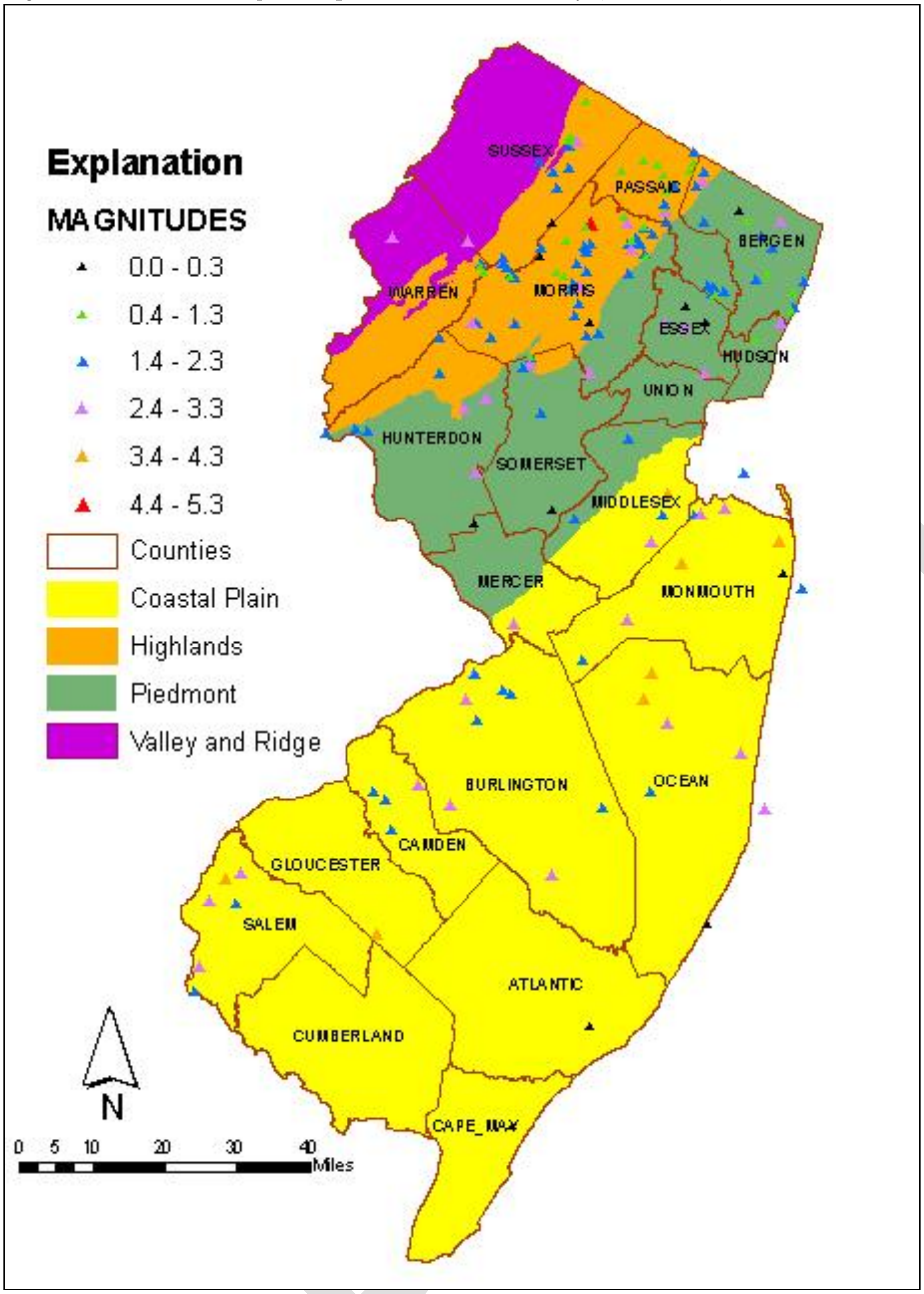
Source: USGS, 2010

Note: The red circle indicates the approximate location of Burlington County. The figure indicates that the County has a PGA of 2-4%g

Previous Occurrences and Losses

As noted in the New Jersey State Hazard Mitigation Plan, although the probability of damaging earthquakes in New Jersey is low, earthquakes do occur on a regular basis in the State. Figure 5.4.3-3 illustrates earthquake epicenters in New Jersey, as obtained from the New Jersey Geological Survey web site, for earthquakes that occurred between 1783 and June 2013. The figure depicts a total of 179 earthquakes with magnitudes ranging from a minimum of 0.4 (Jefferson Township [Morris County] on June 7, 1992) to a maximum of 5.3 (west of New York City on November 30, 1783); most magnitudes were between 1.4 and 2.9.

Figure 5.4.3-3. Earthquake Epicenters in New Jersey (1783-2013)



Source: NJDEP, 2013
Note: The figure indicates Burlington County has been the epicenter to eight earthquake events.

Since the publication of this map (November 26, 2012) one New Jersey earthquake was added:

- 1 km E of Rockaway, NJ (Morris County) on June 23, 2013, 11:54am, magnitude 2.1, depth 2.0 km.

Table 5.4.3-5 depicts these earthquakes events. Several of these events were located within the vicinity of Burlington County.

Table 5.4.3-5. Earthquake Occurrences in the New York/New Jersey Area, 1737-2012.

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
12/19/1737	5.2	Greater NYC Area*	N/A	N/A	Threw down chimneys	Lamont-Doherty
11/30/1783	5.3	North-Central New Jersey*	N/A	N/A	2 Foreshocks (11/24 and 11/30) and 1 aftershock (11/30); threw down chimneys	NJGS, Lamont-Doherty
1/25/1841	0.0	West Orange, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/26/1845	3.8	Greater NYC Area*	N/A	N/A	No reference and/or no damage reported.	Lamont-Doherty
9/9/1848	4.4	Greater NYC area*	N/A	N/A	No reference and/or no damage reported.	Lamont-Doherty
3/5/1861	0.0	Newark, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/11/1874	3.4	Near Nyack and Tarrytown, NY	N/A	N/A	No reference and/or no damage reported.	Lamont-Doherty
9/10/1877	0.0	Burlington, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/10/1880	0.0	Near Morristown, NJ	N/A	N/A	1 aftershock 9/1/1880.	NJGS
8/10/1884	5.2	Greater NYC Area	N/A	N/A	Threw down chimneys; felt from Virginia to Maine	Lamont-Doherty
1/4/1885	3.4	Hudson Valley	N/A	N/A	No reference and/or no damage reported.	Lamont-Doherty
9/1/1895	4.1	Near High Bridge, NJ	N/A	N/A	A moderately strong earthquake, centered near High Bridge, was felt over a considerable area to the northeast and southwest. The total felt area covered points from Maine to Virginia in a long, narrow elliptical zone of about 92,000 square kilometers. Articles fell from shelves and buildings rocked (intensity VI) in several Hunterdon County towns. The shock was fairly sharp at Camden and Burlington. At Philadelphia, Pennsylvania, broken windows and overturned crockery were reported.	NJGS, Lamont-Doherty, Burlington County HMP
5/27/1902	0.0	Bayonne-Wayne, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/11/1902	0.0	Bayonne-Wayne, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/20/1905	4.5	Greater NYC Area*	N/A	N/A	Probably located offshore	Lamont-Doherty
4/23/1910	0.0	Near Atlantic City, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
11/6/1912	0.0	Near Long Beach, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/5/1919	0.0	Cinnaminson, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/26/1921	N/A	N/A	N/A	N/A	Moorestown and Riverton were shaken moderately (intensity V). A rumbling noise was reported to be heard.	NJGS, Burlington County HMP
6/1/1927	3.9	Near Asbury Park, NJ	N/A	N/A	The highest intensity earthquake ever observed in New Jersey occurred in the Asbury Park area. Three shocks were felt along the coast from Sandy Hook to Toms River. Maximum intensities of VII were observed at Asbury Park and Long Branch. Several chimneys fell, plaster cracked, and articles were thrown from shelves. The felt area extended over approximately 7,800 square kilometers.	NJGS, Lamont-Doherty, Burlington County HMP
1/25/1933	0.0	Near Trenton, NJ	N/A	N/A	A sharp jolt was felt over central New Jersey from Lakehurst to Trenton. Although there is some doubt	NJGS, Burlington County HMP

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
					whether the shock was of seismic origin, the event was felt most strongly at Lakehurst, where people reported they were rolled out of bed (intensity V). Other people reported pictures shaken from walls. The shock was also felt at Bordentown, Burlington, Columbus, Englishtown, Freehold, Hightstown, New Egypt, Robbinsville, and White Horse.	
7/19/1937	3.5	Western Long Island, NY	N/A	N/A	One or few earthquakes beneath Long Island	Lamont-Doherty
9/30/1937	0.0	Verona, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/16/1938	0.0	Verona, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/23/1938	3.8	NE of New Egypt, NJ	N/A	N/A	Central New Jersey was disturbed by a shock somewhat stronger than the 1933 event. The earthquake caused minor damage at Gloucester City and Hightstown (intensity V). The total felt area was about 13,000 square kilometers, including bordering portions of Delaware and Pennsylvania. Glassware was broken at Gloucester City and Hightstown and some furniture was displaced at Pitman. A few windows and some glassware were reported broken at Ardmore, Pennsylvania. Four smaller shocks occurred on August 23rd and one on August 27th.	NJGS, Lamont-Doherty, Burlington County HMP
8/23/1938	4.0	Freehold, NJ	N/A	N/A	4 aftershocks felt.	NJGS
12/6/1938	0.0	Verona, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/13/1939	0.0	Union City, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
11/15/1939	3.4	Salem County, NJ	N/A	N/A	Residents of Salem County were startled by earthquake tremors which caused more excitement than damage. The disturbance was reported felt from Trenton to Baltimore, Maryland, and from Cape May to Philadelphia and its adjoining counties. About 16,000 square kilometers were affected. Small objects were reported to have overturned at Deepwater, but little or no damage was noted.	NJGS, Burlington County HMP
4/1/1947	2.7	Pompton Lakes NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/16/1949	0.0	Hopewell, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/3/1951	3.6	Rockland County, NY	N/A	N/A	Northeastern New Jersey experienced minor effects from an earthquake on September 3, 1951 that was apparently centered in Rockland County, New York. On March 23, 1957, a shock affected west-central New Jersey, near the site of the 1895 earthquake. Chimneys cracked (intensity VI), windows and dishes broke, and pictures fell at Lebanon. A cracked chimney was also reported from Hamden. At Long Valley some walls were cracked and plaster fell. The felt area was small in comparison with the other shocks previously described.	Lamont-Doherty, NJGS, Burlington County HMP

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
8/17/1953	3.2	Bergen County, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/31/1954	0.0	Long Branch, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/23/1957	2.9	Schooley's Mountain, NJ	N/A	N/A	Walls cracked, dishes broke.	NJGS, Lamont-Doherty
12/27/1961	2.7	5 km W of Flemington, NJ	N/A	N/A	In northeastern Philadelphia and adjoining portions of New Jersey and Pennsylvania residents were alarmed by loud rumbling sounds. In New Jersey, the tremor was felt by many at Bordentown and Trenton, where houses shook (intensity V) and windows and dishes rattled.	NJGS, Burlington County HMP
10/13/1962	0.0	Pompton Lakes, NJ	N/A	N/A	1 aftershock 12/20/1962.	NJGS
12/10/1968	2.7	SE of Camden, NJ	N/A	N/A	A similar disturbance affected much of the same area as the 12/27/1961. An earthquake measured at magnitude 2.5 occurred in Burlington County. The press reported some broken windows. Intensity V effects were noted at Camden, Morrestown and at Darby and Philadelphia, Pennsylvania. It was reported that toll booths on the Benjamin Franklin and Walt Whitman Bridges in Philadelphia trembled during the shock.	NJGS, Burlington County HMP
4/25/1969	0.0	Near Sussex, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/6/1969	0.0	Ogdensburg, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/28/1973	3.5	E.OF Wilmington, DE	N/A	N/A	Most of New Jersey and adjoining portions of Delaware, Maryland, and Pennsylvania experienced a moderately strong earthquake. One town in southern Connecticut and one in eastern Virginia also reported the shock. The magnitude 3.8 tremor was centered in northwestern Salem County, near the Delaware River border with the State of Delaware. Observers reported cracked plaster (intensity V) at Laurel Springs and Penns Grove and cracked cinder blocks at Harrisonville. Also, small objects shifted and fell in several towns. Similar types of minor damage occurred in nearby areas of Delaware, Maryland, and Pennsylvania.	NJGS, Burlington County HMP
7/10/1973	2.6	E.OF Wilmington, DE	N/A	N/A	No reference and/or no damage reported.	NJGS
3/11/1976	2.8	Pompton Lakes, NJ	N/A	N/A	1 aftershock, some damage.	NJGS
4/13/1976	3.1	Near Ridgefield, NJ	N/A	N/A	The shock felt widely.	NJGS
12/5/1976	0.0		N/A	N/A	No reference and/or no damage reported.	NJGS
12/5/1976	1.8	Schooley's Mountain, NJ	N/A	N/A	1 aftershock 12/07/1976.	NJGS
1/21/1977	2.7	Lakehurst, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/10/1977	1.1	High Bridge, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
7/2/1977	2.3	Hampton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/27/1977	1.5	Sparta, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
11/27/1977	1.8	Oakland, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/23/1977	2.3	Schooley's Mountain, NJ	N/A	N/A	5 foreshocks 12/4 to12/8 and 5 aftershocks 12/23	NJGS
2/15/1978	1.6	Boonton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
4/3/1978	2.0	Off Sandy Hook	N/A	N/A	No reference and/or no damage reported.	NJGS
5/18/1978	1.5	Bloomingdale, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/16/1978	0.0	Sparta, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/30/1978	2.9	Mahwah-Oakland, NJ	N/A	N/A	1 aftershock on same day.	NJGS
1/30/1979	3.5	Cheesequake, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/2/1979	1.9	Chester, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/23/1979	2.9	Chester, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/10/1979	3.1 "Cheesequake Earthquake"	Bernardsville, NJ (epicenter in Morris County)	N/A	N/A	Felt by some people in Manhattan	NJGS, Lamont-Doherty
3/25/1980	2.8	Hainesburg, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
4/5/1980	2.9	S. of Seaside, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/2/1980	2.8	Keyport, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/30/1980	3.0	Medford Lakes, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/19/1981	2.0	Boonton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/18/1981	2.1	Ramsey, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/21/1981	1.8	Denville, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
4/12/1982	2.4	Mt Holly, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
7/29/1982	2.4	Seaside Heights, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/16/1982	1.6	Franklin, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/19/1983	2.7	Oldwick, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/1/1983	1.5	Dover, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/6/1983	1.5	Fort Lee, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/15/1983	1.5	Ringwood, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/12/1984	2.0	Asbury Park, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/13/1984	2.1	Mount Hope, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/3/1984	1.3	Kinnelon, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/6/1984	1.7	Near Morristown, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/2/1984	1.7	Mount Olive, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/12/1984	2.4	Byram, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/12/1984	2.1	Byram, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/25/1984	2.0	Near Mt. Olive, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/3/1984	1.5	Byram, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/13/1984	1.7	Byram, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/14/1984	1.7	N of Milford, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/15/1984	1.8	Byram, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
12/17/1984	1.6	Byram, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/19/1985	4	Ardsley, NY	N/A	N/A	Many people in the NYC area felt this earthquake	Lamont-Doherty
2/8/1986	1.7	Flanders, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/23/1986	1.8	Port Murray, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/29/1986	1.5	Kinnelon, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
7/15/1986	1.5	Franklin, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/15/1986	2.3	Near New Egypt, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/15/1986	1.9	Near Roebling, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
11/23/1986	2.8	Tranquility, NJ	N/A	N/A	Felt in Sussex and Warren.	NJGS
4/24/1987	1.9	South of Lake Mohawk, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/16/1987	1.4	Near Paterson, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/5/1987	1.7	SW of Newton	N/A	N/A	No reference and/or no damage reported.	NJGS
8/6/1987	1.1	SW of Newton	N/A	N/A	No reference and/or no damage reported.	NJGS
8/6/1987	1.1	SW of Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/6/1987	2.1	Burlington, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
4/13/1988	1.4	Dover, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/20/1988	1.0	10 KM NW of Morristown, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/22/1988	1.0	Wanaque, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/23/1988	1.1	Wanaque, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/22/1989	2.0	Englewood, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/27/1989	1.1	NY-NJ Border	N/A	N/A	No reference and/or no damage reported.	NJGS
9/3/1989	2.0	S of Staten Island	N/A	N/A	No reference and/or no damage reported.	NJGS
9/3/1989	2.5	S of Staten Island	N/A	N/A	No reference and/or no damage reported.	NJGS
1/26/1990	1.0	Franklin, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/10/1990	1.8	Mt. Freedom, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
8/21/1990	0.7	Wanaque, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/23/1990	2.9	Hancock's Bridge, NJ	N/A	N/A	Felt in NJ, DE and PA.	NJGS
5/12/1991	1.3	Wanaque, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
7/5/1991	1.3	Pompton Plains, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
9/29/1991	2.2	Somerdale Boro, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/9/1992	3.1	New Brunswick, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/4/1992	1.4	Kinnelon, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/7/1992	0.4	Jefferson Township, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/13/1992	1.0	West Milford, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/26/1993	2.5	Cherry Hill, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/15/1993	2.6	Perrineville, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/23/1994	1.6	Butler, N.J.	N/A	N/A	No reference and/or no damage reported.	NJGS
1/27/1995	2.3	Rockaway, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
4/1/1995	1.5	Rockaway, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/26/1995	1.5	Kinnelon, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/27/1995	1.3	NE of Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/27/1995	1.4	NE of Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/18/1996	1.5	Ringwood	N/A	N/A	No reference and/or no damage reported.	NJGS
2/19/1996	1.7	Ringwood, NJ	N/A	N/A	1 aftershock 22 minutes later.	NJGS
2/19/1996	0.8	5 km W Ringwood, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/23/1996	0.8	6.4 km W of Ringwood, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/26/1996	0.0	Near Mt. Arlington, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/24/1996	2.0	9 km S Crestwood Village, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
11/12/1996	1.3	21 km NE Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
11/12/1996	0.8	21 km NE Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/11/1997	0.0	3 km W of Rendall Park, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/25/1997	0.5	1 km NE Fort Lee, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/27/1997	1.6	4.6 km N of Rockaway, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
7/15/1997	2.3	12 km NE of Princeton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/21/1997	0.5	3 km SW Woodcliff Lake, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/24/1997	0.5	3 km SW Secaucus, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
3/25/1998	1.9	13 km S Salem, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/20/1998	1.2	2 km SE Kinnelon, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
6/30/1998	1.9	3 km S Butler, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/12/1999	1.4	1 km NW of Clifton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/31/1999	1.5	2 km W of Emerson, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
5/31/1999	2.3	8 km W of Fort Dix, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
1/17/2001	2.4	Manhattan	N/A	N/A	Felt in the Upper East Side of Manhattan, Long Island City, and Queens	Lamont-Doherty
7/14/2001	1.9	7.1 km NE of Boonton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
10/17/2001	2.6	Manhattan	N/A	N/A	Felt in the Upper East Side of Manhattan, Long Island City, Astoria, and Queens	Lamont-Doherty
8/9/2002	1.5	5.4 km N of Somerville, NJ (epicenter in Bridgewater)	N/A	N/A	No reference and/or no damage reported.	NJGS
8/24/2003	1.5	6 km SW of Morris Plains,	N/A	N/A	No reference and/or no damage reported.	NJGS
8/26/2003	3.5	3 km North of Milford, NJ	N/A	N/A	A magnitude 3.5 earthquake occurred 3 km North of Milford, NJ. No reference and/or no damage reported.	NJGS
3/22/2004	2.1	2km NE from Runnemede, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/17/2004	2.0	6km ESE from Pennsville, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
04/23/2005	1.9	1.3 Km East of Lodi, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/09/2005	2.1	16 km W of Franklin Lakes, NJ	N/A	N/A	Aftershock 55 min later, 1.3 M	NJGS
02/16/2006	2.6	22km NE of Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
02/17/2006	0.9	20km NE of Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
02/21/2006	1.3	20.4km NE of Newton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
05/15/2006	2.0	9 km S of Fair Lawn, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
06/28/2007	2.1	7 km E of Fairfield, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
02/03/2009	3.0	3.5km SSW of Rockaway, NJ	N/A	N/A	A magnitude 3.0 earthquake occurred 3.5km SSW of Rockaway, NJ. There were reports of people having felt this earthquake throughout New Jersey.	NJGS, USGS
02/14/2009	2.4	5 km NNE of Boonton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS, USGS
2/18/2009	1.1	3 km SSW of Kinnelon, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/16/2009	1.4	1 km ESE of Oradell, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
2/16/2009	2.3	2 km SSE of Dover, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
07/01/2009	2.8	2.25km ESE of Pennsville, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS, USGS
12/21/2009	2.3	13 km S of Phillipsburg, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
12/26/2009	2.0	8 km NW of Morris Plains, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
02/05/2010	1.5	3 km NW of Far Hills, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
02/07/2010	1.2	3 km NW of far Hills, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
02/10/2010	2.2	1 km W of Wanaque	N/A	N/A	No reference and/or no damage reported.	NJGS
02/21/2010	2.6	Gladstone, NJ	N/A	N/A	This earthquake hit just before 9am and prompted numerous phone calls to police. No damages were reported. Many people in New Jersey reported having felt this earthquake.	NJGS, USGS, NJ.com
02/21/2010	2.3	Gladstone, NJ	N/A	N/A	This event was most likely an aftershock from the morning's earthquake. Numerous people in New Jersey reported having felt this earthquake.	NJGS, USGS, NJ.com
06/06/2010	2.3	6 km SE of Sayreville, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS, USGS
12/25/2010	2.1	1 km W of Clifton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
05/08/2011	1.2	1 km SW of Clifton, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
05/10/2011	1.9	2 km N of Mt. Holly, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
05/29/2011	1.3	3 km S of Fort Lee, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
05/29/2011	1.9	24 km SSW of Lakehurst, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
06/09/2011	1.6	2 km SE of S. Plainfield, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
08/23/2011	4.2	Virginia	N/A	N/A	In Burlington City, Burlington County, Temple B'nai	Planning Committee,

Date(s) of Event	Magnitude	Location	FEMA Declaration Number	County Designated?	Losses/Impacts	Source(s)
					Israel's synagogue building, built during 1801, sustained some water damage when tremor-caused openings in the roof allowed standing water to leak in, and about 20 bricks fell, damaging a congregant's car. Non-essential county employees were allowed to leave work early as precautionary measures.	USGS
07/17/2012	1.1	16 km NW of Morristown, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
07/18/2012	1.1	18 km NW of Morristown, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
08/23/2012	1.2	1.4 km E of Ringwood, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS
11/05/2012	2.0	3 km SW of Mahwah, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS, USGS
11/23/2012	2.2	Greater Philadelphia Area/New Jersey	N/A	N/A	Numerous reports of people having felt the earthquake in southwestern New Jersey.	NJGS, USGS
6/23/2013	2.1	1 km E of Rockaway, NJ	N/A	N/A	No reference and/or no damage reported.	NJGS

Source: NJGS, 2013; USGS, 2013; Won-Young Kim, Lamont-Doherty Earth Observatory of Columbia University, 1999; Burlington County HMP, 2008
Note: Yellow shading indicates an event that was epicentered in Burlington County.
* Location very poorly determined; may be uncertain by 50 miles.

E	East
FEMA	Federal Emergency Management Agency
Km	Kilometers
N	North
N/A	Not Applicable
NJ	New Jersey
NJGS	New Jersey Geologicaly Survey
NYC	New York City
NYSDPC	New York State Disaster Preparedness Commission
S	South
USGS	U.S. Geological Survey
W	West

Earthquakes in Burlington County are not common, with documented information on earthquake events and their location is being relatively scarce. According to Planning Area officials, there is no record of earthquake occurrences within the Planning Area. However, depending on the magnitude, the impacts of earthquake events can be far-reaching; therefore, reported incidences within the surrounding counties or states could have created indirect impacts upon Burlington County.

Probability of Future Events

Earthquakes cannot be predicted. They strike without warning, at any time of the year, and at any time of the day or night. Earthquake hazard maps – sometimes referred to as "PGA maps" – are used as a tool to project the likelihood of a various intensity quake being exceed at a certain location over a given period of time. They depict the PGA, expressed as a percentage of the force of gravity that can be expected to be exceeded at a given location for a particular probability of exceedance over a specific time frame. Figure 5.4.3-2 is an example of an earthquake hazard map for New Jersey as prepared by the USGS Earthquake Hazards Program. It shows PGA values for New Jersey that have a 10 percent chance of being exceeded over 50 years.

Earthquake hazard maps illustrate the distribution of earthquake shaking levels that have a certain probability of occurring over a given time period. As stated previously, according to the Earthquake Hazard Map of New Jersey, there is a 10 percent chance over 50 years that an earthquake with a PGA of greater than 2%g to 4%g (Figure 5.4.3-2) will be centered within Burlington County and/or its participating jurisdictions. This earthquake, if it did occur, would likely have associated with it light to moderate perceived shaking and little to no damage.

Earlier in this section, the identified hazards of concern for Burlington County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for ranking hazards. Based on historical records and input from the Planning Committee, the probability of occurrence for earthquakes in the County is considered "occasional" (is likely to occur within 100 years as presented in Table 5.3-3). Although no reported incidences have occurred within Burlington County, it is anticipated that the County will experience indirect impacts from earthquakes that may affect the general building stock, local economy and may induce secondary hazards such as sporatic ignition of fires and utility failure.

VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the earthquake hazard, the entire County has been identified as the exposed hazard area. Therefore, all assets in Burlington County (population, structures, critical facilities and lifelines), as described in the County Profile (Section 4), are vulnerable. The following section includes an evaluation and estimation of the potential impact of the earthquake hazard on Burlington County including the following:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, safety and health of residents, (2) general building stock, (3) critical facilities, (4) economy and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2008 Burlington County Hazard Mitigation Plan
- Further data collections that will assist understanding of this hazard over time

Overview of Vulnerability

Earthquakes usually occur without warning and can impact areas a great distance from their point of origin. The extent of damage depends on the density of population and building and infrastructure construction in the area shaken by the quake. Some areas may be more vulnerable than others based on soil type, the age of the buildings and building codes in place. Compounding the potential for damage – historically, Building Officials Code Administration (BOCA) used in the Northeast were developed to address local concerns including heavy snow loads and wind; seismic requirements for design criteria are not as stringent compared to the west coast's reliance on the more seismically-focused Uniform Building Code). As such, a smaller earthquake in the Northeast can cause more structural damage than if it occurred out west.

The level of seismic hazard, the frequency and severity of earthquakes, is substantially lower in New Jersey than in more seismically active states such as California or Alaska. The level of seismic risk, the threat to buildings, infrastructure, and people, is significant in the State, especially in northern New Jersey. The level of seismic risk (potential damages) in the State is higher than might be expected because the vast majority of the buildings and infrastructure in New Jersey have been built with minimal or no consideration of earthquakes; therefore, the majority of buildings and infrastructure in the State is more vulnerable to earthquake damage than the buildings and infrastructure in more seismically active states where inventory has been built with consideration of earthquakes (NJOEM, 2011).

The entire population and general building stock inventory of the County is at risk of being damaged or experiencing losses due to impacts of an earthquake. Potential losses associated with the earth shaking were calculated for Burlington County for three probabilistic earthquake events, the 100-year, 500- and 2,500-year mean return periods (MRP). The impacts on population, existing structures, critical facilities and the economy within Burlington County are presented below, following a summary of the data and methodology used.

Data and Methodology

A probabilistic assessment was conducted for Burlington County for the 100-, 500- and 2,500-year MRPs using HAZUS-MH 2.1 to analyze the earthquake hazard and provide a range of loss estimates for Burlington County. 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 by Census tract. According to the New York City Area Consortium for Earthquake Loss Mitigation (NYCEM), probabilistic estimates are best for urban planning, land use, zoning and seismic building code regulations (NYCEM, 2003). The default assumption is a magnitude 7 earthquake for all return periods. In addition, an annualized loss run was also conducted in HAZUS-MH 2.1 to estimate the annualized general building stock dollar losses for Burlington County.

In addition to the probabilistic scenarios mentioned, an annualized loss run was conducted in HAZUS 2.1 to estimate the annualized general building stock dollar losses for the County. The annualized loss methodology combines the estimated losses associated with ground shaking for eight return periods: 100, 250, 500, 750, 1000, 1500, 2000, 2500-year, which are based on values from the USGS seismic probabilistic curves. Annualized losses are useful for mitigation planning because they provide a baseline upon which to 1) compare the risk of one hazard across multiple jurisdictions and 2) compare the degree of risk of all hazards for each participating jurisdiction.

As noted in the HAZUS-MH Earthquake User Manual '*Uncertainties are inherent in any loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effects upon buildings and facilities. They also result from the approximations and simplifications that are necessary for comprehensive analyses. Incomplete or inaccurate inventories of the built environment, demographics and economic parameters add to the uncertainty. These factors can result in a range of uncertainly in loss estimates produced by the HAZUS Earthquake Model, possibly at best a factor of two or more*.' However, HAZUS' potential loss estimates are acceptable for the purposes of this HMP.

The occupancy classes available in HAZUS-MH 2.1 were condensed into the following categories (residential, commercial, industrial, agricultural, religious, government, and educational) to facilitate the analysis and the presentation of results. Residential loss estimates address both multi-family and single family dwellings. Impacts to critical facilities and utilities were also evaluated.

Data used to assess this hazard include data available in the HAZUS-MH 2.1 earthquake model, USGS data, data provided by NJ Geological and Water Survey, professional knowledge, and information provided by the County's Planning Committee. All exposure and loss estimates discussed in the assessment below are for Burlington County.

Impact on Life, Health and Safety

Overall, the entire population of Burlington County is exposed to the earthquake hazard event. According to the 2010 U.S. Census, Burlington County had a population of 448,734 people. The impact of earthquakes on life, health and safety is dependent upon the severity of the event. Risk to public safety and loss of life from an earthquake in Burlington County is minimal with higher risk occurring in buildings as a result of damage to the structure, or people walking below building ornamentation and chimneys that may be shaken loose and fall as a result of the quake.

Populations considered most vulnerable are located in the built environment, particularly near unreinforced masonry construction. In addition, the vulnerable population includes the elderly (persons over the age of 65) and individuals living below the Census poverty threshold. These socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

Residents may be displaced or require temporary to long-term sheltering due to 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 following a disaster event. Table 5.4.3-6 summarizes the households HAZUS-MH 2.1 estimates will be displaced and population that may require short-term sheltering as a result of the 100-, 500- and 2,500-year MRP earthquake events.

Table 5.4.3-6. Summary of Estimated Sheltering Needs for Burlington County

Scenario	Displaced Households	Persons Seeking Short-Term Shelter
100-Year Earthquake	0	0
500-Year Earthquake	9	5
2,500-Year Earthquake	206	121

Source: HAZUS-MH 2.1

Table 5.4.3-7. Estimated Displaced Households and Population Seeking Short-Term Shelter from the 500- and 2,500-year MRP Events per Municipality

Municipality	500-Year MRP Event		2,500-Year MRP Event	
	Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering
Bass River Township	0	0	0	0
Beverly City	0	0	2	1
Bordentown City	0	0	5	3
Bordentown Township	0	0	5	3
Burlington City	0	0	6	4
Burlington Township	1	0	12	8
Chesterfield Township	0	0	0	0
Cinnaminson Township	0	0	3	2
Delanco Township	0	0	1	1
Delran Township	1	1	10	6
Eastampton Township	0	0	4	2
Edgewater Park Township	1	0	9	5
Evesham Township	1	1	22	11
Fieldsboro Borough	0	0	0	0
Florence Township	0	0	7	4
Hainesport Township	0	0	1	0
Lumberton Township	0	0	7	4
Mansfield Township	0	0	1	0
Maple Shade Township	1	1	25	12
Medford Lakes Borough	0	0	0	0
Medford Township	0	0	7	4
Moorestown Township	1	0	8	4
Mount Holly Township	0	0	7	5

Municipality	500-Year MRP Event		2,500-Year MRP Event	
	Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering
Mount Laurel Township	1	1	27	13
New Hanover Township	1	1	3	6
North Hanover Township	0	0	5	4
Palmyra Borough	0	0	6	3
Pemberton Borough	1	0	1	1
Pemberton Township	0	0	9	6
Riverside Township	0	0	6	4
Riverton Borough	0	0	2	1
Shamong Township	0	0	**0**	5
Southampton Township	0	0	1	1
Springfield Township	0	0	0	0
Tabernacle Township	0	0	1	0
Washington Township	0	0	0	0
Westampton Township	0	0	1	1
Willingboro Township	0	0	3	2
Woodland Township	0	0	0	0
Wrightstown Borough	0	0	1	1
Burlington County (Total)	**9**	**5**	**208**	**127**

Source: HAZUS-MH 2.1

Note: The population displaced and seeking shelter was calculated using the 2000 U.S. Census data (HAZUS-MH 2.1 default demographic data).

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

There are 0 injuries or casualties estimated for the 100-year event. An estimated 6 injuries that require medical attention (no hospitalization), and one injury which requires hospitalization are estimated for the 500-year event. There are no casualties estimated for the 500-year event.

Table 5.4.3-8 summarizes the injuries and casualties estimated for the 2,500-year MRP earthquake event.

Table 5.4.3-8. Estimated Number of Injuries and Casualties from the 2,500-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
Injuries	90	91	83
Hospitalization	12	14	15
Casualties	2	2	2

Source: HAZUS-MH 2.1

Impact on General Building Stock

After considering the population exposed to the earthquake hazard, the value of general building stock exposed to and damaged by 100-, 500- and 2,500-year MRP earthquake events was evaluated. In addition, annualized losses were calculated using HAZUS-MH 2.1. The entire study area's general building stock is considered at risk and exposed to this hazard.

The HAZUS-MH 2.1 model estimates the value of the exposed building stock and the loss (in terms of damage to the exposed stock). Refer to Table 4-3 in the County Profile (Section 4) for general building stock data replacement value statistics (structure and contents).

For this plan update and using HAZUS-MH 2.1, a probabilistic model was run for the purposes of this Plan to estimate annualized dollar losses for Burlington County. Annualized losses are useful for mitigation planning because they provide a baseline upon which to 1) compare the risk of one hazard across multiple jurisdictions and 2) compare the degree of risk of all hazards for each participating jurisdiction. Please note that annualized loss does not predict what losses will occur in any particular year. The estimated annualized losses are approximately $490,000 per year (building and contents) for the County.

According to NYCEM, where earthquake risks and mitigation were evaluated in the New York, New Jersey and Connecticut region, most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking (NYCEM, 2003). NYCEM indicates there is a strong correlation between PGA and the damage a building might experience. The HAZUS-MH model is based on the best available earthquake science and aligns with these statements. HAZUS-MH 2.1 methodology and model were used to analyze the earthquake hazard for the general building stock for Burlington County. See Figure 5.4.3-2 earlier in this profile that illustrates the geographic distribution of PGA (g) across the County for 100-, 500- and 2,500-year MRP events at the Census-Tract level.

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

Potential building damage was evaluated by HAZUS-MH 2.1 across the following damage categories (none, slight, moderate, extensive and complete). Table 5.4.3-9 provides definitions of these five categories of damage for a light wood-framed building; definitions for other building types are included in HAZUS-MH technical manual documentation. General building stock damage for these damage categories by occupancy class and building type on a County-wide basis is summarized for the 100-, 500-

and 2,500-year events in Table 5.4.3-10, Table 5.4.3-11, and Table 5.4.3-12. Damage loss estimates include structural and non-structural damage to the building and loss of contents.

Table 5.4.3-9. Example of Structural Damage State Definitions for a Light Wood-Framed Building

Damage Category	Description
Slight	Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations.
Complete	Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Source: HAZUS-MH Technical Manual

Table 5.4.3-10. Estimated Buildings Damaged by General Occupancy for 100-year, 500-year and 2,500-year MRP Earthquake Events

Category	Average Damage State														
	100-Year MRP					500-Year MRP					2,500-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Residential	146,091	0	0	0	0	144,448	1,389	235	18	1	126,934	14,829	3,844	444	39
Commercial	8,373	0	0	0	0	8,223	115	31	3	0	6,907	937	448	75	6
Industrial	2,526	0	0	0	0	2,484	32	9	1	0	2,091	271	140	21	2
Education, Government, Religious and Agricultural	2,031	0	0	0	0	1,996	28	7	0	0	1,689	226	98	16	1

Source: HAZUS-MH 2.1

Table 5.4.3-11. Estimated Number of Buildings Damaged by Building Type for 100-year, 500-year and 2,500-year MRP Earthquake Events

Category	Average Damage State														
	100-Year MRP					500-Year MRP					2,500-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Wood	128,278	0	0	0	0	127,236	951	88	3	0	113,403	12,364	2,354	153	4
Steel	6,261	0	0	0	0	6,171	71	17	1	0	5,214	642	352	50	3
Concrete	1,494	0	0	0	0	1,477	14	3	0	0	1,230	165	91	7	1
Reinforced Masonry	2,549	0	0	0	0	2,510	27	11	1	0	2,197	187	139	26	0
Un-reinforced Masonry	17,664	0	0	0	0	17,066	438	142	17	1	13,493	2,507	1,335	289	39
Manufactured housing	2,367	0	0	0	0	2,294	55	18	1	0	1,758	360	225	22	1

Source: HAZUS-MH 2.1

Table 5.4.3-12. Estimated Building Value (Building and Contents) Damaged by the 500- and 2,500-Year MRP Earthquake Events

Municipality	Estimated Total Damages*			Percent of Total Building and Contents RV**		Estimated Residential Damage		Estimated Commercial Damage	
	Annualized Loss	500-Year	2,500-Year	500-Year	2,500-Year	500-Year	2,500-Year	500-Year	2,500-Year
Bass River Township	582	34,400	681,313	0.02%	0.43%	27,181	534,986	3,627	66,097
Beverly City	2,869	133,458	3,132,532	0.04%	0.89%	68,545	1,666,177	24,679	532,178
Bordentown City	5,670	257,933	6,168,477	0.04%	1.01%	143,997	3,526,892	74,110	1,620,981
Bordentown Township	10,342	470,498	11,448,498	0.04%	0.93%	306,706	7,602,349	123,438	2,777,673
Burlington City	12,302	581,386	13,393,965	0.04%	0.94%	314,813	7,413,190	172,572	3,706,425
Burlington Township	28,952	1,339,142	31,217,900	0.04%	0.96%	800,025	18,706,440	383,233	8,371,362
Chesterfield Township	4,065	183,065	4,465,191	0.04%	0.93%	132,588	3,224,733	25,688	576,067
Cinnaminson Township	18,882	855,855	20,698,192	0.04%	0.87%	478,128	11,734,933	249,115	5,461,562
Delanco Township	3,937	177,698	4,299,559	0.04%	0.89%	87,487	2,141,195	53,632	1,193,620
Delran Township	16,915	776,712	18,627,724	0.04%	0.87%	457,923	11,237,491	251,705	5,575,281
Eastampton Township	5,303	252,644	5,909,106	0.04%	0.83%	181,216	4,320,869	61,047	1,332,471
Edgewater Park Township	8,041	376,182	8,810,212	0.04%	0.92%	228,739	5,490,641	124,961	2,763,757
Evesham Township	45,897	2,249,290	52,194,101	0.03%	0.81%	1,223,532	29,407,873	886,896	19,272,126
Fieldsboro Borough	587	26,364	658,027	0.04%	0.91%	15,589	387,305	6,268	139,832
Florence Township	12,762	582,037	14,067,701	0.04%	0.93%	359,527	8,885,742	158,270	3,553,509
Hainesport Township	7,235	332,379	7,746,155	0.04%	0.92%	148,569	3,546,063	138,277	2,992,198
Lumberton Township	11,165	541,886	12,322,765	0.04%	0.82%	342,259	8,001,139	160,332	3,330,757
Mansfield Township	17,213	692,031	18,467,937	0.04%	0.94%	159,090	3,929,099	66,032	1,450,783
Maple Shade Township	18,835	891,009	20,823,776	0.04%	0.89%	610,247	14,457,396	218,378	4,744,609
Medford Lakes Borough	3,035	155,390	3,614,863	0.03%	0.64%	126,373	2,970,890	21,883	466,196
Medford Township	25,726	1,281,078	29,320,553	0.03%	0.78%	730,833	17,263,269	436,580	9,150,550
Moorestown Township	34,859	1,620,231	37,652,784	0.04%	0.89%	700,587	16,875,372	719,683	15,415,779
Mount Holly Township	14,388	662,828	15,420,860	0.04%	0.93%	290,701	6,945,682	270,402	6,072,289
Mount Laurel Township	55,593	2,647,509	60,735,547	0.04%	0.87%	1,444,764	34,250,301	997,422	21,265,557
New Hanover Township	15,641	695,886	16,078,842	0.04%	1.00%	266,492	6,005,592	404,214	9,474,401
North Hanover Township	6,011	291,341	6,481,531	0.04%	0.95%	182,064	4,139,009	80,081	1,665,033
Palmyra Borough	7,390	342,248	8,222,910	0.04%	0.87%	224,506	5,489,349	81,226	1,791,600
Pemberton Borough	1,338	66,456	1,551,519	0.04%	0.83%	34,815	826,066	11,762	250,874
Pemberton Township	23,092	1,123,478	26,014,189	0.03%	0.80%	726,192	16,988,323	264,983	5,880,430
Riverside Township	7,038	324,073	7,818,567	0.04%	0.88%	203,326	4,924,482	66,479	1,451,016
Riverton Borough	2,842	133,131	3,138,205	0.04%	0.89%	94,897	2,279,157	26,520	573,231

Municipality	Estimated Total Damages*			Percent of Total Building and Contents RV**		Estimated Residential Damage		Estimated Commercial Damage	
	Annualized Loss	500-Year	2,500-Year	500-Year	2,500-Year	500-Year	2,500-Year	500-Year	2,500-Year
Shamong Township	4,406	224,969	5,159,622	0.03%	0.65%	159,390	3,689,784	47,757	1,004,719
Southampton Township	8,119	420,416	9,429,203	0.03%	0.72%	305,694	6,919,006	84,669	1,754,397
Springfield Township	3,624	170,342	4,007,620	0.04%	0.87%	102,955	2,479,707	44,288	948,654
Tabernacle Township	5,000	257,830	5,802,928	0.03%	0.62%	171,109	3,861,449	50,318	1,023,896
Washington Township	592	31,192	665,716	0.03%	0.61%	16,177	341,838	7,516	154,836
Westampton Township	11,500	530,753	12,342,800	0.04%	0.93%	223,821	5,417,968	221,997	4,753,228
Willingboro Township	26,015	1,236,441	29,418,463	0.03%	0.82%	912,641	22,223,133	234,479	5,060,908
Woodland Township	572	30,345	691,827	0.03%	0.60%	26,029	596,921	2,190	46,023
Wrightstown Borough	1,458	68,939	1,524,577	0.05%	1.09%	24,552	574,024	32,736	694,972
Burlington County (Total)	**489,790**	**23,068,842**	**540,226,257**	**0.04%**	**0.86%**	**13,054,080**	**311,275,831**	**7,289,445**	**158,359,875**

Source: HAZUS-MH 2.1
RV: Replacement Value
*Total is sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious and government).
**Total replacement value (building and contents) for the County is greater than $62 billion.

It is estimated that there would be more than $23 million in damages to buildings in the County during a 500-year earthquake event. This includes structural damage, non-structural damage and loss of contents, representing less than one-percent of the total replacement value for general building stock in Burlington County. For a 2,500-year MRP earthquake event, HAZUS-MH estimates 4,530 buildings will be at least moderately damaged. The estimated total building damage is greater than $540 million, less than one-percent of the total general building stock replacement value (total replacement value is greater than $62.7 billion for the County). Residential and commercial buildings account for most of the damage for earthquake events.

Earthquakes can cause secondary hazard events such as fires. No fires are anticipated as a result of the 100-, 500- or 2,500-year MRP events.

Impact on Critical Facilities

After considering the general building stock exposed to, and damaged by, 100-, 500- and 2,500-year MRP earthquake events, critical facilities were evaluated. All critical facilities (essential facilities, transportation systems, lifeline utility systems, high-potential loss facilities and user-defined facilities) in Burlington County are considered exposed and vulnerable to the earthquake hazard. Refer to subsection "Critical Facilities" in Section 4 (County Profile) of this Plan for a complete inventory of critical facilities in the County.

HAZUS-MH 2.1 estimates the probability that critical facilities may sustain damage as a result of 100-, 500- and 2,500-year MRP earthquake events. Additionally, HAZUS-MH estimates percent functionality for each facility days after the event. For the 100-Year MRP event, HAZUS-MH 2.1 estimates it is 99% probable that emergency facilities (police, fire, EMS and medical facilities), schools and specific facilities identified by Burlington County as critical (i.e., user-defined facilities such shelters, municipal buildings and Departments of Public Works) will not experience any structural damage. These facilities are estimated to be nearly 100% functional on day one of the 100-year MRP earthquake event. Therefore, the impact to critical facilities is not significant for the 100-year event.

Table 5.4.3-13 and Table 5.4.3-14 list the percent probability of critical facilities sustaining the damage category as defined by the column heading and percent functionality after the event for the 500-year and 2,500-year MRP earthquake events.

Table 5.4.3-13. Estimated Damage and Loss of Functionality for Critical Facilities in Burlington County for the 500-Year MRP Earthquake Event

Type	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Fire	89 - 91	3 - 7	2- 3	0 - 1	0	88 - 91	96 - 97	99	99
Police	89 - 91	3 - 7	2- 3	0 - 1	0	88 - 91	96 - 97	99	99
EOC	89 - 91	3 - 7	2- 3	0 - 1	0	88 - 91	96 - 97	99	99
Hospital	99	1 – 3	0 – 1	0	0	98 - 99	99	99	99
School	89 - 90	6 - 7	2 - 3	0 - 1	0	88 - 90	96 - 97	99	99
Shelter	94 - 95	3 - 4	1	0	0	95 - 96	98 - 99	99	99
Senior	95	3 - 4	1	0	0	95	97 - 98	99	99
Municipal	95 - 97	3 – 7	0 - 1	0	0	95	98 - 99	99	99

Source: HAZUS-MH 2.1

Table 5.4.3-14. Estimated Damage and Loss of Functionality for Critical Facilities in Burlington County for the 2,500-Year MRP Earthquake Event

Type	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Fire	57 - 68	17 - 21	14 - 16	4 - 5	0 - 1	58 - 68	77 - 80	94 - 96	96 - 97
Police	57 - 62	18 - 21	15 - 16	4 - 5	1	58 - 68	77 - 80	94 - 96	96 - 97
EOC	57 - 68	17 - 21	14 - 16	4 - 5	0 - 1	58 - 68	77 - 80	94 - 96	96 - 97
Hospital	78 - 79	13 - 17	0 - 10	2 - 8	0 - 1	78 - 79	87 - 92	97 - 99	99 - 100
School	57 - 61	20 - 21	15 - 16	5	1	57 - 60	78 - 79	94 - 95	96 - 97
Shelter	67 - 70	17 - 19	10 – 11	2 – 3	0	68 - 73	87 - 91	97 - 98	100
Senior	69- 70	17 - 19	10 -11	2 - 3	0	67 - 70	86 - 87	97	100
Municipal	67 - 74	16 - 19	9 - 11	2 - 3	0	68 - 71	87 - 91	97 - 98	100

Source: HAZUS-MH 2.1

Impact on Economy

Earthquakes also have impacts on the economy, including: loss of business function, damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. A Level 2 HAZUS-MH analysis estimates the total economic loss associated with each earthquake scenario, which includes building- and lifeline-related losses (transportation and utility losses) based on the available inventory (facility [or GIS point] data only). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is reported in the "Impact on General Building Stock" section discussed earlier. Lifeline-related losses include the direct repair cost to transportation and utility systems and are reported in terms of the probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion. Additionally, economic loss includes business interruption losses associated with the inability to operate a business due to the damage sustained during the earthquake as well as temporary living expenses for those displaced. These losses are discussed below.

It is significant to note that for the 500-year event, HAZUS-MH 2.1 estimates the County will incur approximately $5.2 million in income losses (wage, rental, relocation and capital-related losses) in addition to the 500 –year event structural, non-structural and content building stock losses ($17.9 million). For the 2,500-year event, HAZUS-MH 2.1 estimates the County will incur nearly $86.7 million in income losses, mainly to the residential and commercial occupancy classes associated with wage, rental, relocation and capital-related losses.

Utility damage results are not considered to be significant as a result of the 100-year and 500-year events. For the 500-year event, there is a 96-percent or greater probability that utilities will not experience any damage; and up to a four-percent probability 'slight' damage could be experienced. Therefore, utility loss estimates as a result of the 100- and 500-year events are not discussed further in this assessment for this HMP. Table 5.4.3-15 summarizes the estimated losses to utilities as a result of the 2,500-year event.

Earthquake events can significantly impact road bridges. These are important because they often provide the only access to certain neighborhoods. Since softer soils can generally follow floodplain boundaries, bridges that cross watercourses should be considered vulnerable. A key factor in the degree of vulnerability will be the age of the facility, which will help indicate to which standards the facility was built.

HAZUS-MH estimates the long-term economic impacts to the County for 15-years after the earthquake event. In terms of the highway transportation infrastructure, HAZUS-MH estimates $35 Million in direct repair costs to bridges in the County as a result of a 2,500-year event. No loss is estimated for highway segments.

It is estimated that the airports in Burlington County will be 91% functional on day one of the 2,500-year event and an estimated 68-percent probability they will experience slight damage.

Table 5.4.3-15. Estimated Utility Impacts in Burlington County from the 2,500-year MRP Earthquake Event

Type	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communication	36 - 41	41 - 43	17 - 19	2 – 3	0	88 - 90	99	100	100
Electric	76 - 77	13 - 14	9 - 10	1	0	83 - 85	99	100	100
Water	34 - 40	40 - 43	15 - 18	1 - 2	0	69 - 71	98 - 99	99	100
Wastewater	36 - 45	40 - 43	15 - 20	1 - 2	0	87 – 91	98 -99	100	100

Source: HAZUS-MH 2.1

HAZUS-MH 2.1 also estimates the volume of debris that may be generated as a result of an earthquake event to enable the study region to prepare and rapidly and efficiently manage debris removal and disposal. Debris estimates are divided into two categories: (1) reinforced concrete and steel that require special equipment to break it up before it can be transported, and (2) brick, wood and other debris that can be loaded directly onto trucks with bulldozers (HAZUS-MH Earthquake User's Manual).

For the 100-year MRP event, HAZUS-MH 2.1 estimates 0 tons of debris will be generated. For the 500-year MRP event, HAZUS-MH 2.1 estimates more than 9,314 tons of debris will be generated. For the 2,500-year MRP event, HAZUS-MH 2.1 estimates greater than 125,565 tons of debris will be generated (Table 5.4.3-16).

Table 5.4.3-16. Estimated Debris Generated by the 500- and 2,500-year MRP Earthquake Events

Municipality	500-Year		2,500-Year	
	Brick/Wood (tons)	Concrete/Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)
Bass River Township	12.7	2.6	132.8	43.3
Beverly City	45.9	11.7	519.8	255.4
Bordentown City	86.9	23.5	983.6	513.1
Bordentown Township	150.9	40.1	1735.8	880.6
Burlington City	194.3	51.3	2155.0	1090.1
Burlington Township	422.3	132.1	4682.0	2856.9
Chesterfield Township	56.6	17.9	648.6	394.3
Cinnaminson Township	254.9	73.6	2931.5	1643.4
Delanco Township	65.8	20.1	749.1	450.0
Delran Township	249.3	65.2	2845.0	1438.4
Eastampton Township	81.6	18.7	934.2	402.4
Edgewater Park Township	132.6	34.1	1487.7	747.2
Evesham Township	666.7	172.1	7510.7	3671.3
Fieldsboro Borough	7.9	1.9	91.9	42.8
Florence Township	187.9	48.3	2163.0	1068.7
Hainesport Township	102.4	32.2	1155.2	718.2
Lumberton Township	173.5	45.9	1898.2	945.9
Mansfield Township	258.5	119.7	2982.6	2770.1
Maple Shade Township	332.2	84.6	3663.8	1805.1
Medford Lakes Borough	46.7	8.7	534.1	177.0
Medford Township	378.3	100.5	4234.8	2128.4
Moorestown Township	500.8	161.0	5541.4	3478.1
Mount Holly Township	204.7	59.1	2300.4	1301.8
Mount Laurel Township	822.6	227.6	9103.7	4776.2
New Hanover Township	156.7	67.0	1709.9	1452.4
North Hanover Township	100.2	25.3	1126.0	523.9
Palmyra Borough	124.8	30.6	1419.0	665.6
Pemberton Borough	24.8	6.1	276.2	130.1
Pemberton Township	357.9	83.0	4077.6	1741.4
Riverside Township	126.4	33.7	1431.7	734.0
Riverton Borough	46.1	11.6	522.5	250.1
Shamong Township	70.8	16.0	811.5	324.7
Southampton Township	147.3	33.0	1663.1	670.4

Municipality	500-Year		2,500-Year	
	Brick/Wood (tons)	Concrete/Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)
Springfield Township	52.3	13.4	589.3	284.0
Tabernacle Township	86.6	21.5	949.6	421.3
Washington Township	12.7	4.5	133.3	85.7
Westampton Township	151.1	45.2	1706.5	1002.3
Willingboro Township	363.4	74.0	4210.5	1552.3
Woodland Township	10.8	1.9	122.2	37.3
Wrightstown Borough	21.1	6.2	226.9	131.0
Burlington County (Total)	**7,288.8**	**2,025.5**	**81960.6**	**43605.3**

Source: HAZUS-MH 2.1

Future Growth and Development

As discussed in Section 4, areas targeted for future growth and development have been identified across the County. It is anticipated that the human exposure and vulnerability to earthquake impacts in newly developed areas will be similar to those that currently exist within the County. Current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts than older, existing construction that may have been built to lower construction standards.

Effect of Climate Change on Vulnerability

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

Secondary impacts of earthquakes could be magnified by climate change. Increased saturation of soils by more frequent and/or intense storms could increase the risk for liquefaction. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

Additional Data and Next Steps

Additional data needed to further refine the County's vulnerability assessment include: (1) updated demographic data to update the default data in HAZUS-MH; and (2) updated building data to update the default data in HAZUS-MH. Additionally, the County can identify un-reinforced masonry critical facilities and privately-owned buildings (i.e., residences) using local knowledge and/or pictometry/orthophotos. These buildings may not withstand earthquakes of certain magnitudes and plans to provide emergency response/recovery efforts for these properties can be set in place. Further mitigation actions include training of County and municipal personnel to provide post-hazard event rapid visual damage assessments, increase of County and local debris management and logistic capabilities, and revised regulations to prevent additional construction of non-reinforced masonry buildings.