4.15 Earthquake

4.15.1 Hazard Profile

An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the Earth's crust. Earthquakes result from crustal strain, volcanism, landslides, or the collapse of caverns and mines. Located near the center of the North American Tectonic plate, earthquakes in Virginia are known as "intraplate seismicity", and typically occur on faults at depths between 3 and 15 miles.

4.15.1.1 Magnitude/ Severity/ Frequency

The majority of property damage and earthquake related deaths result from the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, which are directly related to distance from the fault and regional geology. Earthquakes can also cause landslides (the down-slope movement of soil and rock) and liquefaction (in which ground soil loses the ability to resist shear and acts much like quick sand).

Most earthquakes are caused by the release of stresses accumulated along active fault planes within the Earth's outer crust. No active major fault lines are located in or near the CVPDC area. The North American plate follows the continental border with the Pacific Ocean in the west, but follows the Mid-Atlantic Ridge in the east. Earthquakes occurring along the Mid-Atlantic Ridge usually pose little risk to humans, due to its location in the middle of the Atlantic Ocean. The greatest risk for earthquakes in the United States is along the Pacific Coast and Midwest.

Earthquakes are measured in terms of their magnitude and intensity. Magnitude is the amount of energy that is released by an earthquake and is often measured using the Richter Magnitude Scale (shortened to Richter scale). The scale is based on an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of seismic wave amplitude. Each unit increase in magnitude on the Richter Scale corresponds to a tenfold increase in wave amplitude, or a 32-fold increase in energy. Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale (Table 4-146) based on direct and indirect measurements of seismic effects in the United States. The scale levels are typically described using roman numerals, with a I corresponding to imperceptible (instrumental) events, IV corresponding to moderate (felt by people awake), to XII for catastrophic (total destruction). Compared to the Mercalli scale which is based on observed effects of earthquakes, the Richter scale doesn't measure quake damage. Damage is dependent on a variety of factors located at or near the epicenter, including population/building density and local geological conditions.

> ***Peak ground acceleration***
>
> *During an earthquake, when the ground is shaking, it experiences acceleration. The peak ground acceleration (PGA) is the largest increase in velocity recorded by a particular station during an earthquake.*
> *https://earthquake.usgs.gov/hazards/learn/technical.php#accel*

The Richter scale does not provide accurate estimates for very large magnitude earthquakes. A newer, more uniformly applicable extension of the magnitude scale, known as Moment Magnitude (or Mw), was developed particularly for measuring very large earthquakes. Moment magnitude gives the most reliable estimate of earthquake size.[76] The moment magnitude scale is based on the total moment release of the earthquake. Moment magnitude is a product of the distance a fault moved and the force required to move it. It is derived from modeling recordings of the earthquake at multiple stations. Moment magnitude estimates are about the same as Richter magnitudes for small to large earthquakes but only the moment magnitude scale is capable of measuring M8 and greater events accurately.

Mineral earthquake

August. 23, 2011. Louisa County, central Virginia. The epicenter of Virginia's largest earthquake was 13 km south-southwest of Mineral, Virginia, in the central Virginia seismic zone. The shock is known as the Mineral earthquake. The moment magnitude was Mw 5.7, mbLg magnitude 6.3. The earthquake was felt throughout much of the eastern United States and southeastern Canada, possibly by more people than any other earthquake in U.S. history. It was the largest and most damaging earthquake in the eastern United States since the 1886 Charleston, South Carolina earthquake. Damage in the epicentral area represents Modified Mercalli intensity VIII, with many instances of broken and collapsed masonry walls and chimneys, as well as shifting of structures on their foundations. Significant damage occurred to structures at distances in excess of 130 km to the northeast in the Washington DC area. The rupture process was a complex reverse fault event, initiating at a depth of 8 km. The mainshock was followed by a prolific aftershock sequence (August, 2014).

4.15.1.2 Geographical Location and Extent

In 2014, the US Geological Survey updated national seismic hazard maps which include the latest science-based information on potential future earthquake ground motions. The hazard models incorporate more than 100 years of global earthquake observations at several hundred thousand sites across the United States. Probabilistic ground motion maps are typically used to assess the magnitude and frequency of seismic events. These maps measure the probability of exceeding a certain ground motion, expressed as percent peak ground acceleration (%PGA), over a specified period of years. Figure 4-152 is the long-term national earthquake hazard map by USGS. It depicts peak ground accelerations having a 2 percent probability of being exceeded in 50 years, for a firm rock site. According to the map, all the jurisdictions in the CVPDC area are located in low probability areas; therefore, the future threat is low.

The severity of earthquakes is site specific and is influenced by proximity to the earthquake epicenter and soil type, among other factors. The 100-year return period or one percent probability of happening in any given year for a significant earthquake is very low, with southwest Virginia having a slightly higher chance of experiencing such an event.

4.15.1.3 Previous Occurrences

In Virginia, a written record of earthquakes exists back to the 18th century. Table 4-147 and Figure 4-153 show the significant earthquakes that have been recorded. Most of Virginia's recorded earthquakes have been magnitude 4.5 or less, and the associated damage has been minor (cracks in foundation, tumbling chimneys, etc.). The largest magnitude earthquake in Virginia, a 5.8 magnitude (MMI VI) on the Richter scale, occurred on August 23, 2011. The epicenter of the earthquake was located in Louisa County, Virginia, approximately 80 miles northeast of Lynchburg. It was likely felt by more people than any other earthquake in U.S. history: approximately 1/3 of the U.S. population. According to VDEM, this

[76] https://www.usgs.gov/faqs/moment-magnitude-richter-scale-what-are-different-magnitude-scales-and-why-are-there-so-many

earthquake caused between $200 and $300 million in damages, of which only about $100 million were insured. Those damages included the North Anna Nuclear Generating Station in Louisa, a gas leak in Charlottesville, the Lake Jackson Dam in Manassas, and the Washington Monument.[77] In response to this event, The Federal Emergency Management Agency issued a major disaster declaration (DR-4042) to offer assistance to the residents and businesses that suffered damages in central Virginia.

Earthquakes occur underground along geologic faults. Although Virginia has many faults, nearly all of them are inactive. Most earthquakes in Virginia are not associated with a known fault, but concentrated in three distinct seismic zones (Figure 4-153): the Central Virginia seismic zone (CSVZ), the Giles County seismic zone (GCSZ), and the Eastern Tennessee seismic zone (ETSZ). The CVPDC area is situated on the periphery or within the CVSZ. Although there are documented damages from earthquakes in the CVPDC region, and estimated epicenters from the 1800s located in Lynchburg (Figure 4-153), there has never been a well recorded earthquake that has occurred in the CVPDC area.

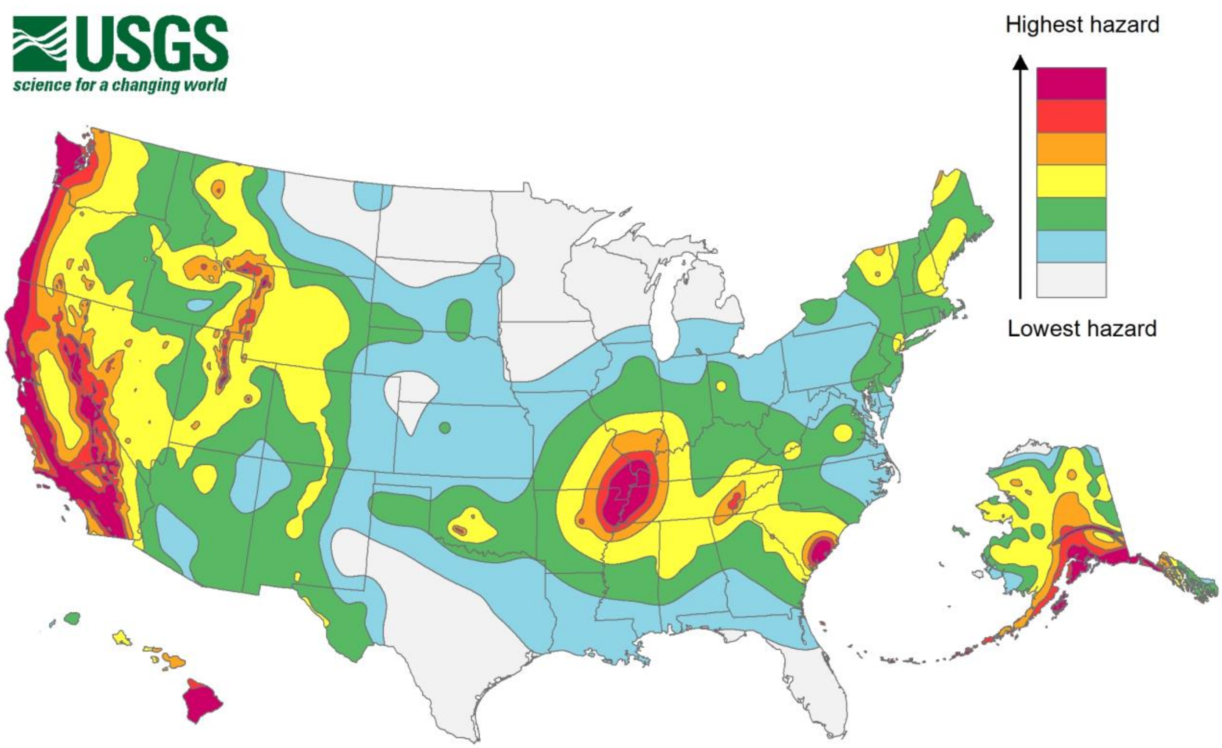


Figure 4-152 USGS 2018 Long-term National Seismic Hazard Map

[77] https://www.vaemergency.gov/earthquakes/earthquakes-in-virginia/

Table 4-146 Modified Mercalli Intensity (MMI) Scale and corresponding Richter Scale

MMI Scale	Intensity	Description of Effects	Corresponding Richter Magnitude Scale
I	Instrumental	Felt by very few people; barely noticeable.	1.0-2.0
II	Feeble	Felt by a few people, especially on upper floors.	2.0-3.0
III	Slight	Noticeable indoors, especially on upper floors, but may not be recognized as an earthquake.	3.0-4.0
IV	Moderate	Noticeable indoors, especially on upper floors, but may not be recognized as an earthquake.	4.0
V	Slightly Strong	Felt by almost everyone, some people awakened. Small objects moved. trees and poles may shake.	4.0-5.0
VI	Strong	Felt by everyone. Difficult to stand. Some heavy furniture moved, some plaster falls. Chimneys may be slightly damaged.	5.0-6.0
VII	Very Strong	Slight to moderate damage in well-built ordinary structures. Considerable damage to poorly built structures. Some walls may fall.	6.0
VIII	Destructive	Little damage in specially built structures. Considerable damage to ordinary buildings, severe damage to poorly built structures. Some walls collapse.	6.0-7.0
IX	Ruinous	Considerable damage to specially built structures, buildings shifted off foundations. Ground cracked noticeably. Wholesale destruction. Landslides.	7.0
X	Disastrous	Most masonry and frame structures and their foundations destroyed. Ground badly cracked. Landslides. Wholesale destruction.	7.0-8.0
XI	Very Disastrous	Total damage. Few, if any, structures standing. Bridges destroyed. Wide cracks in ground. Waves seen on ground.	8.0
XII	Catastrophic	Total damage. Waves seen on ground. Objects thrown up into the air.	8.0 or greater

(Note: This Table indicates earthquakes are measured by the amount of damage they can cause (modified Mercalli scale) and by the amount of energy they release (Richter scale))

Table 4-147 Significant earthquakes in Virginia (magnitude greater than 4.5) (Source: VA DMME)[78]

Date	Local Time	Magnitude	Magnitude Type	Intensity	Localities
02/02/1774 (a)	2:00pm	4.5	Mb	VI	Petersburg
03/09/1828	10:00pm	5	Mb	V	Southwest VA
08/27/1833	6:15am	5	Mb_lg	VI	Richmond-Charlottesville
04/29/1852	12:45pm	4.9	Mb	VI	Grayson-Wythe
05/2/1853	9:20am	4.6	Mb	VI	VA/WVA border

[78] https://www.dmme.virginia.gov/dgmr/majorearthquakes.shtml and http://www.magma.geos.vt.edu/vtso/va_quakes/VA-Eq.html

Date	Local Time	Magnitude	Magnitude Type	Intensity	Localities
12/22/1875	11:45pm	4.5	Mb_lg	VII	Richmond
05/31/1897 (b)	1:58pm	5.5	Mw	VIII	Pearisburg
11/25/1898	3:10pm	4.6	Mb	V	Pulaski-Wytheville
02/13/1899	4:30am	4.7	Mb	V	Wytheville
4/9/1918	9:09pm	4.6	ML	VI	Luray
12/9/2003 (c)	3:59pm	4.5	Mb_lg	VI	Columbia
8/23/2011 (d)	12:51pm	5.8	Mw	VIII	Mineral
8/25/2011	12:07am	4.5	Mb_lg	VI	Mineral

(a) The first documented earthquake in Virginia. (b) The second largest earthquake in Virginia. (c) The largest earthquake recorded in Virginia since the widespread use of modern seismic equipment in the 1970's. (d) The largest Virginia earthquake recorded by seismometers.

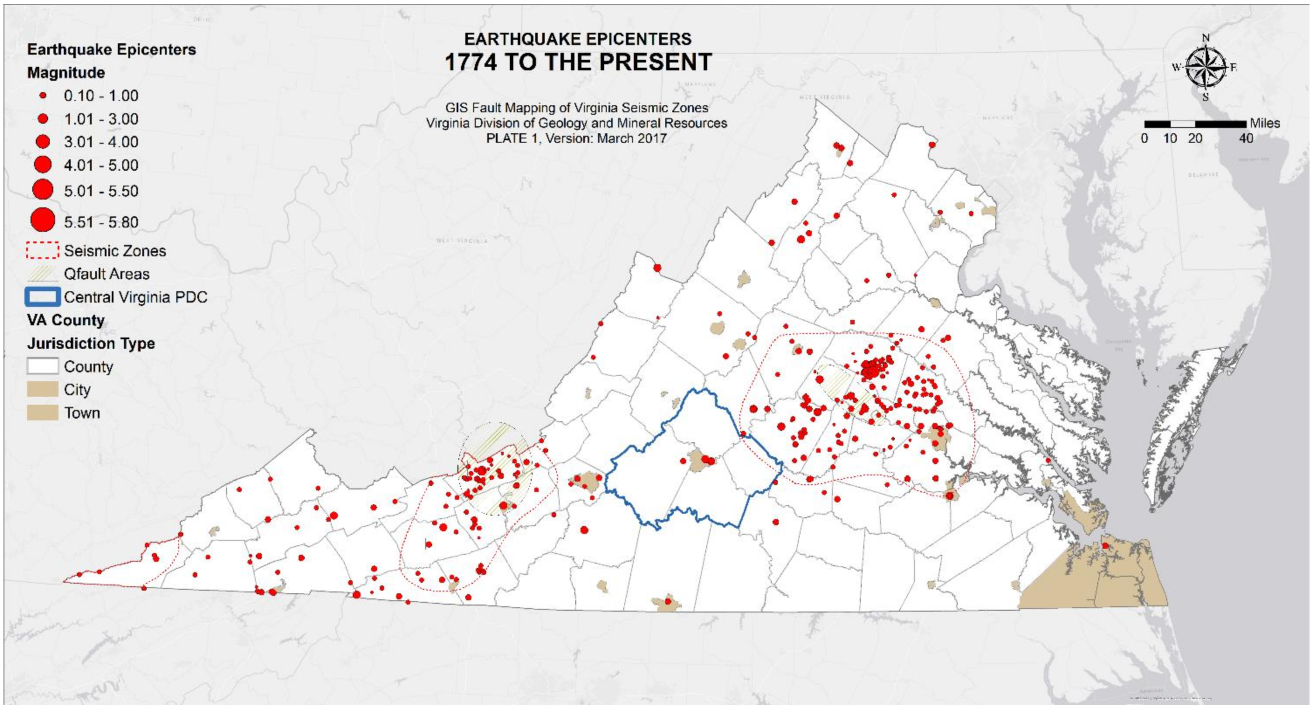


Figure 4-153 Earthquake epicenters in Virginia, 1774 - 2017

4.15.1.4 Relationship to Other Hazards

Figure 4-154 shows the interrelationship (causation, concurrence, *etc.*) between this hazard and other hazards discussed in this plan update.

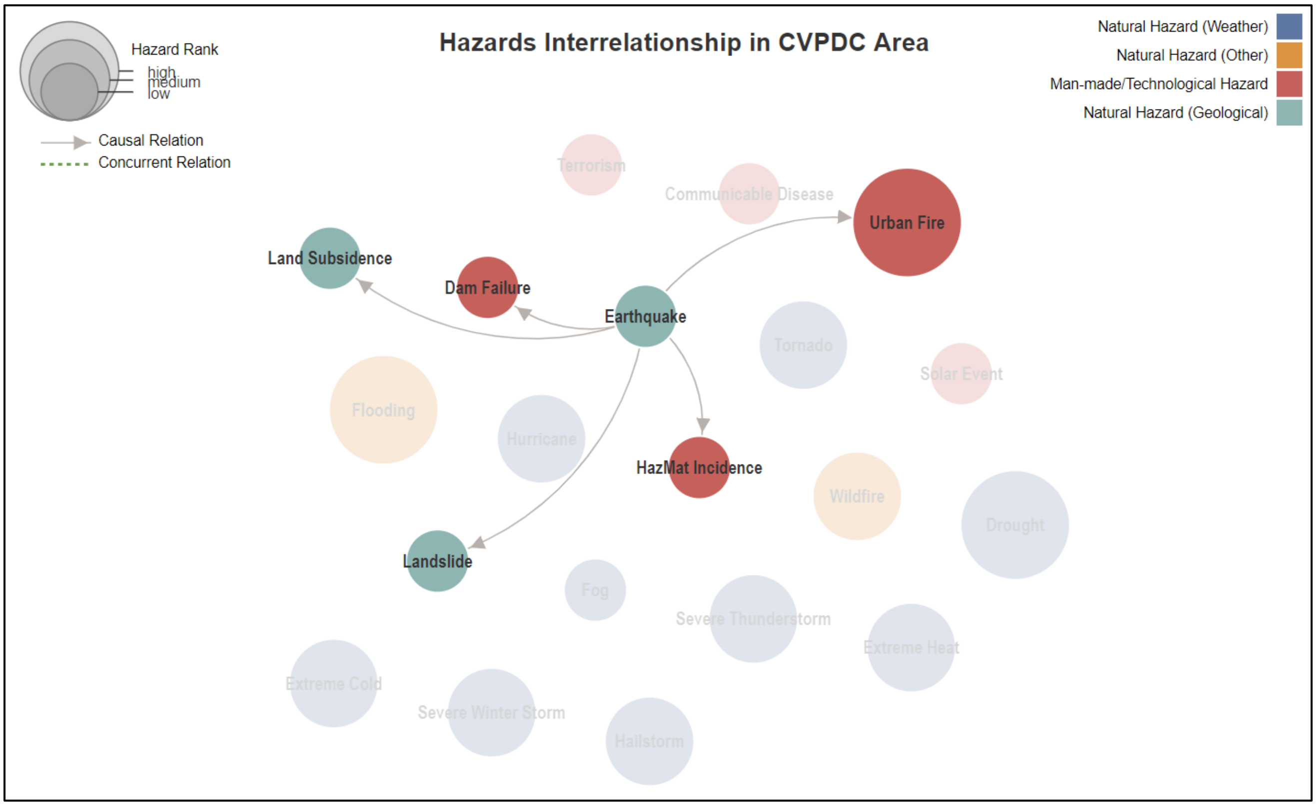


Figure 4-154 Hazards interrelationship

4.15.2 Impact & Vulnerability

Earthquakes in Virginia are low probability, high-consequence events. If Central Virginia experienced an earthquake with a magnitude 6.0 or greater, a worst-case scenario would include the collapse of bridges and tall buildings, flash-flooding from breached reservoirs, widespread electrical fires, and exploding gas pipelines. Damage would be compounded as ruptured water lines would hinder fire abatement and disrupted transportation systems would delay the evacuation of seriously injured persons.

4.15.3 Risk Assessment and Jurisdictional Analysis

In spite of extensive research and sophisticated equipment, earthquakes remain impossible to predict.

According to FEMA, earthquake risk is related to the following factors:

1. Ground motion;
2. Fault rupture under or near a building, often occurring in buildings located close to faults;
3. Reduction of the soil bearing capacity under or near a building;
4. Earthquake-induced landslide near a building; and
5. Earthquake-induced waves in bodies of water near a building.

Fissuring, settlement, and permanent horizontal and vertical shifting of the ground often accompany large earthquakes. Although not as pervasive or as costly as the shaking itself, these ground failures, such as fault rupture, liquefaction and landslides, can significantly increase damage and under certain circumstances can be the dominant cause of damage. Landslides can be triggered by earthquake shaking. They can significantly damage structures, as well as transportation and utility lifelines, that are located on them or in their downslope paths. Liquefaction which occurs when loose, water-saturated sand is shaken by the earthquake and turns into a fluid-like substance, can cause it to lose the ability to support buildings and other structures. Areas along rivers where sandy sediments have been deposited along the course are susceptible to liquefaction.

4.15.3.1 Risk to Critical Facilities

The 2011 Mineral, Virginia earthquake led to a gas leak incident in Charlottesville. In the CVPDC area, there are both natural gas transmission pipelines and hazardous liquid transmission pipelines traversing the region that could be affected by a major earthquake (see Hazardous Material Incidents section of this plan). Earth movement associated with earthquakes can cause pipelines to shift and possibly rupture resulting in dangerous leaks. Older, more brittle pipelines would be more susceptible to damage as the result of abrupt earth movements. Given the low probability of this type of event, no additional assessment was deemed necessary in this plan update.

4.15.3.2 Loss Estimates

Earthquake loss estimation and planning scenarios quantify seismic risk based on seismic hazard and exposure and vulnerability of the built environment. The latest Hazus Earthquake Model (Hazus 4.2 SP3) was used to estimate damages and loss of buildings and essential facilities from earthquake events. Hazus is a regional loss estimation tool that uses population and building data aggregated at the census tract level. Building value and construction cost estimates are adjusted to reflect regional variations. The assessment with Hazus includes loss of buildings, critical facilities, and transportation and utility lines. This updated plan utilizes Hazus Level 2 analysis for the module. It uses modified default databases built into the methodology for information on building square footage and value, population characteristics, costs of building repair, and certain basic economic data.

The plan update team made some enhancement on the default dataset to optimize the analysis. First, the default building inventory data was adjusted to reflect the region's characteristics. The building inventory classification system in Hazus was developed to provide an ability to differentiate between buildings with substantially different damage and loss characteristics. The building type category is represented by low-rise (1-3 stories), mid-rise (4-7 stories, or typically 60-120 feet high), and high-rise (8+ stories, or typically 120+ feet high) in its building inventory data. By default, every building in the Hazus Earthquake model is considered a low-rise structure. However, there are some mid-rise and high-rise unreinforced masonry structures in downtown Lynchburg and Bedford County which are susceptible to damage from an earthquake (Table 4-148). The Lynchburg eTRAKiT Database was used to retrieve detailed parcel level information (*e.g.,* number of stories, occupancy, *etc.*) for Lynchburg City. [79] The relationships between building occupancy and building type were modified in the Hazus model to reflect the necessary changes. Secondly, soil maps, liquefaction potential, landslide potential, and water depth maps were also applied to the model rather than using the default information.

[79] eTRAKiT Database, City of Lynchburg. https://etrakit.lynchburgva.gov

Table 4-148 Mid-rise and high-rise buildings in CVPDC Area

Building	Floors	Height (ft)	Built Year	Address
Bank of the James Building	20	222	1972	828 Main Street
Allied Arts Building	17	185	1931	725 Church Street
Bank of America Building	11	118	1913	801 Main Street
Westminster Canterbury I	8	96	N/A	501 VES Road
Holiday Inn Select	8	96	1983	601 Main Street
Riverviews Artspace	8	96	1898	901 Jefferson Street
Lynchburg Utilities Division	7	84	1967	525 Taylor Street
920 Commerce Street	7	84	1906	920 Commerce Street
1101 Jefferson Street	7	84	1906	1101 Jefferson Street
The Virginian Building	7	84	1913	712-718 Church Street
Krise Building	7	75	1904	201-209 Ninth Street
Bedford County Courthouse	6	74	N/A	125-131 East Main Street
1309 Jefferson Street	6	72	N/A	1309 Jefferson Street
The Courtland Center	6	72	1909	620 Court Street
Jefferson House	6	72	1973	1818 Langhorne Square
Residence Hall 33	6	72	N/A	Flames Way, Liberty University
Westminster Canterbury II	6	72	N/A	501 VES Road
700 Main Street	6	72	1979	700 Main Street
Verizon Building	6	72	1945	700 Church Street
918 Commerce Street	6	72	1908	918 Commerce Street
Appalachian Building	6	72	1983	800 Main Street
528 Jackson Street	5	61	N/A	528 Jackson Street
Hilton Garden Inn Lynchburg	5	60	2008	4025 Wards Road
Lynchburg General Hospital	5	60	2007	1901 Tate Springs Road
Days Inn Airport	5	60	1981	3320 Candlers Mountain Road
YWCA Building	5	60	1912	626 Church Street
Lynchburg Social Services	5	60	1910	99 Ninth Street
926 Commerce Street	5	60	1904	926 Commerce Street
Craddock Terry Hotel	5	60	1906	1312 Commerce Street
1001 Church Street	5	60	1957	1001 Church Street

Earthquake loss analysis involves identifying the size and location of the earthquake and estimating its associated ground motions and ground deformations due to ground failure. The severity of an earthquake is site specific, and is influenced by proximity to the earthquake epicenter and soil type, among other factors. There are different ways to define an earthquake scenario for this analysis in Hazus, such as using historical events, probabilistic events, and arbitrary events. In this plan update, probabilistic, annualized, and user defined scenarios were considered to estimate the damage.

4.15.3.3 Probabilistic Earthquake Loss

A probabilistic assessment was conducted for the CVPDC for the 500- and 2,500-year return periods using a Level 2 analysis in Hazus to analyze the earthquake hazard and provide a range of loss estimates. The probabilistic method uses information developed by the USGS from historic earthquakes and inferred faults, locations and magnitudes to calculate the probable ground shaking levels that may be experienced during a recurrence period by Census tract. The results are provided in Table 4-149 and Table 4-150, and Panels A and B of Figure 4-156.

Table 4-149 Estimated Direct Economic Loss for Buildings in a 500-Year Event

Locality	Capital Stock Losses ($K)				Income Losses ($K)				Total Loss ($K)
	Cost Structural Damage	Cost Non-Structural Damage	Cost Contents Damage	Inventory Loss	Relocation Loss	Capital Related Loss	Wage Losses	Rental Income Loss	
Lynchburg	2,106	3,634	883	29	1,318	478	611	714	9,722
Amherst	661	1,064	204	8	413	63	93	159	2,665
Town of Bedford	231	401	111	5	156	53	82	78	1,117
Bedford	1,833	3,027	564	15	1,086	133	188	368	7,212
Appomattox	401	679	135	3	253	27	47	86	1,631
Campbell	1,355	2,230	485	26	861	177	230	319	5,683
Total	**6,587**	**11,035**	**2,331**	**85**	**4,087**	**930**	**1,251**	**1,723**	**28,030**

Note: Scenario is based on a 500-year probabilistic event. Updated Default VA mapping scheme was used to ensure taller, unreinforced masonry structures were accounted for in the analysis. All values are in thousands of dollars. Town values are included in the totals for the corresponding county.

Table 4-150 Estimated Direct Economic Loss for Buildings in a 2500-Year Event

Locality	Capital Stock Losses ($K)				Income Losses ($K)				Total Loss ($K)
	Cost Structural Damage	Cost Non-Structural Damage	Cost Contents Damage	Inventory Loss	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	
Lynchburg	12,638	38,405	15,235	528	8,196	3,141	3,977	4,278	86,399
Amherst	4,125	11,541	4,201	154	2,663	426	611	1,004	24,725
Town of Bedford	1,379	4,255	1,910	86	970	342	519	461	9.923
Bedford	10,848	30,284	10,549	255	6,636	849	1,176	2,178	62,775
Appomattox	2,647	7,809	2,882	52	1,744	194	328	571	16,227
Campbell	7,984	22,478	8,670	438	5,265	1,145	1,470	1,883	49,332
Total	**39,621**	**114,771**	**43,447**	**1,513**	**25,474**	**6,097**	**8,082**	**10,375**	**249,380**

Note: Scenario is based on a 2500-year probabilistic event. Updated Default VA mapping scheme was used to ensure taller, unreinforced masonry structures were accounted for in the analysis. All values are in thousands of dollars. Town values are included in the totals for the corresponding county.

4.15.3.4 Annualized Earthquake Loss

The annualized earthquake loss (AEL) is the estimated long-term value of earthquake losses to the general building stock in any single year in a specified geographic area (e.g., state, county, metropolitan area). It addresses two key components of seismic risk: the probability of ground motion occurring in a given study area and the consequences of the ground motion in terms of physical damage and economic loss. According to the

Hazus Estimated Annualized Earthquake Losses for the United States (FEMA 2017),[80] the AEL to the national building stock is $6.1 billion per year, while the Virginia account for $11.74 million per year. The three seismic zones aforementioned don't pose a significant earthquake threat.

The process for computing AEL with Hazus includes three steps. First, process the USGS earthquake hazard data for the 2011 Louisa County Earthquake into a Hazus-compatible format. Second, estimate losses at the census tract level for specific return periods using the updated building inventory. Third, compute the AEL using the earthquake model.

The following maps and tables (Table 4-151, Figure 4-155, and Figure 4-156, Panel C) illustrate the average annual loss for the regional earthquake hazard. Hazus estimated the total annualized economic loss to be approximately $307 thousand dollars, which includes capital stock losses and income losses. Building-related losses are highlighted in the Figure 4-155 below.

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

While building-related losses are a reasonable indicator of relative regional earthquake risk, it is important to recognize that these estimates are not absolute determinants of the total risk from earthquakes. This is because factors such as the amount of debris generated and social losses including casualty estimates, displaced households, and shelter requirements need to be considered. Seismic risk also depends on other parameters not included herein such as damages to lifelines and other critical facilities and indirect economic loss.

Table 4-151 Estimated Direct Economic Loss for Buildings in Annualized Scenario

Locality	Capital Stock Losses ($K)				Income Losses ($K)				Total Loss ($K)
	Cost Structural Damage	Cost Non-Structural Damage	Cost Contents Damage	Inventory Loss	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	
Lynchburg	19	44	14	1	12	5	6	6	107
Amherst	6	13	4	0	4	1	1	1	30
Town of Bedford	2	5	2	0	1	1	1	1	12
Bedford	16	35	10	0	10	1	2	3	77
Appomattox	4	9	3	0	2	0	0	1	19
Campbell	12	26	8	0	8	2	2	3	62
Total	59	131	40	1	38	38	12	16	307

Note: Updated VA mapping scheme was used to ensure taller, unreinforced masonry structures were accounted for in the analysis. All values are in thousands of dollars. Town values are included in the totals for the corresponding county.

[80] Hazus Estimated Annualized Earthquake Losses for the United States. FEMA. April 2017. https://www.fema.gov/media-library-data/1497362829336-7831a863fd9c5490379b28409d541efe/FEMAP-366_2017.pdf

4.15.3.5 Annualized Social Impact

For the annualized loss results, Hazus estimated there would be no casualties due to earthquake damage.

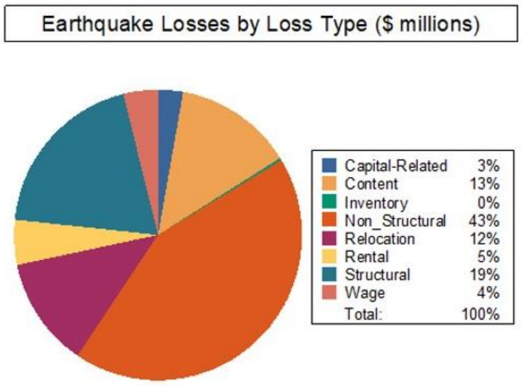
4.15.3.6 User-defined Scenario Earthquake Loss (Hypothetical)

A user-defined scenario was created using a magnitude 5 earthquake located 6km underground (same depth as the 2011 Mineral Earthquake which had a magnitude of 5.8). The epicenter was placed in a seismic activity zone developed by the Virginia Department of Mines, Minerals and Energy. The Hazus analysis indicates the loss estimates for this particular scenario are much higher than many of the probabilistic scenarios (Table 4-152; Figure 4-156, Panel D).

Table 4-152 Estimated Direct Economic Loss for Buildings in User-defined Scenario

	Capital Stock Losses ($K)				Income Losses ($K)				
Locality	Cost Structural Damage	Cost Non-Structural Damage	Cost Contents Damage	Inventory Loss	Relocation Loss	Capital Related Loss	Wage Losses	Rental Income Loss	Total Loss ($K)
Lynchburg	3,473	6,906	1,907	74	2,184	818	1,045	1,204	17,611
Amherst	2,092	4,863	1,465	50	1,335	203	303	530	10,840
Bedford City	66	80	10	0	43	14	22	22	2,487
Bedford	599	923	148	3	328	57	79	125	2,262
Appomattox	5,584	19,241	7,587	69	3,564	258	437	1,078	37,817
Campbell	1,632	2,949	710	29	1,050	198	257	367	7,192
Total	13,446	34,961	11,826	226	8,503	1,547	2,144	3,327	75,980

Note: The scenario is a user-defined earthquake with a 5.0 magnitude which was located in the eastern part of the CVPDC Area in Appomattox County. New mapping scheme for the Downtown Census Tract was used. All values are in thousands of dollars.



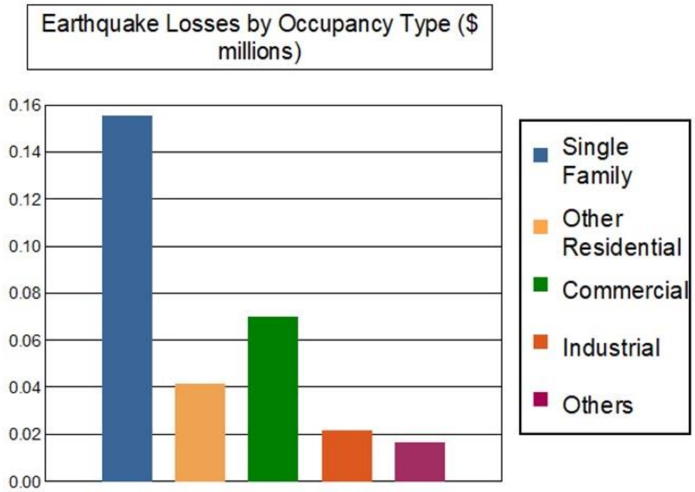


Figure 4-155 Total Building-related Earthquake Losses

4.15.4 Probability of Future Occurrence

Though very rare, earthquakes have the potential to affect the CVPDC area. According to James R. Martin II, the former director of the Earthquake Engineering Center for the Southeastern United States, recent seismological studies suggest that the southern Appalachian highlands have the potential for even larger earthquakes than have occurred in the past. Although experts can estimate the likelihood of an earthquake occurring in a particular region, it is impossible to predict an earthquake, both in occurrence as well as in magnitude.

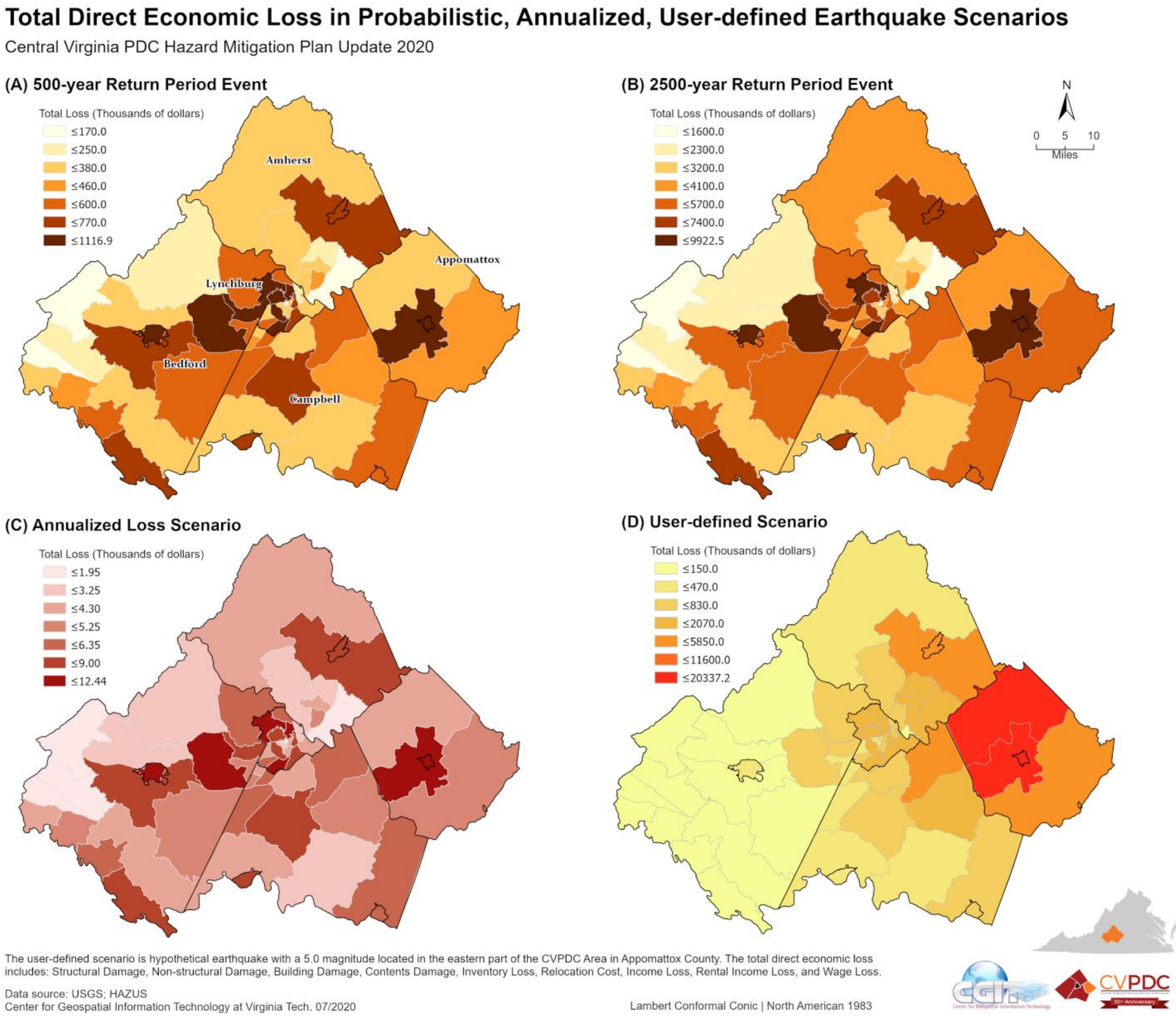


Figure 4-156 Total Direct Economic Loss in Probabilistic, Annualized, User-defined Earthquake Scenarios for CVPDC Area

4.15.5 References

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