4.3.3 Earthquake

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

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

- Surface faulting: Displacement that reaches the Earth's surface during a slip along a fault. Commonly occurs with shallow earthquakes—those with an epicenter of less than 20 kilometers (km).
- Ground motion (shaking): Movement of the Earth's surface from earthquakes or explosions. Ground motion or shaking is produced by waves generated by a sudden slip on a fault or sudden pressure at the explosive source, and that travel through the Earth and along its surface.
- Landslide: Movement of surface material down a slope.
- Liquefaction: A process by which water-saturated sediment temporarily loses strength and acts as a fluid, like the wet sand near the water at the beach. Earthquake shaking can cause this effect.
- Tectonic deformation: Change in the original shape of a material caused by stress and strain.
- Tsunami: A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major sub-marine slides, or exploding volcanic islands.
- Seiche: Sloshing of a closed body of water, such as a lake or bay, from earthquake shaking (USGS 2012).

Ground shaking is the primary cause of earthquake damage to man-made structures. Damage can be increased when soft soils amplify ground shaking. Soils influence damage in different ways. Soft soils can amplify the motion of earthquake waves, producing greater ground shaking and increasing stresses on built structures on the land surface. Loose, wet, sandy soils also can cause damage when they lose strength and flow as a fluid when shaken, causing foundations and underground structures to shift and break (Stanford 2003).

The National Earthquake Hazard Reduction Program (NEHRP) developed five soil classifications (A to E) distinguished by soil shear-wave velocity that alters severity of an earthquake; each classification is listed in Table 4.3.3-1. Class A soils (hard rock) reduce ground motion from an earthquake, and Class E soils (soft soils) amplify and magnify ground shaking, and increase building damage and losses.

Table 4.3.3-1. NEHRP Soil Classifications

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

Source: Federal Emergency Management Agency (FEMA) 2013

The following sections discuss location and extent, range of magnitude, previous occurrence, future occurrence, and vulnerability assessment associated with the earthquake hazard in Fulton County.

4.3.3.1 Location and Extent

Focal depth and geographic position of the epicenter of an earthquake commonly determine its location. Focal depth of an earthquake is the depth from the Earth's surface to the region where an earthquake's energy originates (the focus or hypocenter). The epicenter of an earthquake is the point on the Earth's surface directly above the hypocenter. Earthquakes usually occur without warning, and their effects can be felt in areas at great distances from the epicenter.

According to the Pennsylvania Bureau of Topographic and Geologic Survey, events that occur in the Commonwealth involve very small impact areas (less than 100 kilometers in diameter). The most seismically active region in the Commonwealth is in southeastern Pennsylvania in the area of Lancaster County (PEMA 2018). Areas of Pennsylvania, including Fulton County, may be subject to the effects of earthquakes with epicenters outside the Commonwealth.

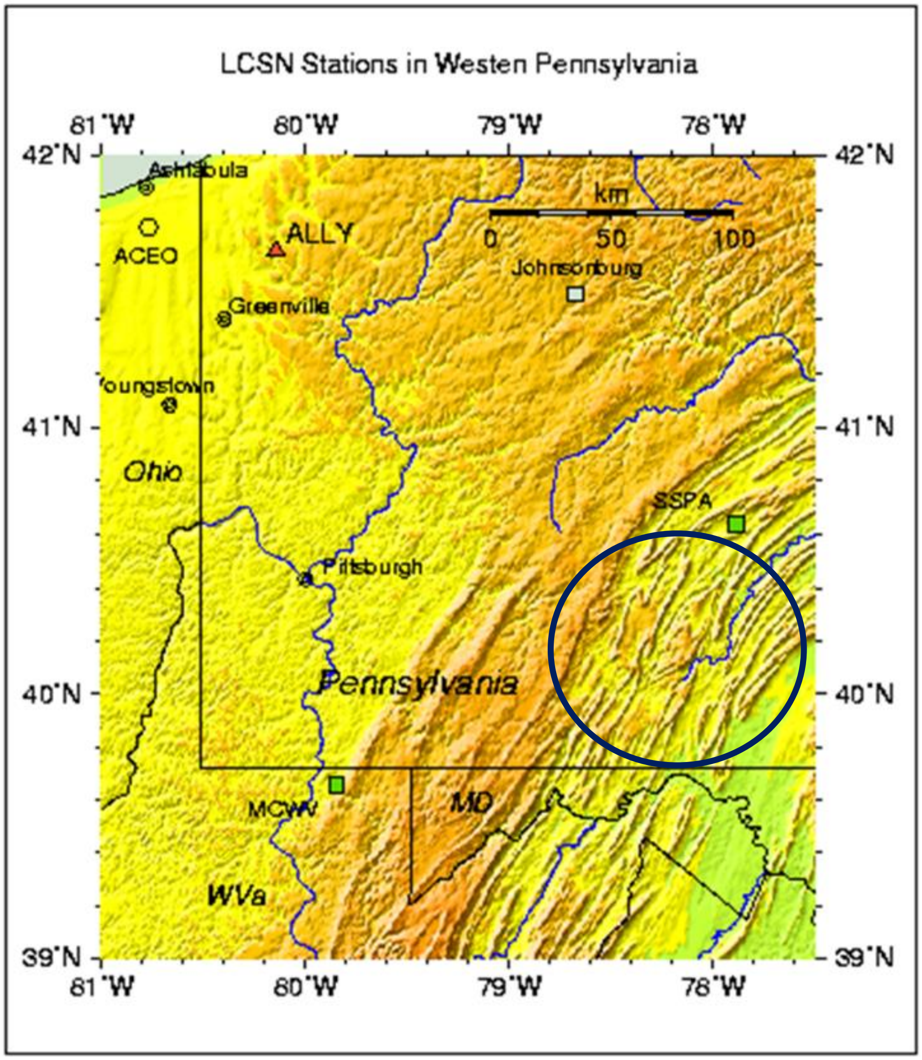
The Pennsylvania State Hazard Mitigation Plan includes a map of earthquake hazard zones throughout the Commonwealth (shown on Figure 4.3.3-1) (PEMA 2018). Fulton County falls within the lowest hazard zone with a 4-percent Peak Ground Acceleration (PGA) (USGS 2014).

Figure 4.3.3-1. Relative earthquake hazard zones of Pennsylvania

Source: PEMA 2018
Note: Fulton County is within the blue oval on the map.

The Lamont-Doherty Cooperative Seismographic Network (LCSN) monitors earthquakes that occur primarily in the northeastern United States. Goals of the project are to compile a complete earthquake catalog for this region, assess earthquake hazards, and study causes of earthquakes in the region. LCSN operates 40 seismographic stations in the following seven states: Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania, and Vermont. Figure 4.3.3-2 shows locations of seismographic stations in eastern Pennsylvania. The figure shows three stations in Huntingdon, Pennsylvania; Meadville, Pennsylvania; and northern West Virginia. The network is composed of broadband and short-period seismographic stations (LCSN 2012).

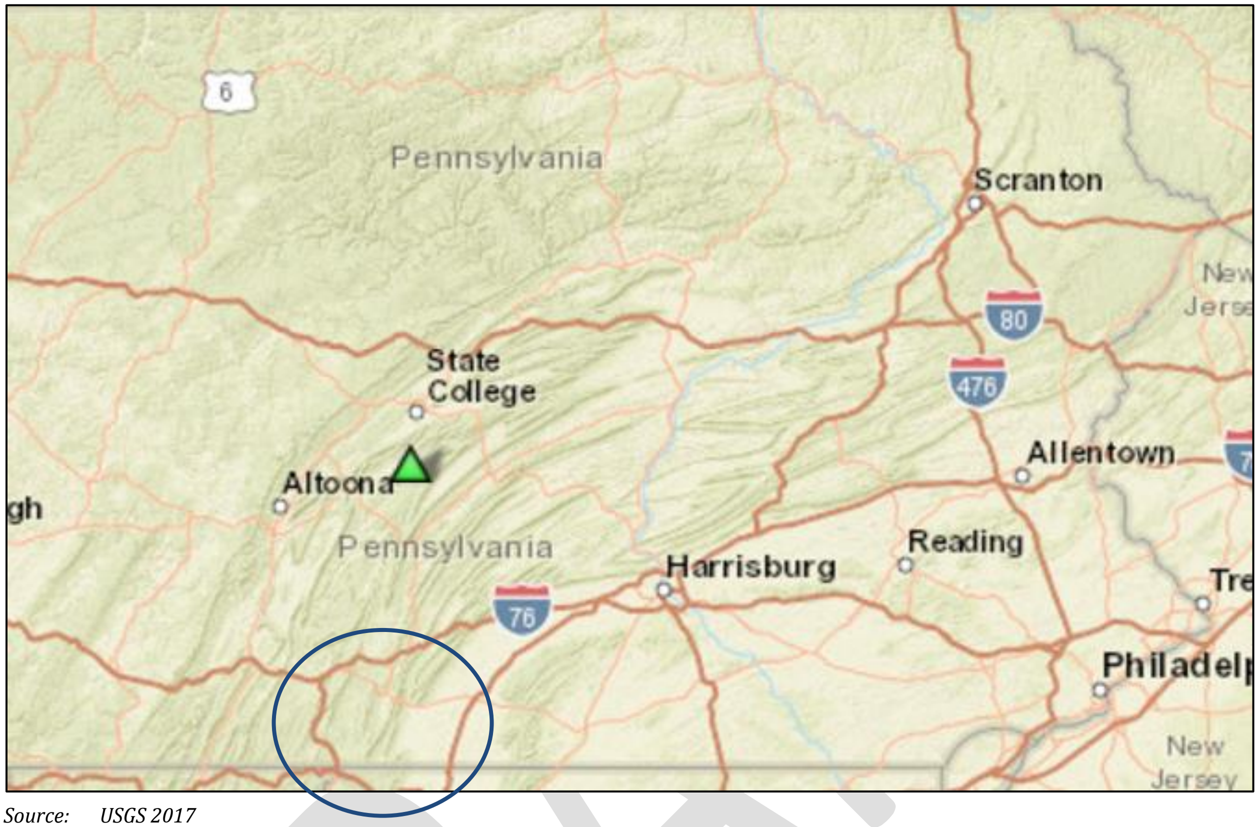
Figure 4.3.3-2. Lamont-Doherty Seismic Stations Locations in Western Pennsylvania



Source: LCSN 2012
Note: Fulton County is approximately located within the oval on the map.

In addition to the Lamont-Doherty Seismic Stations, USGS operates a global network of seismic stations to monitor seismic activity. While no seismic stations are within Fulton County, the closest station is in Huntingdon, Pennsylvania hosted by Pennsylvania State University (USGS, n.d.). Figure 4.3.3-3 shows the location of the closest seismic stations to Fulton County.

Figure 4.3.3-3. USGS Seismic Stations



Source: USGS 2017

Note: Seismic station location is indicated by green triangle, and Fulton County is within the blue oval.

The USGS manages the website *Did You Feel It?* (http://earthquake.usgs.gov/earthquakes/dyfi/) for citizens to report earthquake experiences and to share information regarding the earthquake and its effects. The website is intended to gather citizens' experiences during an earthquake and incorporate the information into detailed maps for illustrating shaking intensity and damage assessments (USGS 2017).

4.3.3.2 Range of Magnitude

Seismic waves are vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude or extent of an earthquake is a given value of the earthquake size, or amplitude of the seismic waves, as measured by a seismograph. The Richter magnitude scale (Richter scale) was developed in 1932 as a mathematical device to compare sizes of earthquakes. The Richter scale is the most widely known scale that measures magnitude of earthquakes. It has no upper limit and is not used to express damage. An earthquake in a densely populated area that results in many deaths and considerable damage may have the same magnitude and shock in a remote area that did not undergo any damage. Table 4.3.3-2 lists Richter scale magnitudes and corresponding earthquake effects associated with each magnitude.

Table 4.3.3-2. Richter Scale Magnitudes

Richter Magnitude	Earthquake Effects
3.5 or less	Generally, not felt, but recorded
3.5 to 5.4	Often felt, but rarely causes damage
Under 6.0	At most, slight damage to well-designed buildings; can cause major damage to poorly constructed buildings over small regions.

Richter Magnitude	Earthquake Effects
6.1 to 6.9	Can be destructive up to about 100 kilometers from epicenter.
7.0 to 7.9	Major earthquake; can cause serious damage over large areas.
8.0 or greater	Great earthquake; can cause serious damage in areas several hundred kilometers across.

Source: PEMA 2018

Based on historical data of earthquakes with a recorded intensity, little damage is expected in Fulton County from earthquake events. However, because the worst earthquake recorded in Pennsylvania was a magnitude 5.2, a worst-case scenario for this hazard would be if an earthquake of similar magnitude occurred in Fulton County or near the border in an adjacent county, causing mild damage in populated areas.

The intensity of an earthquake is based on observed effects of ground shaking on people, buildings, and natural features, and varies with location. The Modified Mercalli Intensity (MMI) scale expresses the intensity of an earthquake and is a subjective measure that describes the strength of a shock felt at a particular location. The MMI scale expresses intensity of an earthquake's effects in a given locality according to a scale from I to XII. Descriptions of MMI scales appear in Table 4.3.3-3. Earthquakes that occur in Pennsylvania originate deep within the Earth's crust and not on an active fault. No injury or severe damage from earthquake events has been reported in Fulton County.

Table 4.3.3-3. Modified Mercalli Intensity Scale with Associated Impacts

Scale	Intensity	Description Of Effects	Corresponding Richter Scale Magnitude
I	Instrumental	Detected only on seismographs	<4.2
II	Feeble	Some people feel it	
III	Slight	Felt by people resting; feels like a truck rumbling by	
IV	Moderate	Felt by people walking	
V	Slightly Strong	Sleepers awake; church bells ring	<4.8
VI	Strong	Trees sway; suspended objects swing; objects fall off shelves	<5.4
VII	Very Strong	Mild alarm; walls crack; plaster falls	<6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures; poorly constructed buildings are damaged	<6.9
IX	Ruinous	Some houses collapse; ground cracks; pipes break open	
X	Disastrous	Ground cracks profusely; many buildings are destroyed; liquefaction and landslides are widespread	<7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes, and cables are destroyed; general triggering of other hazards occurs	<8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves	>8.1

Source: PEMA 2018

Seismic hazards are often expressed in terms of Peak Ground Acceleration (PGA) and Spectral Acceleration (SA). USGS defines PGA and SA as the following: "PGA is what is experienced by a particle on the ground. SA is approximately what is experienced by a building, as modeled by a particle mass on a massless vertical rod having the same natural period of vibration as the building" (USGS 2012). Both PGA and SA can be measured in *g* (the acceleration caused by gravity) or expressed as a percent acceleration force of gravity (percent g). For example, at 100 percent g PGA (equivalent to 1.0 g) during an earthquake (an extremely strong ground motion), objects accelerate sideways at the same rate as when they drop from a ceiling. At 10 percent g PGA, ground acceleration is 10 percent that of gravity (New Jersey Office of Emergency Management [NJOEM] 2011). PGA and SA hazard maps provide insight into location-specific vulnerabilities (New York State Disaster Preparedness Commission [NYSDPC] 2011).

PGA is a common earthquake measurement that indicates three factors: (1) geographic area affected, (2) probability of an earthquake at each level of severity, and (3) strength of ground movement (severity) expressed in percent g. In other words, PGA expresses the severity of an earthquake and is a measure of how hard the earth shakes (or accelerates) in a given geographic area (NYSDPC 2011). Damage levels from an earthquake vary with intensity of ground shaking and with seismic capacity of structures, as noted in Table 4.3.3-4.

Table 4.3.3-4. Damage Levels Experienced in Earthquakes

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

Source: NJOEM 2011

Note: % g Percent of force of gravity
PGA Peak Ground Acceleration

National maps of earthquake shaking hazards have been produced since 1948. These maps provide information essential for creating and updating seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities, and land use planning applied in the United States. Scientists frequently revise these maps to reflect new information and knowledge. Buildings, bridges, highways, and utilities built to meet modern seismic design requirements are typically able to withstand earthquakes better, with less damage and disruption. After thoroughly reviewing the studies, professional organizations of engineers update seismic-risk maps and seismic design requirements specified in building codes (Brown and others 2001).

To analyze the earthquake hazard in Fulton County, a probabilistic assessment was conducted for the 500-year mean return period (MRP) in Hazards U.S.–Multi-Hazard (HAZUS-MH) v4.2. A HAZUS analysis evaluates statistical likelihood that a specific event will occur and the consequences of that event. A 500-year MRP event is an earthquake with a 0.2-percent chance that the mapped ground motion levels (PGA) will be exceeded in any given year.

Figure 4.3.3-4 illustrates the geographic distribution of PGA (percent *g*) across Fulton County for each event. Potential losses estimated by HAZUS-MH for the MRP and the associated PGA are discussed in the Vulnerability Assessment section (Section 4.3.3.5) of this profile.

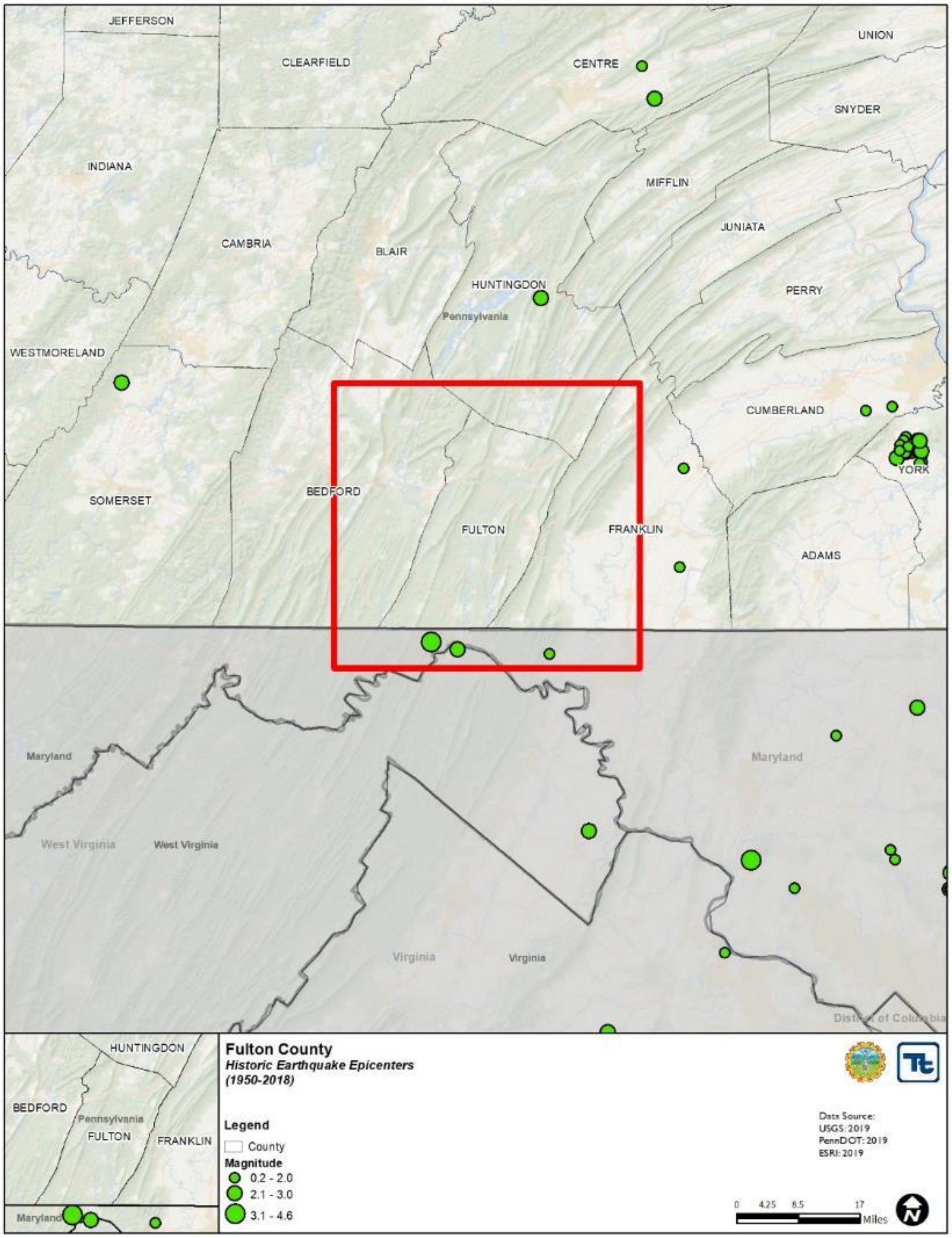
Figure 4.3.3-4. Peak Ground Acceleration Modified Mercalli Scale in Fulton County for a 500-Year MRP Earthquake Event

Source: *HAZUS-MH v4.2*
Note: *The Peak Ground Acceleration for the 500-year MRP is 3.0-3.2%g.*

4.3.3.3 Past Occurrence

The historical record of earthquakes goes back approximately 200 years. In Pennsylvania, about 35 earthquakes have caused light damage since the Colonial period. Nearly half of these events had out-of-state epicenters (PEMA 2018). Figure 4.3.3-5 is a map of earthquake epicenters in Pennsylvania from 1950 to 2018. No damages were reported in Fulton County.

Figure 4.3.3-5. Earthquake Epicenters in Pennsylvania (1950-2018)



Source: USGS 2019
Note: Fulton County is approximately located within the red square.

According to the USGS, there have been no earthquake epicenters recorded in Fulton County. PEMA's Pennsylvania Disaster History list includes no significant earthquake events in Pennsylvania, and no Federal Emergency Management Agency (FEMA) major disasters (DR) or emergency declarations (EM) have occurred for significant earthquake events in Pennsylvania (FEMA 2019).

Historically, large earthquakes in eastern North America have occurred in three regions: (1) Mississippi Valley near the Town of New Madrid, Missouri; (2) St. Lawrence Valley region of Quebec, Canada; and (3) Charleston, South Carolina. In February 1925, one of the region's largest earthquakes on record occurred (magnitude near 7.0) with its epicenter in a region of Quebec. If a similar-magnitude earthquake would occur in the western part of the Quebec region, some moderate damage might be expected in one or more counties of Pennsylvania's northern tier. An earthquake with an estimated magnitude of about 7.5 occurred on August 31, 1886, in Charleston, South Carolina. The earthquake was felt in most of Pennsylvania.

Other earthquakes have occurred in east coast areas, including eastern Massachusetts, southeastern New York, and northern New Jersey. Moderate earthquakes occurred in southeastern New York and northern New Jersey and were felt in eastern Pennsylvania. If an earthquake of magnitude 6.0 or greater would occur in that area, damage would likely result in easternmost counties of Pennsylvania, but not in Fulton County.

4.3.3.4 Future Occurrence

Earthquakes cannot be predicted and could occur any time of the day or year. Major earthquakes are infrequent in the State and county and may occur only once every few hundred years or longer, but the consequences of major earthquakes may potentially be very high. Based on the historic record, the future probability of damaging earthquakes impacting Fulton County is low.

According to the USGS earthquake catalog, between 1950 and 2019, there have been no earthquakes with epicenters in Fulton County. Based on available historical data, future occurrences of earthquake events can be considered *possible* as defined by the Risk Factor Methodology probability criteria (Section 4.4).

4.3.3.5 Vulnerability Assessment

To understand risk, a community must evaluate which assets are exposed or vulnerable in the identified hazard area. The entire county has been identified as exposed to the earthquake hazard. Therefore, all assets in Fulton County (population, structures, critical facilities, and lifelines) described in the County Profile (Section 2), are vulnerable. The following section provides an evaluation and estimation of the potential impact of the earthquake hazard on Fulton County, including the following:

- Impact on: (1) life, safety, and health of residents; (2) general building stock; (3) critical facilities; (4) economy; (5) environment; and (6) future growth and development
- Effect of climate change on vulnerability
- Further data collections that will assist understanding of this hazard over time

Earthquakes usually occur without warning and can be felt in areas at great distance from their point of origin. Extent of damage depends on density of population, as well as building and infrastructure construction in the area shaken by the quake. Some areas may be more vulnerable than others based on soil type, age of buildings, and building codes in place. Compounding potential for damage is that, historically, Building Officials Code Administration (BOCA) in the northeastern United States was 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. Thus, a smaller earthquake in the northeastern United States can cause more structural damage than if it occured in the western part of the United States.

The entire population and general building stock inventory of the county are at risk for damage or loss from impacts of an earthquake. Potential losses associated with earth shaking were calculated for Fulton County for the 500-year MRP event. A summary of the data used and methodology applied for this assessment appears below, followed by impacts on population, existing structures, critical facilities, and the economy within Fulton County.

Impact on Life, Health, and Safety

Overall, the entire population of Fulton County is exposed to the earthquake hazard event. According to the 2013-2017 American Community Survey 5-Year Estimates, Fulton County has an estimated total population of 14,631 people. The numbers in the vulnerability assessment reflect the 2010 U.S. Census data because Hazards U.S.--Multi-Hazards (HAZUS-MH) v4.2 uses that as the default database for demographics data. The impact of earthquakes on life, health, and safety depends on the severity of the event. Risks to public safety and loss of life from an earthquake in Fulton County are 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 locations and construction quality of their housing.

Residents may be displaced or require temporary to long-term sheltering as a result of the event. The number of people requiring shelter is generally less than the number displaced, as some displaced persons use hotels or stay with family or friends after a disaster event. Table 4.3.3-5 summarizes the estimated sheltering needs for Fulton County.

Table 4.3.3-5. Summary of Estimated Sheltering Needs for Fulton County

Scenario	Displaced Households	Persons Seeking Short-Term Shelter
500-Year Earthquake	2	1

Source: HAZUS-MH v4.2

Structural building damage correlates strongly to the number of injuries and casualties from an earthquake event (NYCEM 2003). Furthermore, different sectors of the community would be exposed to the hazard depending on time of day of occurrence. For example, HAZUS considers that maximum residential occupancy occurs at 2:00 a.m.; educational, commercial, and industrial sectors maximum occupancy at 2:00 p.m.; and peak commute time at 5:00 p.m. Whether affected directly or indirectly, the entire population would have to deal with consequences of earthquakes to some degree. Business interruption could prevent people from working, road closures could isolate populations, and loss of functions of utilities could affect populations that suffered no direct damage from an event. HAZUS-MH v4.2 did not estimate any injuries, hospitalizations, and casualties as a result of the 500-year MRP event.

Impact on General Building Stock

The entire study area’s general building stock is considered at risk and exposed to this hazard. The HAZUS-MH v4.2 model estimates value of exposed building stock and loss (in terms of damage to exposed stock). The County Profile section of this HMP (Section 2) presents statistics on replacement values of general building stock (structure and contents).

A probabilistic model was run to estimate annualized dollar losses within Fulton County by application of HAZUS-MH v4.2. Annualized losses are useful for mitigation planning because they provide a baseline that can be used to compare (1) risk of one hazard across multiple jurisdictions, and (2) degree of risk of all hazards within each participating jurisdiction. Notably, annualized loss does not predict losses in any particular year. Estimated earthquake annualized losses are approximately $163K per year (building and contents) within 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 would directly or indirectly result from ground shaking (NYCEM 2003). NYCEM found a strong correlation between PGA and damage a building might undergo. The HAZUS-MH v4.2 model is based on the best available earthquake science and aligns with these statements. HAZUS-MH v4.2 methodology and model were used to analyze the earthquake hazard for the general building stock within Fulton County. Figure 4.3.3-4 earlier in this profile illustrates the geographic distribution of PGA (%*g*) across the county for the 500-year MRP event.

In addition, according to NYCEM (NYCEM 2003), a building's construction determines how well it can withstand the force of an earthquake. The NYCEM report indicates that unreinforced masonry buildings are most at risk during an earthquake because the walls are prone to collapse outward, whereas steel and wood buildings absorb more of the earthquake's energy. Additional attributes that affect a building's capability to withstand an earthquake's force include its age, number of stories, and quality of construction. HAZUS-MH considers building construction and age of buildings in its analysis. Default building ages and building types already incorporated into the inventory were used because the default general building stock was used for this HAZUS-MH analysis.

Potential building damage was evaluated by HAZUS-MH v4.2 across the following damage categories: none, slight, moderate, extensive, and complete. Table 4.3.3-6 provides definitions of these categories of damage for a light wood-framed building; definitions for other building types are included in the HAZUS-MH technical manual documentation. General building stock damage for these damage categories by occupancy class on a countywide basis is summarized for the 500-year event in Table 4.3.3-7.

Table 4.3.3-6. 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 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 because of the crippled wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Source: FEMA 2015a

Table 4.3.3-7. Estimated Buildings Damaged by General Occupancy for 500-year MRP Earthquake Event

Category	Average Damage State 500-Year MRP None	Slight	Moderate	Extensive	Complete
Residential	6,271 (92.5%)	111 (1.5%)	32 (0.4%)	3 (0.0%)	0 (0.0%)
Commercial	276 (3.8%)	5 (0.1%)	1 (0.0%)	0 (0.0%)	0 (0.0%)
Industrial	112 (1.5%)	2 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Education, Government, Religious, and Agricultural	157 (2.2%)	2 (0.0%)	1 (0.0%)	0 (0.0%)	0 (0.0%)

Source: HAZUS-MH v4.2

Table 4.3.3-8 summarizes estimated building value (buildings and contents) for the 500-year MRP earthquake event. Damage loss estimates include structural and non-structural damage to buildings and loss of contents. Losses for each municipality are less than 1 percent of their total replacement cost value.

Table 4.3.3-8. Estimated Building Value (Building and Contents) Damaged by the Annualized, 500-Year MRP Earthquake Event

Municipality	Total Replacement Cost Value (Building and Contents)	Estimated Total Damages*		Estimated Residential Damage	Estimated Commercial Damage
		Annualized Loss	500-Year	500-Year	500-Year
Ayr Township	$328,056,000	$1,210	$101,915	$68,558	$16,152
Belfast Township	$181,485,000	$703	$63,689	$54,618	$4,409
Bethel Township	$243,010,000	$941	$85,281	$73,134	$5,904
Brush Creek Township	$110,481,000	$351	$36,840	$31,370	$2,524
Dublin Township	$153,284,000	$488	$51,113	$43,523	$3,502
Licking Creek Township	$203,625,000	$648	$67,900	$57,817	$4,653
McConnellsburg Borough	$276,419,000	$1,020	$85,873	$57,767	$13,610
Taylor Township	$141,644,000	$451	$47,232	$40,218	$3,236
Thompson Township	$155,461,000	$602	$54,557	$46,786	$3,777
Todd Township	$298,975,000	$1,103	$92,880	$62,481	$14,721
Union Township	$106,265,000	$411	$37,292	$31,981	$2,582
Valley-Hi Borough*	$5,827,000	$19	$1,943	$1,655	$133
Wells Township	$58,946,000	$188	$19,656	$16,737	$1,347
Fulton County	**$2,263,478,000**	**$8,133**	**$746,171**	**$586,646**	**$76,550**

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

An estimated $748,000 in damages would occur to buildings in the county during a 500-year earthquake event. This takes into account structural damage, non-structural damage, and loss of contents, representing less than 1 percent of total replacement value for general building stock in Fulton County (total replacement value within the county would exceed $2.2 billion). Earthquakes can cause secondary hazard events such as fires. According to the HAZUS-MH earthquake model, no fires are anticipated as a result of the 500-Year MRP event.

Impact on Critical Facilities

After consideration of general building stock exposed to and damaged by each earthquake event, critical facilities were evaluated. All critical facilities (essential facilities, transportation systems, lifeline utility systems, high-potential loss facilities, and user-defined facilities) in Fulton County are considered exposed and vulnerable to the earthquake hazard. The Critical Facilities subsection of this HMP in Section 2 (County Profile) discusses the inventory of critical facilities in Fulton County.

HAZUS-MH v4.2 estimates the probability that critical facilities may sustain damage as a result of the 500-year MRP earthquake event. Additionally, HAZUS-MH v4.2 estimates percent functionality of each facility days after the event. Table 4.3.3-9 (500-year MRP earthquake event) lists percent probabilities that critical facilities and utilities would sustain damages within the damage categories (column headings), and list percent functionalities after different numbers of days following those events (column headings).

Table 4.3.3-9. Estimated Damage to and Loss of Functionality of Critical Facilities and Utilities in Fulton County for the 500-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	94	3	1	0-1	0-1	94	98	100	100
Police	94	3	1	0-1	0-1	94	98	100	100
Fire	95	3	1	0-1	0-1	94	98	100	100
EOC	0	0	0	0-1	0-1	100	100	100	100
School	94	3	1	0-1	0-1	94	98	100	100
Utilities									
Potable	99	0-1	0-1	0	0	100	100	100	100
Wastewater	99	0-1	0-1	0	0	100	100	100	100
Electric	99	0-1	0-1	0	0	100	100	100	100
Communication	99	0-1	0-1	0	0	100	100	100	100

Source: HAZUS-MH v4.2
Notes:
EOC = Emergency Operations Center

Impact on Economy

Earthquakes also impact the economy, including loss of business function, damage to inventory (buildings, transportation, and utility systems), relocation costs, wage loss, and rental loss due to repair and replacement of buildings. HAZUS-MH v4.2 estimates building-related economic losses, including income losses (wage, rental, relocation, and capital-related losses) and capital stock losses (structural, non-structural, content, and inventory losses). Economic losses estimated by HAZUS-MH v4.2 are summarized in Table 4.3.3-10

Table 4.3.3-10. Building-Related Economic Losses from the 500-Year MRP Earthquake Event

Level of Severity	Mean Return Period 500-year
Income Losses	
Wage	$30,000
Capital Related	$21,600
Rental	$62,400
Relocation	$189,500
Subtotal	**$303,500**
Capital Stock Losses	
Structural	$269,200
Non-Structural	$392,800
Content	$56,700
Inventory	$2,200
Subtotal	**$747,900**

Source: HAZUS-MH v4.2.

For a 500-year event, HAZUS-MH 4.2 estimates that the county would incur approximately $8.5 million in income losses (wage, rental, relocation, and capital-related losses) in addition to structural, non-structural, and content building stock losses ($748,000).

The HAZUS-MH v4.2 analysis did not take into account damage to roadway segments. However, these features assumedly would undergo damage as a result of ground failure, and an earthquake event thus would interrupt regional transportation and distribution of materials. According to HAZUS-MH Earthquake User Manual, losses to the community resulting from damages to lifelines could be much greater than costs of repair (FEMA 2015a).

Earthquake events can significantly damage road bridges; this is important because they often provide the only access to certain neighborhoods. Because softer soils can generally follow floodplain boundaries, bridges that cross watercourses should be considered vulnerable. A key factor in degree of vulnerability is age of a facility, which helps indicate the standards the facility was built to achieve.

HAZUS-MH Earthquake User's Manual also estimates 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 up before transport, and (2) brick, wood, and other debris that can be loaded directly onto trucks with bulldozers (FEMA 2015a).

Table 4.3.3-11 summarizes the estimated debris generated by the earthquake scenario in HAZUS-MH v4.2.

Table 4.3.3-11. Estimate Debris Generated by 500-year MRP Earthquake Event

Municipality	500-Year	
	Brick/Wood (tons)	Concrete/Steel (tons)
Ayr Township	221	54
Belfast Township	199	38
Bethel Township	199	38

Municipality	500-Year	
	Brick/Wood (tons)	Concrete/Steel (tons)
Brush Creek Township	203	40
Dublin Township	203	40
Licking Creek Township	203	40
McConnellsburg Borough	221	54
Taylor Township	203	40
Thompson Township	199	38
Todd Township	221	54
Union Township	199	38
Valley-Hi Borough	203	40
Wells Township	203	40
Fulton County	**2,673**	**557**

Source: HAZUS-MH 4.2

Impact on the Environment

Earthquakes can lead to numerous, widespread, and devastating environmental impacts. These impacts may include but are not limited to:

- Induced flooding or landslides
- Poor water quality
- Damage to vegetation
- Breakage in sewage or toxic material containments

Secondary impacts can include train derailments, roadway damages, spillage of hazardous materials (HazMat), and utility interruption.

Future Growth and Development

As discussed in Section 2.4 of this HMP, areas targeted for future growth and development have been identified across the county. Human exposure and vulnerability to earthquake impacts in newly developed areas are anticipated to be similar to those current 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

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. National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes (NASA 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could undergo liquefaction during seismic activity as a result of the increased saturation. Dams storing increased volumes of water as a result of changes in the hydrograph could fail during seismic events. No current models are available to estimate these impacts.

Additional Data and Next Steps

Ground shaking is the primary cause of earthquake damage to man-made structures, and soft soils amplify ground shaking. One contributor to site amplification is velocity at which rock or soil transmits shear waves (S-waves). The NEHRP developed five soil classifications defined by their shear-wave velocity that alter severity of an earthquake. These soil classifications range from A to E, whereby 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. When this soil information becomes available, it may be incorporated into HAZUS-MH v4.2 to further refine the county's vulnerability assessment.

A HAZUS-MH v4.2 earthquake analysis was conducted for Fulton County by use of the default model data. Additional data needed to further refine and enhance the county's vulnerability assessment includes identifications of unreinforced masonry critical facilities and privately-owned buildings (i.e., residences) via local knowledge and/or pictometry/orthophotos. Use of soil type data can also lead to more accurate estimates of potential losses to the county. These buildings may not withstand earthquakes of certain magnitudes and plans to provide emergency response/recovery efforts for these properties can be established. 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.