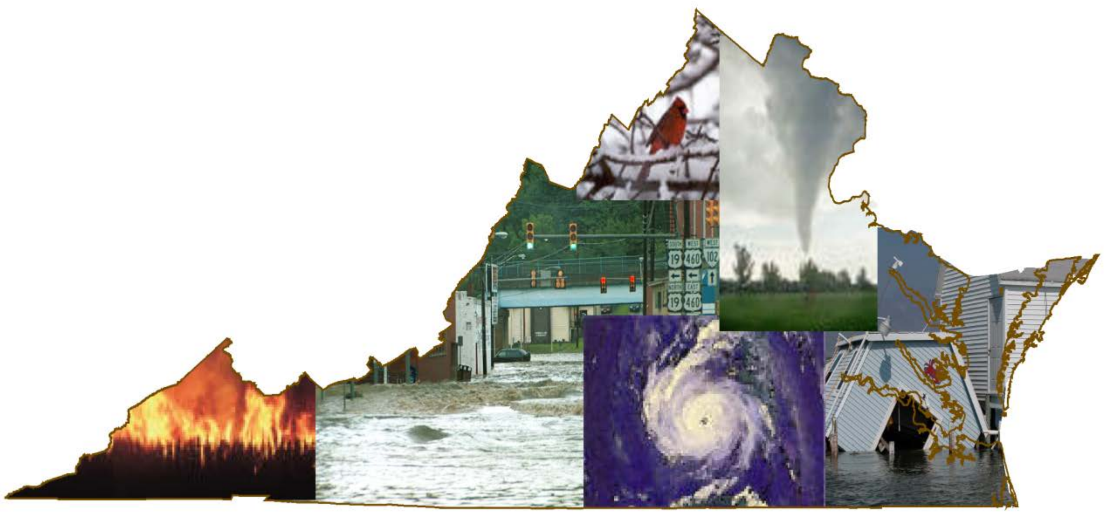
COMMONWEALTH OF VIRGINIA

Hazard Mitigation Plan



Chapter 3
Hazard Identification and Risk Assessment (HIRA)

Section 3.13 - Earthquakes

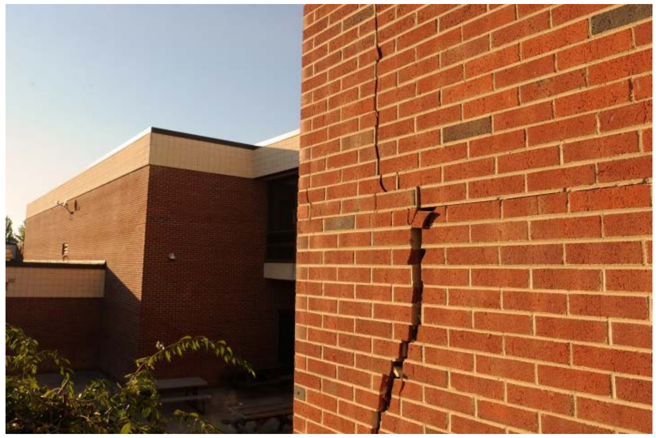
SECTION 3.13

TABLE OF CONTENTS

TABLES AND FIGURES

Section 3.13: Earthquake

Description



Louisa County
August 2011
Source: EPA Michael Reynolds

The surface of the earth consists of solid masses, called tectonic plates, which float on a liquid core. The areas where separate plates meet each other are called faults. An earthquake is a sudden movement of the earth's crust caused by the abrupt release of strain that has accumulated over a long period of time. Records show that some seismic zones in the United States experience moderate to major earthquakes approximately every 50 to 70 years, while other areas have recurrence intervals for the same size earthquake of about 200 to 400 years.[1] Most of the well-known areas of strain, or faults, are located in the Western United States, where most recent earthquakes have occurred. However, the Eastern and Central United States are also vulnerable to devastating earthquakes. Earthquakes in the Central and Eastern U.S. are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast.

Earthquakes everywhere occur on faults within bedrock, usually miles below the surface. Some bedrock beneath central Virginia was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most of the bedrock formed when the supercontinent rifted apart about 200 million years ago to form what is the northeastern U.S., the Atlantic Ocean, and Europe.

At well-studied plate boundaries, like the San Andreas Fault in California, scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Central Virginia seismic zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea, are known as interplate earthquakes. Intraplate earthquakes occur in the interior of a tectonic plate and are considered rare when compared to earthquakes at plate boundaries. The seismic zone is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake.[2]

[1] HAZUS-MH Risk Assessment and User Group Series How-to-Guide: Using HAZUS-MH for Risk Assessment (FEMA 433/August 2004)
[2] Virginia Tech Seismology Observatory (http://www.geol.vt.edu/outreach/vtso/index.html)

The severity of an earthquake can be expressed in terms of both intensity and magnitude. However, the two terms are quite different, and they are often confused. Intensity is based on the observed effects of ground shaking on people, buildings, and natural features. It varies from place to place within the disturbed region depending on the location of the observer with respect to the earthquake epicenter. Magnitude is related to the amount of seismic energy released at the hypocenter of the earthquake. It is based on the amplitude of the earthquake waves recorded on instruments which have a common calibration. The magnitude of an earthquake is thus represented by a single, instrumentally determined value.

Earthquake severity is commonly measured on two different scales, the Modified Mercalli Intensity scale and by the Richter Magnitude scale. The following Table 3.13-1 provides ranking and classification definitions for the two scales.

Table 3.13-1: Comparison of earthquake scales

Richter Magnitude Scale	Modified Mercalli Intensity Scale
1.0 to 3.0	I
3.0 to 3.9	II to III
4.0 to 4.9	IV to V
5.0 to 5.9	VI to VII
6.0 to 6.9	VII to IX
7.0 and Higher	VIII or Higher
Defined Modified Mercalli Intensity Scale Rating	
I	Not Felt except by a very few under especially favorable conditions
II	Felt only by a few persons at rest, especially on upper floors of buildings
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors, disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Earthquakes are the results of forces deep within the Earth's interior that continuously affect the surface of the Earth. The energy from these forces is stored in a variety of ways within the rocks. When this energy is suddenly released, for example by shearing movements along faults in the crust of the Earth, an earthquake results.

The area of the fault where the sudden rupture takes place is called the focus or hypocenter of the earthquake. The point on the Earth's surface directly above the focus is called the epicenter of the earthquake[3].

Historic Occurrence

To date, there has been one Federal Declared Disaster for an earthquake in the Commonwealth (See section 3.3).

Historical earthquake occurrences (Table 3.13-2) are based on available records from the Virginia Tech Seismological Observatory (VTSO), Seismicity of the United States (USGS Paper 1527) and Earthquakes in Virginia and Vicinity 1774 – 2004 (USGS Paper 2006 1017). The VTSO operates a digital seismic network with stations in Virginia and West Virginia and compiles a catalog of historical and recent, instrumentally located, earthquakes in the southeastern U.S. region. Since 1977, the southeastern regional seismic network operators have contributed over 1,500 instrumentally located hypocenters and magnitudes to the catalog. Smaller events before this time were usually recorded on the basis of personal observations and resulting damages.

Figure 3.13-1 shows the epicenter locations of historical earthquakes and the main two zones in Virginia that are more susceptible to earthquakes. These zones, as mapped by the USGS, are believed to be sources of most Magnitude 6 or greater earthquakes during the past 1.6 million years around Virginia.

While it is important to identify historical earthquake occurrences within the Commonwealth, it is also important to acknowledge that impacts can be felt within the Commonwealth from outside sources. Effects from intraplate earthquakes in other states are often felt in Virginia. The New Madrid fault is considered a major seismic zone for the Southern and Midwestern United States. The New Madrid fault had a series of devastating earthquakes from 1811 through 1812, and intensities of V and VI on the Modified Mercalli Intensity Scale could be felt throughout Virginia. In September of 1886 a magnitude 7.3 earthquake occurred in Charleston, South Carolina. Intensities of II-V on the Modified Mercalli Intensity Scale were felt throughout Virginia. While these events occurred in other states, it is a great example of how the effects of earthquakes are felt over a very broad region east of the Rockies[4].

---

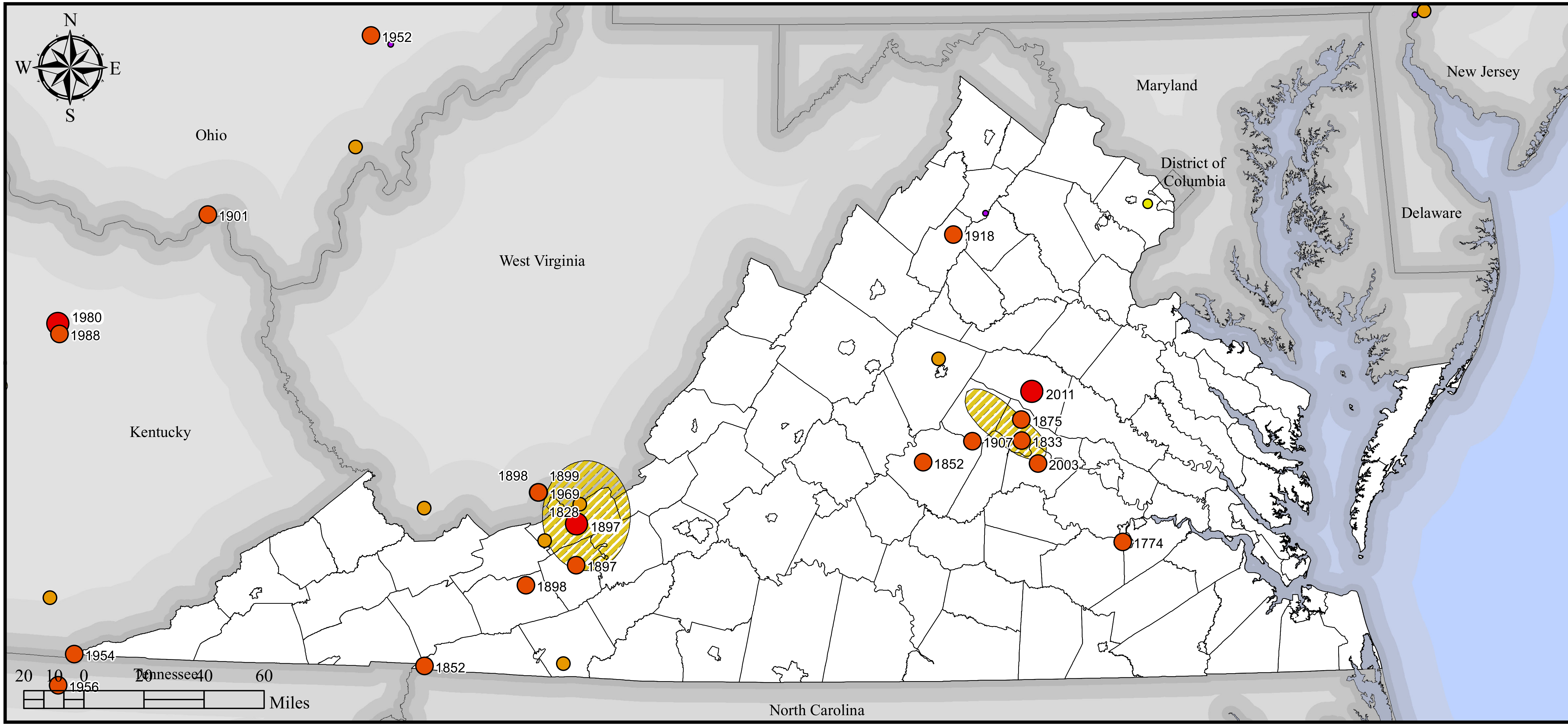
[3] USGS: Severity of an Earthquake http://pubs.usgs.gov/gip/earthq4/severitygip.html
[4] Historic United States Earthquakes. http://earthquake.usgs.gov/regional/states/historical.php

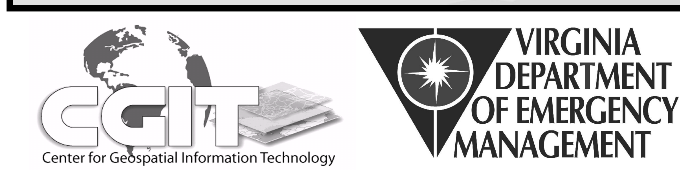
Table 3.13-2: Historical earthquakes in Virginia (1774 – 2012)

Year	Month	Magnitude (Richter Scale)	Epicenter Location	Description
1774	21-Feb	4.5	Petersburg City Prince George County	A sharp earthquake that was felt over much of Virginia displaced houses "considerably off their foundations" at Blandford and Petersburg. Although the shock was severe at Richmond and terrified residents about 80 km north of Richmond at Fredericksburg, it caused no damage at those towns. Several "smart shocks" were reported in parts of Virginia from Feb. 20th to the 22nd. The main tremor rang bells at Salem (now Winston-Salem), N.C.
1833	27-Aug	4.5	Central Virginia Goochland County	A rather strong shock agitated walls of buildings at Lynchburg (west of Richmond, in southern Amherst County) and rattled windows violently. Fences along the road were shaken near the Louisa County Courthouse, northwest of Richmond. It was described as "severe" at Charlottesville, about 85 km northeast of Lynchburg. Two miners were killed in a panic caused by the tremor at a mine near Richmond.
1852	29-Apr	4.8	Town of Wytheville Wythe County	A severe earthquake that was observed over a large area threw down a chimney near Wytheville, in southwest Virginia, and shook down tops of chimneys at Buckingham Courthouse, about 55 km south of Charlottesville. Houses were shaken violently at Staunton, about 65 km west of Charlottesville. A brick was shaken from a chimney as far south as Davie County, N.C. Also felt in the District of Columbia, Maryland, New York, Ohio, and Pennsylvania.
1852	2-Nov	4.3	Central Virginia Buckingham County	Chimney damage occurred at Buckingham, about 55 km south of Charlottesville. This earthquake was reported to be "quite strong" at Fredericksburg, Richmond, and Scottsville. At Scottsville, where every house in the village was shaken, water in the canal was "troubled," and boats were tossed to and fro.
1875	23-Dec	4.8	Central Virginia Goochland County	The highest intensities from this earthquake occurred mainly at towns near the James River waterfront in Goochland and Powhatan Counties, and in Louisa County. In Richmond (Henrico County), the most severe damage was sustained in the downtown business and residential areas adjacent to the James River or on islands in the river. Damage included bricks knocked from chimneys, fallen plaster, an overturned stove, and several broken windows. Waves "suddenly rose several feet" at the James River dock at Richmond, causing boats to "part their cables" and drift below the wharf. At Manakin, about 20 km west of Richmond, shingles were shaken from a roof and many lamps and chimneys were broken. Several small aftershocks were reported through Jan. 2, 1876. Felt from Baltimore, Md., to Greensboro, N.C., and from the Atlantic Coast westward to Greenbrier and White Sulphur Springs, W.Va.
1897	3-May	4.3	Southwest Virginia Pulaski County	This earthquake was most severe at Radford (about 65 km west of Roanoke), where a few chimneys were wrecked and plaster fell from walls. Chimneys were damaged at nearby Pulaski and at Roanoke. Felt in most of southwest Virginia and as far south as Winston-Salem, N.C.
1897	31-May	5.8	Town of Pearisburg Giles County	This earthquake was the largest in intensity and areal extent in Virginia in historical times and is the 3rd largest in the eastern US and was felt in 12 states. The earthquake had a maximum Modified Mercalli Intensity of VIII, and the area of maximum ground motion extended over an elliptical area-from near Lynchburg, Va., west to Bluefield, W.Va., and from Giles County south to Bristol, Tenn. The MM intensity VIII assigned to this earthquake is based on "many downed chimneys" and "changes in the flow of springs." The shock was strong at Pearisburg, where walls of old brick houses were cracked and many chimneys were thrown down or badly damaged. Many chimneys also were shaken down at Bedford, Pulaski, Radford, and Roanoke, Va., and Bristol, Tenn.; many chimneys were damaged at Christiansburg, Dublin, Floyd, Houston, Lexington, Lynchburg, Rocky Mount, Salem, Tazewell, and Wytheville, Va.; Charlotte, Oxford, Raleigh, and Winston, N.C.; Knoxville, Tenn.; and Bluefield, W.Va. Felt from Georgia to Pennsylvania and from the Atlantic Coast westward to Indiana and Kentucky. Aftershocks continued through June 6, 1897 (see Figure 3.13-4).
1898	5-Feb	4.4	Pulaski County	Bricks were thrown from chimneys, furniture was shifted in a few houses, and residents rushed into the streets at Pulaski, about 70 km southwest of Roanoke. Felt throughout southwest Virginia and south to Raleigh, N.C.
1907	11-Feb	4	Town of Arvonia Buckingham County	Chimneys were cracked at Ashby, about 20 km southeast of Arvonia, and a window was broken at a store at Buckingham, 25 km southwest of Arvonia. A "terrific" shock sent people rushing outdoors at Arvonia and displaced furniture. Felt strongly from Powhatan to Albemarle County.
1918	10-Apr	4.6	Town of Luray Page County	In the Shenandoah Valley, at Luray, windows were broken and plaster was cracked severely. Ceilings of houses were cracked badly a few kilometers north of Luray, at Edinburg; windows were broken at Harrisonburg and Staunton, Va., and Washington, D.C. (at Georgetown University). In addition, a new spring formed in Page County, near Hamburg, almost in the middle of a road. A minor aftershock was reported in the area about 5 hours later. Also felt in Maryland, Pennsylvania, and West Virginia.
1919	6-Sep	Unknown	Town of Front Royal Warren County	This earthquake affected towns mainly in Warren and Rappahannock Counties. At Arco, in the Blue Ridge Mountains south of Front Royal, chimneys were damaged, plaster fell from walls, and springs and streams were muddied. Reports from the adjacent northern part of Rappahannock County state that similar shocks were felt and that streams were "rendered turbid." Also felt in parts of Maryland and West Virginia. Several aftershocks occurred.

Year	Month	Magnitude (Richter Scale)	Epicenter Location	Description
1929	26-Dec	3.7	Charlottesville City Albemarle County	A moderate tremor at Charlottesville shook bricks from chimneys in some places; also felt in other parts of Albemarle County.
1959	23-Apr	3.9	Giles County	The earthquake was strongest in Giles County, at Eggleston and Pembroke. Residents there reported several damaged chimneys and articles shaken from shelves and walls. One chimney toppled at the Norfolk and Western Station in Eggleston. Also felt in West Virginia.
1975	11-Nov	3.2	Southwest Virginia Giles County	Windows were broken in the Blacksburg area of Montgomery County, and plaster was cracked at Poplar Hill (south of Pearisburg, in Giles County). Also felt in Pulaski County.
1976	13-Sep	3.3	Southwest Virginia Carroll County	Bricks fell from chimneys and pictures fell from walls in Surry County at Mount Airy, N.C. At the nearby town of Toast, N.C., cracks formed in masonry and plaster. The earthquake was observed in many towns in North Carolina and Virginia and in a few towns in South Carolina and West Virginia.
2003	9-Dec	4.5	Central Virginia Powhatan County *(picture on page 1)*	This was a complex event consisting of two sub-events occurring 12 seconds apart. Felt (V) at Columbia, Fork Union, Goochland, Oilville, Rockville and Sandy Hook; (IV) at Appomattox, Amelia Court House, Amherst, Blackstone, Bumpass, Charlottesville, Chester, Chesterfield, Colonial Heights, Cumberland, Dillwyn, Farmville, Glen Allen, Lawrenceville, Louisa, Manakin Sabot, Mechanicsville, Midlothian, Mineral, Palmyra, Petersburg, Powhatan, Richmond, Scottsville and Spotsylvania; (III) at Alexandria, Fairfax, Falls Church, Fredericksburg, Lexington, Lynchburg, McLean, Roanoke, Staunton and Vienna. Felt in much of Maryland and Virginia. Also felt in north-central North Carolina and a few areas of Delaware, New Jersey, New York, Pennsylvania, and West Virginia.
2008	18-Apr	5.2	Wasbash Valley, Illinois	An earthquake occurred in the Wabash Valley Seismic Zone in southeastern Illinois. A series of aftershocks, including one with an estimated moment magnitude of 4.6, follow the main shock. Although the earthquakes occurred 400 miles from the nearest station in the VT Seismological Observatory's seismic network, they were of sufficient size to be well-recorded in Virginia. *not shown on Figure 3.13-1
2008	6-May	2.0	Annandale	A minor earthquake occurred near Annandale, Virginia. Felt reports were primarily received from people in Fairfax County, Virginia; the District of Columbia; and Montgomery County, Maryland.
2011	23-Aug	5.8	Mineral, Virginia	This was a magnitude 5.8 earthquake that was felt in many jurisdictions and caused significant damage (described earlier in section 3.3). See Figure 3.13-5 and the preceding discussion.

Figure 3.13-1: Significant Earthquakes 1568 - 2011





PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DATA SOURCES:

USGS Significant Earthquakes
USGS Quaternary Faults
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Richter Magnitude
- Unknown
- 1 - 2.9
- 3 - 3.9
- 4 - 4.9
- > 5

Quaternary Faults/Folds

HAZARD IDENTIFICATION:

This map layer contains the locations of significant, historic earthquakes that caused deaths, property damage, and geological effects, or were otherwise experienced by populations in the United States (1568 - 2004).
USGS Quaternary Faults and Folds are believed to be sources of earthquakes, greater than magnitude 6, in the past 1,600,000 years.

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Risk Assessment

In spite of extensive research and sophisticated equipment, it is impossible to predict an earthquake, although experts can estimate the likelihood of an earthquake occurring in a particular region. FEMA has developed a software suite, named HAZU
S, for estimating potential losses from disasters. The HAZUS-MH earthquake model estimates damages and loss to buildings, lifelines and essential facilities from scenario and probabilistic earthquakes.

Earthquake risk is related to the following factors[5]:

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 of near a building
4. Earthquake-induced landslide near a building
5. Earthquake-induced waves in bodies of water near a building

Probability

Earthquakes are low probability, high-consequence events. Although earthquakes may occur only once in the lifetime of an asset, they can have devastating impacts. A moderate earthquake can cause serious damage to unreinforced buildings, building contents, and non-structural systems, and can cause serious disruption in building operations. Moderate and even very large earthquakes are inevitable, although very infrequent, in areas of normally low seismic activity. Consequently, in these regions buildings are seldom designed to deal with an earthquake threat; therefore, they are extremely vulnerable.

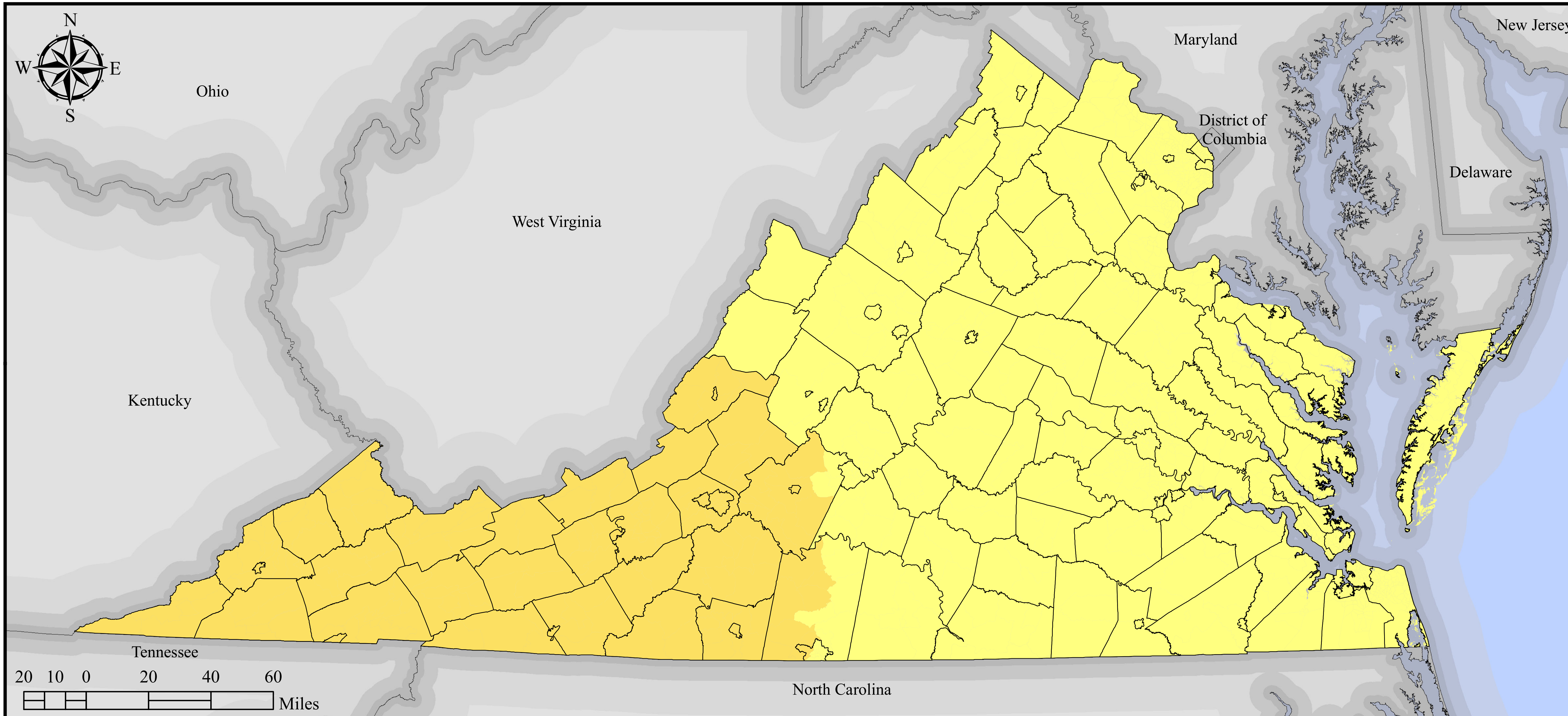
Probabilistic ground motion maps are typically used to assess the magnitude and frequency of seismic events. These maps measure the probability of exceeding a certain ground motion, expressed as percent peak ground acceleration (%PGA), over a specified period of years. The severity of earthquakes is site specific, and is influenced by proximity to the earthquake epicenter and soil type, among other factors. Figures 3.13-2 and 3.13-3 show the PGA zones for the 100-year and 2500-year Return Periods derived from the HAZUS-MH data. The 100-year Return Period or 1% 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. The 2500-year Return period, or 0.04% annual chance of occurrence, is much more varied and similar to the two USGS earthquake zones discussed in the earthquake description. Southwest and Central Virginia have an increased likelihood of experiencing a significant earthquake.

HAZUS-MH can be used to evaluate a variety of hazards and associated risks to support hazard mitigation. This revision of the Hazard Mitigation Plan utilizes only Level 1 analysis for the hurricane and earthquake modules. Level 1 analysis involves using the provided hazard and inventory data with no outside data collection. This is an acceptable level of information for

[5] HAZUS-MH Risk Assessment and User Group Series How-to-Guide: Using HAZUS-MH for Risk Assessment (FEAM 433/August 2004)

mitigation planning; future versions of this plan can be enhanced with Level 2 and 3 analysis. Training is available for localities interested in performing HAZUS analysis at the Emergency Management Institute; FEMA Region III also hosts periodic HAZUS training. VDEM staff can assist with determining needs and FEMA's Hazard Mitigation Technical Assistance Program could be a funding source for future workshops.

Figure 3.13-2: 100 Return Period Peak Ground Acceleration



DATA SOURCES:

HAZUS-MH 2.1 USGS Data
VGIN Jurisdictional Boundaries
ESRI State Boundaries

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

LEGEND:

100-Year PGA (%g)

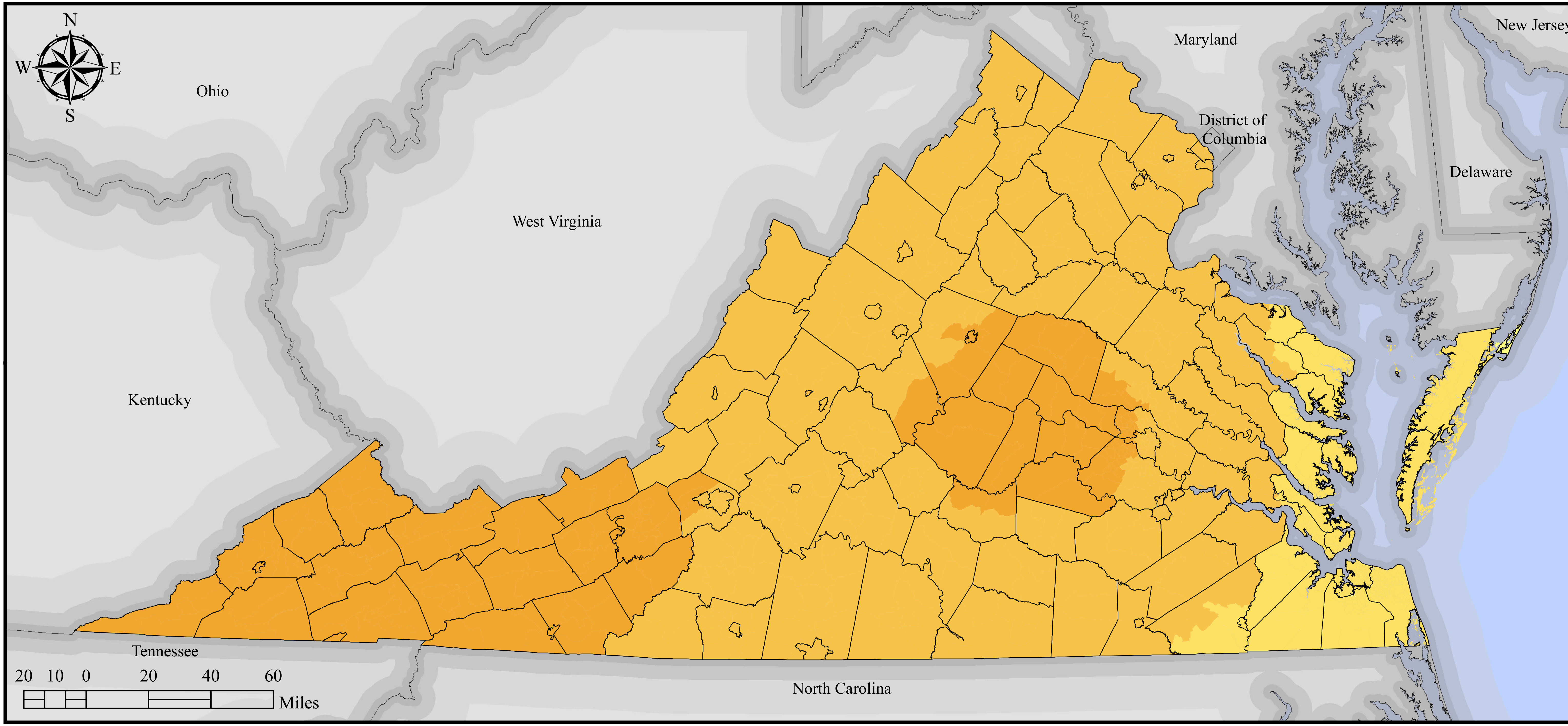
- <1.4
- 1.4 - 3.9
- 3.9 - 9.2
- 9.2 - 18
- 18 - 34
- 34 - 65
- >65

RISK ASSESSMENT:

Peak ground acceleration (PGA) is a measure of earthquake acceleration. PGA can be measured in g (the acceleration due to gravity) or m/s².

The shaking hazard map shows the level of ground motion that has 1 chance in 100 of being exceeded each year.

Figure 3.13-3: 2500 Return Period Peak Ground Acceleration



CGIT Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DATA SOURCES:

HAZUS-MH 2.1 USGS Data
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

2500-Year PGA (%g)

- <3.9
- 3.9 - 9.2
- 9.2 - 18
- 18 - 34
- 34 - 65
- 65 - 124
- >124

RISK ASSESSMENT:

Peak ground acceleration (PGA) is a measure of earthquake acceleration. PGA can be measured in g (the acceleration due to gravity) or m/s².

The shaking hazard map shows the level of ground motion that has 1 chance in 2500 of being exceeded each year (0.04%).

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Impact and Vulnerability

Impacts from earthquakes can be severe and cause significant damage. Ground shaking can lead to the collapse of buildings and bridges; disrupt gas, life lines, electric, and phone service. Death, injuries and extensive property damage are possible vulnerabilities from this hazard. Some secondary hazards caused by earthquakes may include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis and dam failure.

Table 3.13-3 provides the corresponding intensity equivalents in terms of MMI as well as perceived shaking and potential damage expected for given values. These values were used as thresholds to group state and critical facilities into different vulnerability/risk zones based on potential damage.

Table 3.13-3: Modified Mercalli Intensity (MMI) and PGA equivalents

MMI	PGA (%g)	Perceived Shaking	Potential Damage
I	<0.17	Not Felt	None
II	0.17 - 1.4	Weak	None
III	0.17 - 1.4	Weak	None
IV	1.4 -3.9	Light	None
V	3.9 -9.2	Moderate	Very Light
VI	9.2 -18	Strong	Light
VII	18 -34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy
IX	65 – 124	Violent	Heavy
X	> 124	Extreme	Very Heavy
XI	> 124	Extreme	Very Heavy
XII	> 124	Extreme	Very Heavy

Jurisdictional vulnerability and impact in the Commonwealth have been calculated in terms of total direct economic loss, as defined by HAZUS. This includes damage to structural, non-structural, building, contents, inventory loss, relocation, income loss, rental loss, and wage loss. Additional information can be found in the Jurisdiction Risk portion of this section.

Risk

In April 2008, FEMA released an update to the 2000 report that conducted a nationwide evaluation of earthquake ***losses*** in the United States: *HAZUS-MH Estimated Annualized Earthquake Losses for the United States* (FEMA 366, 2008).

The evaluation considers two measures of losses:

- Annualized Earthquake Losses(AEL) in any single year; and
- Annualized Earthquake Loss Ratio (AELR), which is a measure of seismic risk in relation to the value of the building inventory. The ratio is considered a more accurate picture of seismic risk and makes it easier to compare between regions.

FEMA's evaluation ranked Virginia 37th in the nation for AELR in the April 2008 revision. In 2000, Virginia had been ranked 34th in the nation.

The Virginia Tech Seismological Observatory produced a report titled *Seismic Hazard Assessment for Virginia* in 1994 that was supported through funding by VDEM, FEMA, US Nuclear Regulatory Commission, Virginia Power, and the USGS. This study provides a county-by-county assessment of the seismic hazards in Virginia. Geological conditions throughout much of the eastern part of the US are such that identification of seismogenic structures is difficult: no examples of surface faulting due to neotectonic earthquakes are known in the study region. However, it is possible to define areas with common geologic and seismic characteristics. These source zones are taken to represent areas within which available geological information suggests, or at least does not rule out, a common neotectonic environment. These zones include:

1. Giles County, VA
2. Central VA
3. Eastern TN
4. Southern Appalachians
5. Northern VA and MD
6. Central Appalachians
7. Piedmont-Coastal Plains
8. Charleston, SC
9. Appalachian foreland
10. New Madrid

Over much of the region, crustal structure potentially associated with seismicity is not resolved, and the geologic causes of earthquakes are poorly understood. The report summarizes, in depth, the source zones characteristics and hazard calculations used to arrive at the county-by-county analysis; 160 sites within Virginia and in adjacent parts of bordering states. Results show a higher probability of occurrence in the Giles County zone and Central Virginia.

The Giles County event of 1897 has been modeled in HAZUS-MH MR3. This earthquake is one of the most important to have occurred in the eastern United States principally because of the large area over which it was felt. Figure 3.13-4 shows the probable damages that would result from this magnitude earthquake happening in the same location today. Total direct economic loss, as defined by HAZUS, includes damage to structural, non-structural, building, contents, inventory loss, relocation, income loss, rental loss, and wage loss. Damages over $25 million would be expected around the epicenter, Giles County. A radius of damage ranging from $10 - $24 million would be expected to the northeast up to Highland County, to the southeast to Halifax County, and to the southwest to Scott and Wise Counties.

The Mineral earthquake of 2011 has also been modeled in HAZUS-MH MR3. The epicenter of the earthquake was located close to Cuckoo, in Louisa County[6]. Figure 3.13-5 shows the probable damages that would result from this magnitude earthquake. Damages over $100 million would be expected around the epicenter, Louisa County. A radius of damage ranging from $25-$100 million would be expected for parts of Louisa County farther from the epicenter and damages ranging from $10-$25 million would be expected in jurisdictions surrounding Louisa County. Louisa County's Thomas Jefferson Elementary School received approximately $3.2 million in FEMA assistance to rebuild. The elementary school is estimated to cost $13.7 million to rebuild[7]. In addition, Louisa County High School received $19 million in FEMA assistance to rebuild. The estimated cost to rebuild the high school was $43 million[8]. The earthquake also caused significant regional damage including The Washington Monument and the National Cathedral.

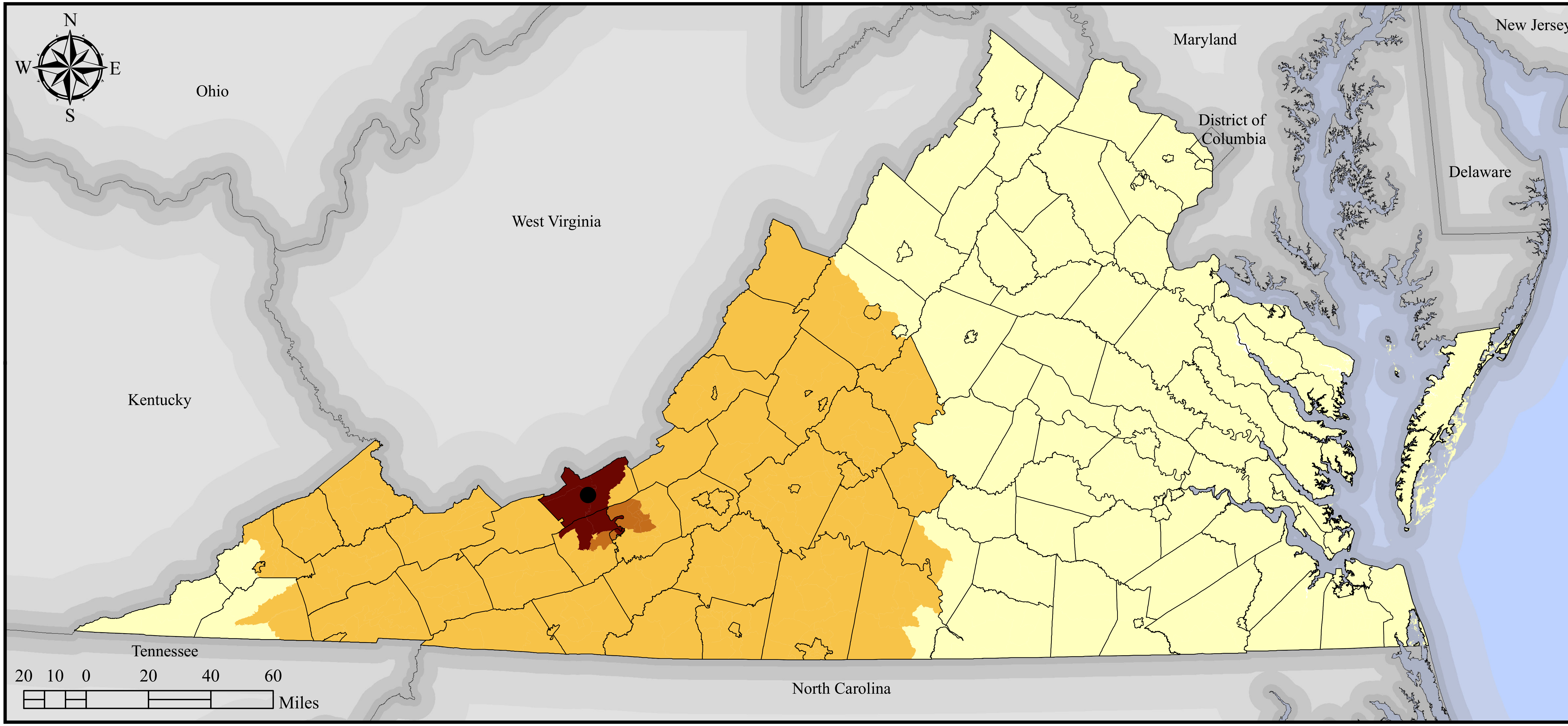
[6] Virginia Department of Mines and Minerals. "Virginia 5.8 magnitude earthquake." Retrieved from http://www.dmme.virginia.gov/DMR3/va_5.8_earthquake.shtml on November 20, 2012

[7] Virginia Department of Emergency Management. "Statement of Governor McDonnell After FEMA Awards $3.2 Million in Disaster Assistance to Replace Earthquake-Damaged Louisa Elementary School." Retrieved from http://www.vaemergency.gov/news/news-releases/2012/Statement-of-Gov-After-FEMA-Awards-Million-In-D-A-To-Replace-Earthquake-dam-school on November 20, 2012.

[8] Virginia Department of Emergency Management. "Louisa County High School Received $19 Million from FEMA to Rebuild." Retrieved from http://www.vaemergency.gov/news/news-releases/2012/Louisa-Co-High-receives-19M on November 12, 2012.

Virginia has not yet experienced a catastrophic earthquake. A Magnitude 6 earthquake is very probable for Virginia and would result in large scale structural failure. Probabilistic magnitude 5 and 6 earthquakes were also modeled for the 2500 return period. Figures 3.13-5 and 3.13-6 show the total loss that would be expected for these events. The modeled events show a higher concentration of damage in Southwest and Central Virginia, as would be expected based on published information from USGS, VTSO, and past events.

Figure 3.13-4:Total Loss from 1897 Historical Epicenter Event (HAZUS)



CGIT Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DATA SOURCES:

HAZUS-MH MR3 Historical Scenario
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

1897 Total Loss

- No Damage
- < $10 Million
- $10 Million - $25 Million
- > $25 Million
- 1897 Epicenter: Magnitude 5.8

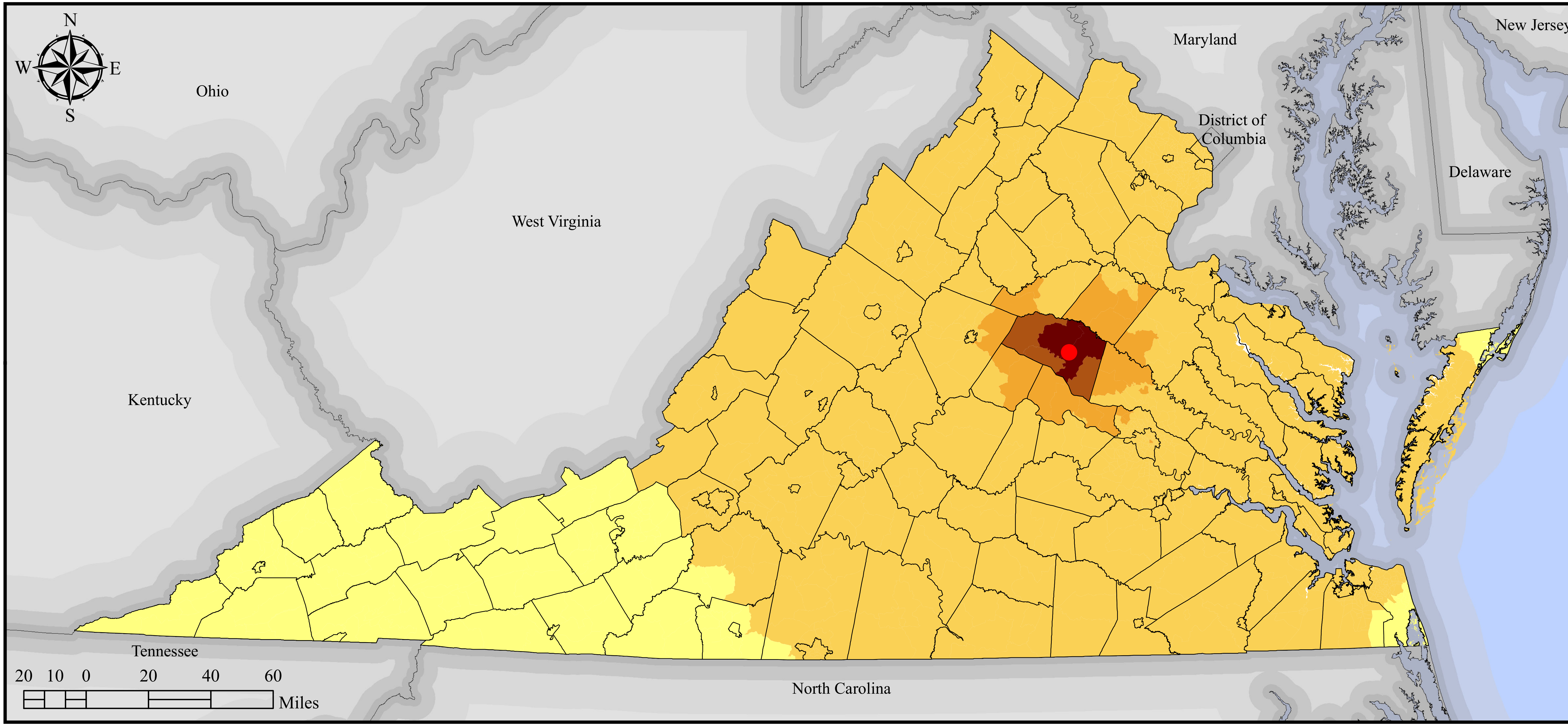
HAZARD IDENTIFICATION:

Historical Epicenter Event located in Giles County was calculated by HAZUS-MH MR3 using the historical senario for a Virginia 1897.

Total Direct Economic Loss includes:
Damage to Structural , Non-Structural, Building, Contents, Inventory Loss, Relocation, Income Loss, Rental Loss and Wage Loss.

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Figure 3.13-5:Total Loss from 2011 Mineral, VA Earthquake (HAZUS)



PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DATA SOURCES:

HAZUS-MH 2.1 Historical Scenario
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Annualized Loss

- No Damage
- < $10 Million
- $10 Million - $25 Million
- $25 Million - $100 Million
- > $100 Million
- 2011 Epicenter: Magnitude 5.8

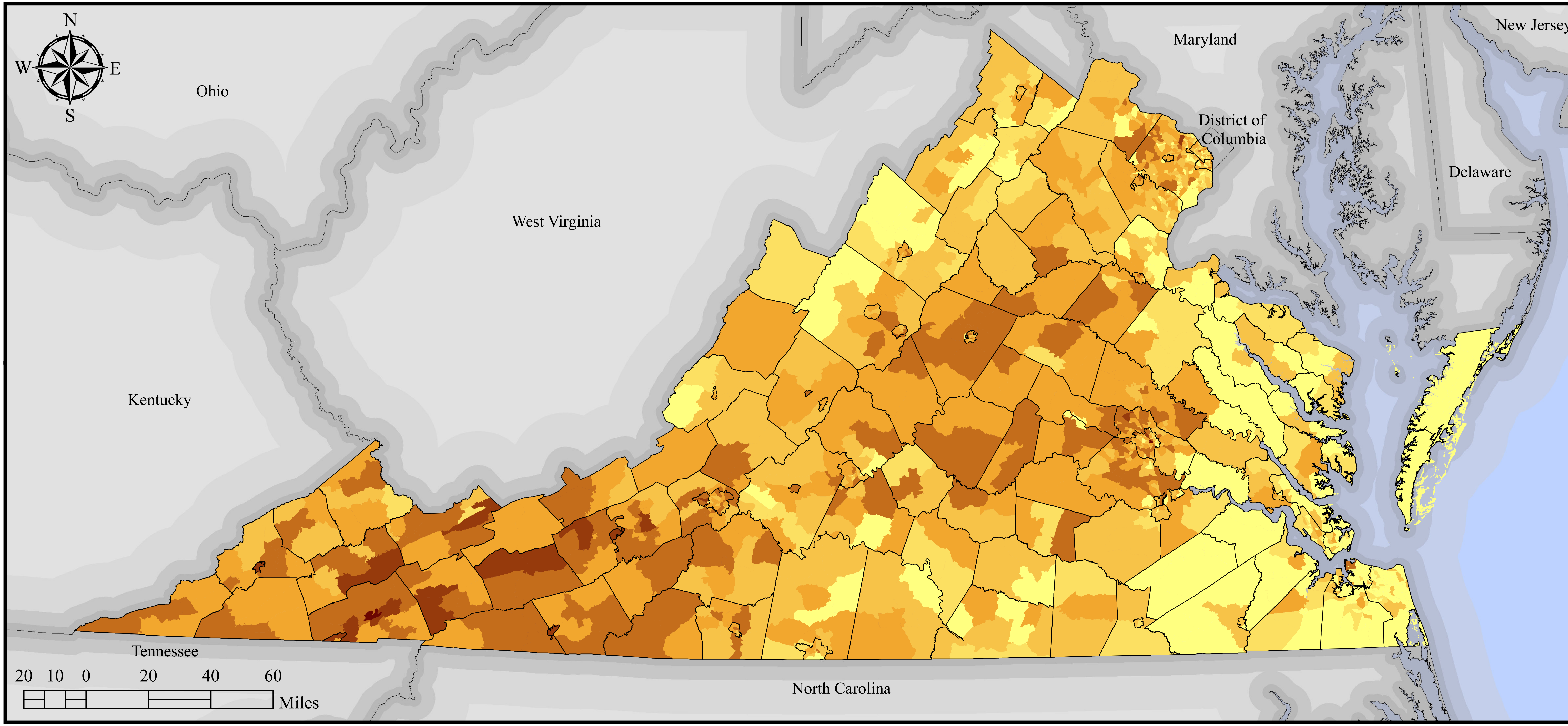
HAZARD IDENTIFICATION:

This earthquake was modeled using the HAZUS-MH 2.1 probabolistic model. Earthquake depth, magnitude, and location were taken into account in this analysis.

Total Direct Economic Loss includes:
Damage to Structural , Non-Structural, Building, Contents, Inventory Loss, Relocation, Income Loss, Rental Loss and Wage Loss.

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Figure 3.13-6: Earthquake Probabilistic 2500 Return Period Magnitude 5



Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

DATA SOURCES:

HAZUS-MH 2.1
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Total Loss by Census Tract

- < $3 Million
- $3 - $4 Million
- $4 - $7 Million
- $7 - $12.5 Million
- $12.5 - $25 Million
- $25 - $50 Million
- > $50 Million

RISK ASSESSMENT:

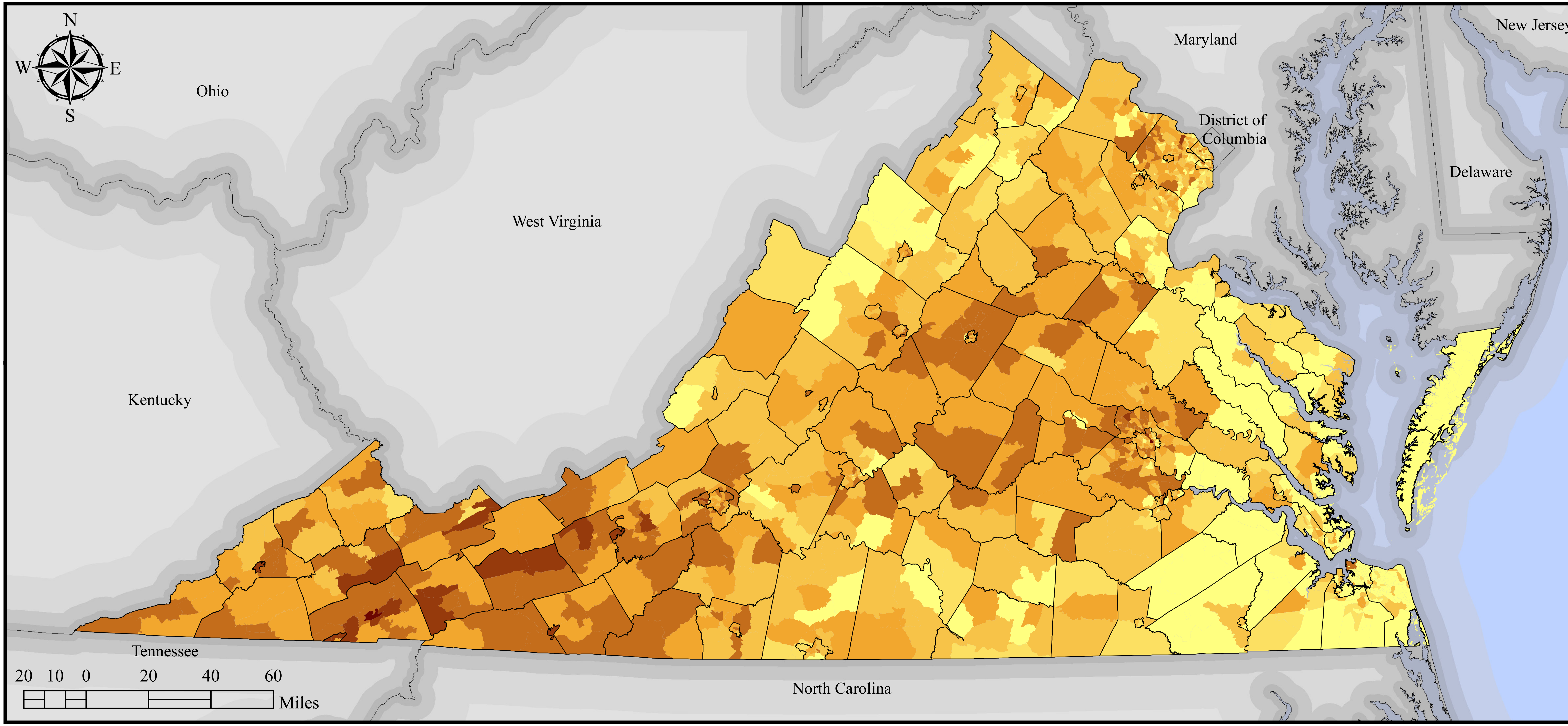
Probabilistic Total Loss was calculated by HAZUS-MH 2.1 using the probabilistic scenario for a 2500 Return Period Magnitude 5 earthquake.

Total Direct Economic Loss includes: Damage to Structural , Non-Structural, Building, Contents, Inventory Loss, Relocation, Income Loss, Rental Loss and Wage Loss.

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Figure 3.13-7: Earthquake Probabilistic 2500 Return Period Magnitude 6



CGIT Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

DATA SOURCES:

HAZUS-MH 2.1
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Total Loss by Census Tract

- < $3 Million
- $3 - $4 Million
- $4 - $7 Million
- $7 - $12.5 Million
- $12.5 - $25 Million
- $25 - $50 Million
- > $50 Million

RISK ASSESSMENT:

Probabilistic Total Loss was calculated by HAZUS-MH 2.1 using the probabilistic scenario for a 2500 Return Period Magnitude 6 earthquake.

Total Direct Economic Loss includes: Damage to Structural , Non-Structural, Building, Contents, Inventory Loss, Relocation, Income Loss, Rental Loss and Wage Loss.

State Facility Risk

At this time earthquake related losses to state facilities was not calculated; improved infrastructure data would lead to better analysis techniques in the future. It was possible to estimate the building damage based on a range of PGA values and type of building construction. The current version of the state facility database is limited in by the available attributes but does include some information on building construction, number of stories, and year built. This information was used to estimate the potential risk to each structure. State facilities were intersected with the PGA zone for the 100-year return period. The total number of facilities located in the PGA potential damage zones is summarized in Table 3.13-4.

Table 3.13-4 State Facilities by PGA zone

Damage Type	Number of State Facilities	Building Value At Risk
Very Light	1,732	$2,373,927,820
Light	7,138	$12,542,243,144
Moderate	4,123	$7,713,197,911
Total	**12,993**	**$22,629,368,875**

The results of this analysis indicate 4,123 buildings are at risk for moderate damage, based on damage description in Table 3.13-3. The 4,123 buildings can be divided between 101 different agencies in Virginia. The top five of those agencies have been listed in Table 3.13-5, by building value. The agencies listed represent approximately 31% of the buildings and 78% of total building value that is within a moderate damage zone.

Table 3.13-5: Top five agencies in a moderate damage zone by building value

Agency	Number of Buildings	Building Value
University of Virginia-Academic Division	602	$2,963,418,014
Virginia Polytechnic Inst. and State University	468	$1,682,336,138
Longwood University	99	$664,363,444
Radford University	81	$502,949,429
UVA at Wise	48	$198,105,206
Total	**1,298**	**$6,011,172,231**

In order to further determine what facilities were at risk for earthquake, four different parameters were used to rank risk per facility: Peak Ground Acceleration, Building Construction, Number of Stories, and Year Built. This information was available for the majority of state facilities in the VAPS database and represents potential risk factors for infrastructure. Table 3.13-6 shows the parameters used for this analysis.

Each State facility was scored based on a combination of these four parameters; as some buildings did not have data for all parameters.

Table 3.13-6: State facility assigned ranking based on earthquake parameters.

PGA (%g)	Assigned Value
<0.07	1
0.07-0.16	2
0.16-0.30	3

Number of Stories	Assigned Value
Low-Rise (1-3)	1
Mid-Rise (4-7)	2
High-Rise (8+)	3

Building Construction	Assigned Value
Steel Frame (VAPS code S)	1
Wood Frame (VAPS code D)	2
Fire Resistive, Modified Fire Resistive, Brick/Masonry/Noncombustible (VAPS codes A,B,C)	3

Year Built	Assigned Value
Post-1970	1
1950-1970	2
Pre-1950	3

The results of this analysis indicate that there are no buildings at high risk for earthquakes, but 5,366 buildings are at medium risk. Table 3.13-7 shows the distribution of risk for state facilities. A large percentage of state facilities are in the medium-low risk category. Mitigation action items can reduce risk by reviewing and updating building codes.

Table 3.13-7: Number of state facilities at risk for earthquake (four parameters)

Risk/Damage	Number of State Facilities
Low	347
Medium-Low	7,280
Medium	5,366

A total of 134 different agencies lie within a medium risk/damage zone. The top five agencies, by building value, have been listed below in Table 3.13-8. The agencies listed represent 27.8% of the buildings and 68.4% of total building value that is within a medium risk/damage zone.

Table 3.13-8: Top five agencies in a medium risk/damage zone by building value

Agency	Number of Buildings	Building Value
University of Virginia Academic Division	616	$3,082,352,704
Virginia Polytechnic Inst. and State University	521	$1,748,028,526
Virginia Commonwealth Uni- Academic Division	199	$1,637,383,445
Longwood University	99	$664,363,444
Department of General Services	57	$655,451,604
Total	**1,492**	**$7,787,579,723**

Critical Facility Risk

Detailed information about the critical facilities was not available for this revision of the plan as discussed in section 3.4. As with state facilities, critical facilities were intersected with the PGA 100-year return-period. The results of the analysis have been summarized in Table 3.13-9 using the potential damage thresholds described earlier in Table 3.13-3. Approximately 19% of the critical facilities are in moderate damage zones (PGA 18-34), 61% in light damage zones (PGA 9.2-18), and 19% in very light damage zones (PGA 3.9-9.2). With more site-specific information (i.e. construction material), analysis could be completed to show the risk and annualized loss to the actual structure and function of the buildings.

Table 3.13-9: Potential damage to critical facilities

Damage Type	Law Enforcement	Transportation	Public Health	Emergency Response	Education	Total
Very Light	115	8	214	519	634	**1,490**
Light	396	37	670	1,697	1,896	**4,696**
Moderate	151	11	191	624	511	**1,488**
Total	**662**	**56**	**1,075**	**2,840**	**3,041**	**7,674**

Earthquake Risk to Energy Pipelines

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. For example, Columbia Gas confirmed that a gas leak in downtown Fredericksburg, Virginia was related to the 2011 Mineral earthquake. After the earthquake, Columbia Gas discovered the leak as part of a company emergency response pipeline safety survey that was conducted as a result of the earthquake. The survey showed that the natural gas was leaking into the storm and sanitary sewer system. This leak resulted in road closings and residence and other building evacuations until repairs were made[9].

[9] Fredericksburg Patch. "Residents Return Home After Gas Leak." Retrieved from http://fredericksburg.patch.com/articles/gas-leak-shutters-downtown-fredericksburg on November 12, 2012.

Jurisdictional Risk

Probabilistic earthquake events can also be modeled in HAZUS-MH 2.1. HAZUS-MH was used to generate damage and loss estimates for the probabilistic ground motions associated with each of eight return periods (100, 250, 500, 750, 1000, 2000, and 2500 years). The building damage estimates were then used as the basis for computing direct economic losses. These include building repair costs, contents and business inventories losses, costs of relocation, capital-related, wage and rental losses.

Annualized loss was computed, in HAZUS, by multiplying losses from eight potential ground motions by their respective annual frequencies of occurrence, and then summing the values. Table 3.13-10 and Figure 3.13-7 show the HAZUS results for the probabilistic annualized loss run. The HAZUS census tract annualized loss values were joined to the county boundaries and summarized. Census tracts that did not intersect with a county boundary were assigned to jurisdictions based on the first five digits of the census tract that represent the FIPs code for the community. Fairfax County has the highest annualized loss due to earthquake; the Commonwealth of Virginia can expect **$12,940,544** in annualized losses due to earthquake.

Table 3.13-10: HAZUS total annualized loss by jurisdiction

Earthquake Annualized Loss Brackets			
> $1 Million			
Fairfax County	$1,238,465		
$500,000 - $999,999			
Henrico County	$726,316	City of Richmond	$591,619
Chesterfield County	$596,915		
$250,000 - $499,999			
Washington County	$359,642	Prince William County	$307,256
Roanoke City	$348,614	Roanoke County	$259,282
Montgomery County	$331,186		
$150,000 - $249,999			
Arlington County	$247,409	Alexandria City	$189,164
Loudoun County	$246,421	Smyth County	$179,399
Albemarle County	$226,231	Wise County	$179,124
Tazewell County	$220,191	Pulaski County	$166,003
Hanover County	$215,922	Henry County	$163,134
Virginia Beach City	$206,109	Charlottesville City	$155,158
Lynchburg City	$200,230	Bristol City	$153,157
$100,000 - $149,999			
Norfolk City	$153,157	Augusta County	$118,193
Spotsylvania County	$136,023	Russell County	$117,572
Franklin County	$134,421	Salem City	$112,705

Danville City	$133,806	Chesapeake City	$110,421
Wythe County	$132,383	Campbell County	$109,733
Scott County	$122,432	Pittsylvania County	$108,739
Lee County	$120,321	Stafford County	$108,719
Newport News City	$119,940	Carroll County	$103,786
Bedford County	$119,270		
$50,000 - $99,999			
Buchanan County	99,189	Mecklenburg County	$60,395
Rockingham County	$92,573	Galax City	$60,328
Harrisonburg City	$81,603	Patrick County	$59,689
Petersburg City	$78,970	Goochland County	$58,031
Botetourt County	$78,581	James City County	$56,013
Fauquier County	$78,564	Powhatan County	$55,723
Hampton City	$77,113	Portsmouth City	$55,263
Giles County	$71,050	Waynesboro City	$54,926
Radford City	$70,045	Culpeper County	$54,688
Halifax County	$68,215	Dickenson County	$53,232
Grayson County	$68,214	Orange County	$52,525
Martinsville City	$67,860	Prince Edward County	$52,284
Frederick County	$66,703	Fredericksburg City	$52,262
Amherst County	$61,306	Staunton City	$51,890
Louisa County	$61,052	Manassas City	$50,671
Shenandoah County	$60,616		
< $49,999			
Fairfax City	$45,650	Nelson County	$37,866
Suffolk City	$42,797	Warren County	$37,462
Norton City	$42,447	Hopewell City	$35,637
Colonial Heights City	$42,257	Alleghany County	$35,592
Winchester City	$42,183	Dinwiddie County	$35,223
Prince George County	$42,008	Nottoway County	$32,402
Fluvanna County	$41,498	Page County	$29,948
York County	$40,253	Caroline County	$29,158
Floyd County	$39,702	Buckingham County	$27,718
Rockbridge County	$39,656	Bland County	$26,759

< $49,999 *Continued*			
Cumberland County	$25,772	Buena Vista City	$14,083
Appomattox County	$25,338	Bath County	$13,333
Amelia County	$24,313	Essex County	$11,916
Isle of Wight County	$23,510	Manassas Park City	$11,546
Gloucester County	$23,472	Sussex County	$11,465
Greene County	$23,117	Emporia City	$11,286
Brunswick County	$22,923	Greensville County	$10,862
Bedford City	$22,769	Craig County	$10,675
Charlotte County	$22,182	Lancaster County	$10,213
Falls Church City	$19,509	Rappahannock County	$9,756
Lexington City	$18,973	Northumberland County	$9,634
King George County	$18,190	Middlesex County	$9,563
Clarke County	$17,756	Franklin City	$8,710
Lunenburg County	$17,605	Charles City County	$7,849
Covington City	$16,882	Richmond County	$6,602
Williamsburg City	$16,750	Poquoson City	$6,248
New Kent County	$16,193	Mathews County	$6,123
Westmoreland County	$16,078	Northampton County	$5,833
King William County	$15,740	Surry County	$5,523
Madison County	$15,635	King and Queen County	$4,754
Accomack County	$14,711	Highland County	$4,229
Southampton County	$14,163		

The hazard ranking for earthquake is based on events reported in the NCDC Storm Events database and a generalized geographic extent. The geographic extent ranking category used the PGA values for the 2500 Return Period. This return period represents a 0.04% annual chance of occurrence in any given year. The ranking parameters used in the risk assessment are illustrated in Figure 3.13-8, along with the total ranking score. The majority of the Commonwealth is in the medium and medium-low risk categories. See section 3.5 for more information on the methodology used for ranking hazards. The ranking results and HAZUS annualized losses highlight similar areas that are at a somewhat higher risk due to earthquake. These areas include Northern Virginia, Richmond City, and Southwest Virginia.

Local Plan Risk Assessment

Local plans were reviewed for spatial data sources used, historical occurrences, hazard probabilities, vulnerability, loss estimations, and land use and development trends.

When available, this information supplements the text and figures of each of the sections in this revision.

Eleven local plans included annualized loss estimates for earthquake and ranked earthquake as low risk. Most of these estimates were based on the HAZUS-MH module. One local plan (City of Franklin) completed a HAZUS analysis but determined that annualized losses were negligible. Table 3.13-11 compares the results of the local and statewide analysis.

Table 3.13-11: Statewide and local plan HAZUS-MH comparisons

PDC/Jurisdiction	Local Plan Analysis	2013 Statewide Analysis
Northern Virginia RC	$2,408,945	$2,356,091
Southside Hampton Roads	$93,000	$480,8326
Richmond-Crater	$1,463,707	$2,550,799
New River Valley	$969,779	$677,8986
West Piedmont PDC	$939,755	$667,649
Lower Peninsula	$428,303	$310,069
Commonwealth RC (Virginia's Heartland)	$247,919	$202,276
Rappahannock-Rapidan RC	$240,000	$211,168
Northern Neck	$65,000	$42,527
Southampton County	$4,180	$14,163
City of Franklin	*Negligible* (< $1,000)	$8,710

Comparison with Local Ranking

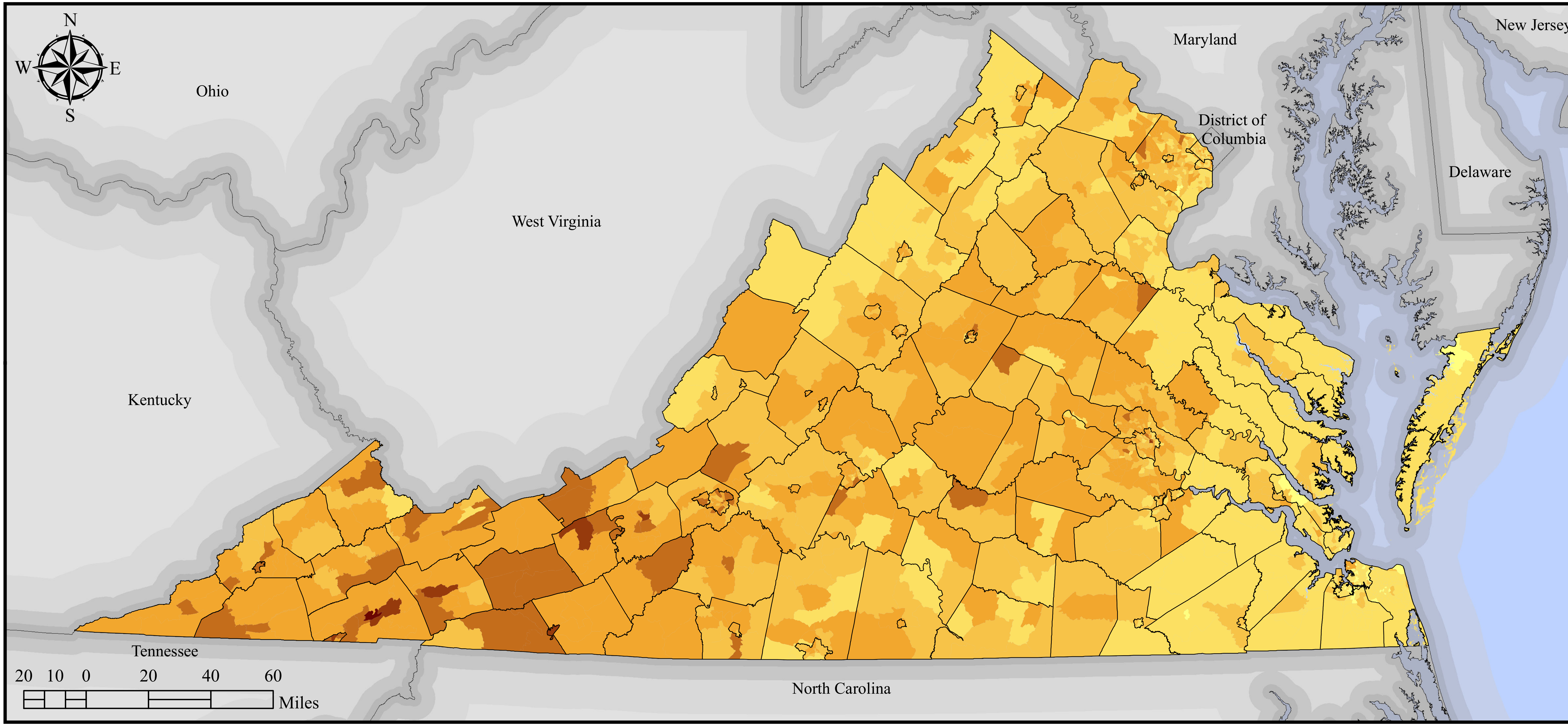
Lenowisco PDC, Cumberland Plateau PDC and the Northern Virginia RC ranked earthquake as a medium hazard for their region.

One plan ranked earthquake as a medium-low hazard and sixteen additional plans ranked earthquake as a low hazard, resulting in a local plan average of low for earthquake. Furthermore, five local and regional plans did not assign a ranking to this hazard. The 2013 statewide analysis has ranked earthquake as medium-low. Section 3.6 (Table 3.6-2) includes the complete ranking of all the local plans.

Changes in Development

The majority of local plans did not specifically address changes in development for each hazard or the effects of changes in development on loss estimates. In most cases overall development patterns were discussed in general. Sixteen of the twenty-five local plans cite their comprehensive plans for current and future land use changes (section 3.2). New River Valley PDC included information improving building codes and standards. The building standards in earthquake hazard areas will be further increased with the new International Building Code.

Figure 3.13-8: Earthquake Probabilistic Annualized Loss



CGIT
Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

DATA SOURCES:

HAZUS-MH 2.1
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Annualized Loss by Census Tract

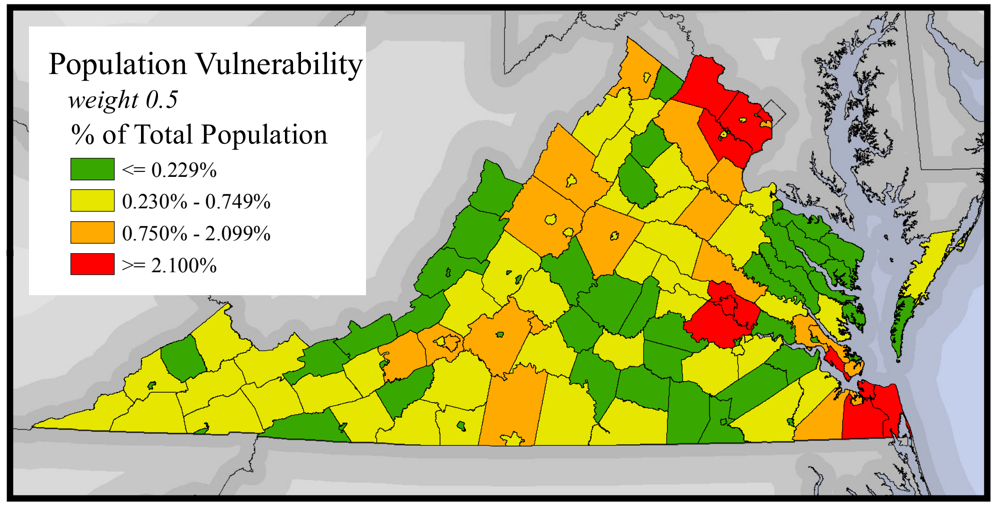
- < $1 Million
- $1 - $5 Million
- $5 - $10 Million
- $10 - $25 Million
- $25 - $50 Million
- $50 - $100 Million
- > $100 Million

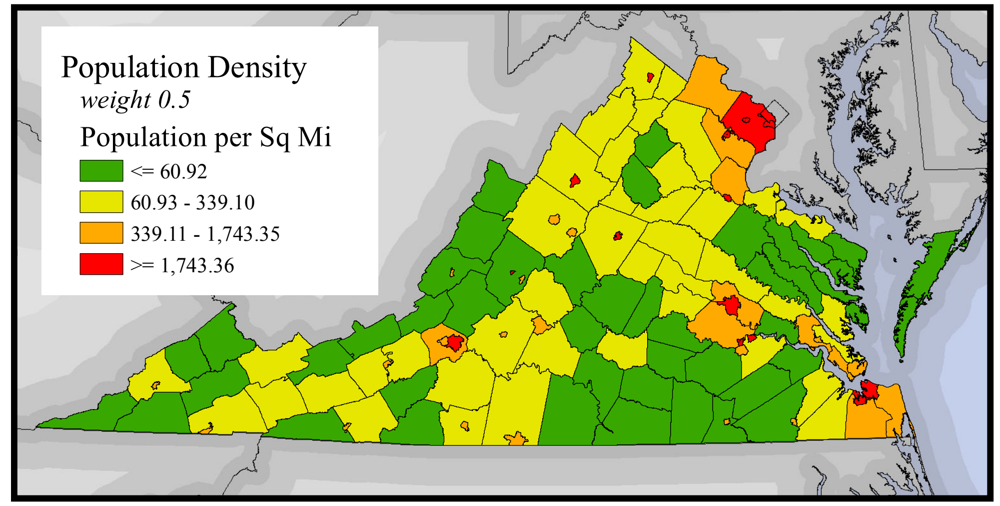
RISK ASSESSMENT:

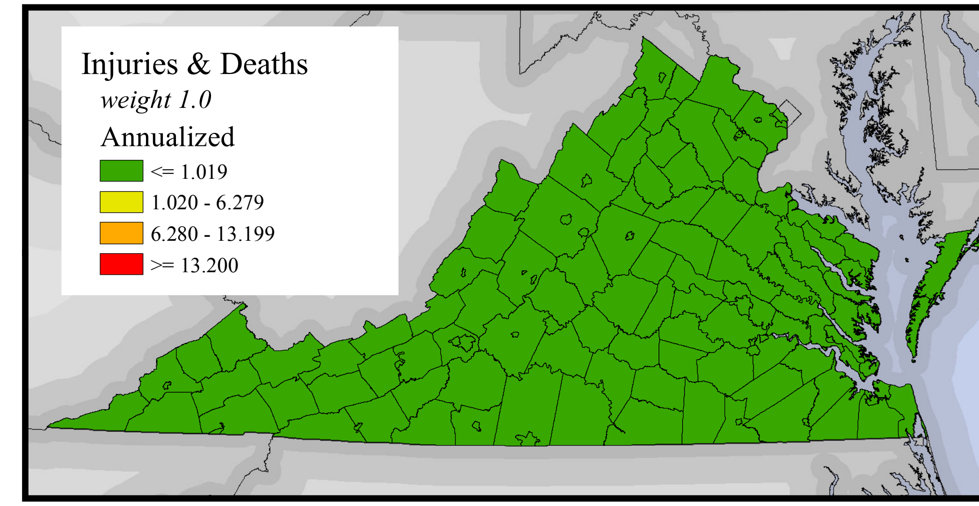
Probabilistic Annualized Loss was calculated by HAZUS-MH 2.1 using the probabilistic senario. Annualized loss is defined as the expected value of loss in any one year, and is developed by aggregating the losses and their exceedance probabilities.

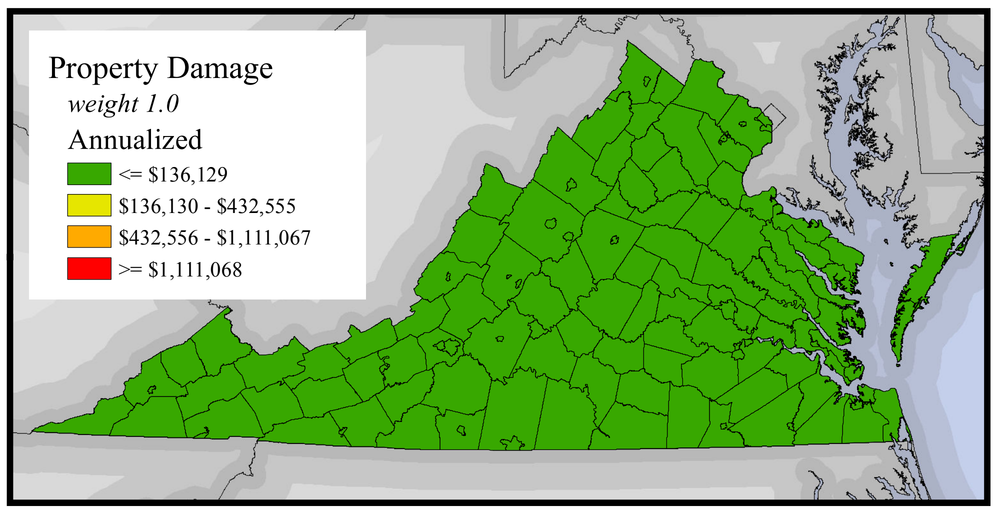
Total Direct Economic Loss includes: Damage to Structural , Non-Structural, Building, Contents, Inventory Loss, Relocation, Income Loss, Rental Loss and Wage Loss.

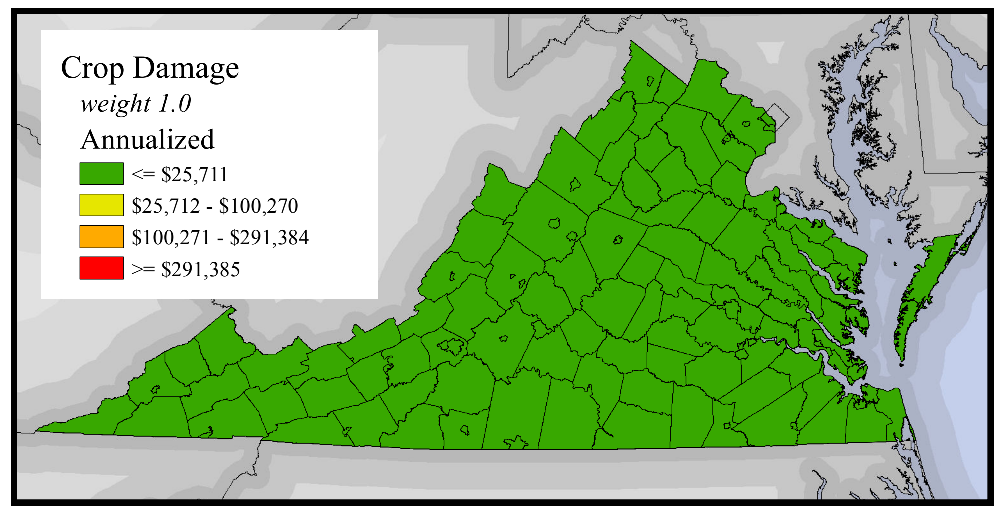
Figure 3.13-9: Earthquake Hazard Ranking Parameters and Risk Map

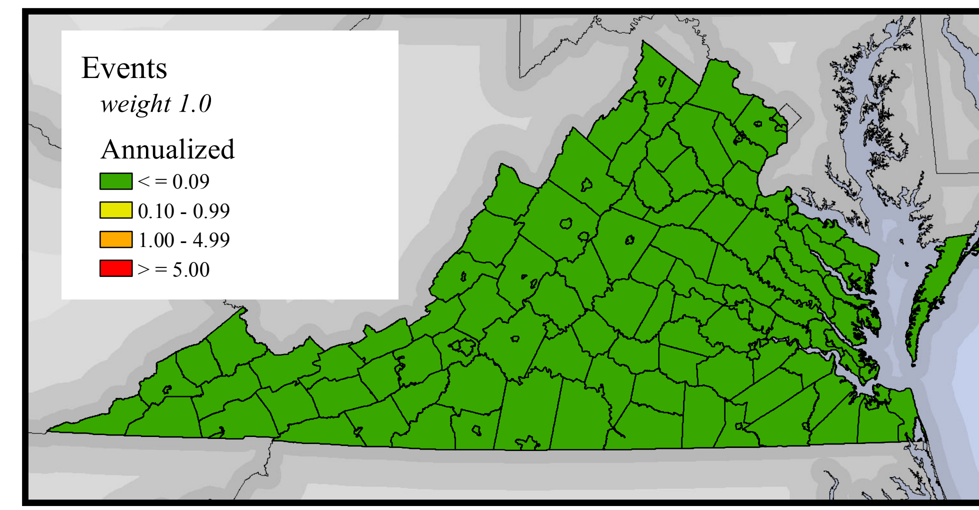


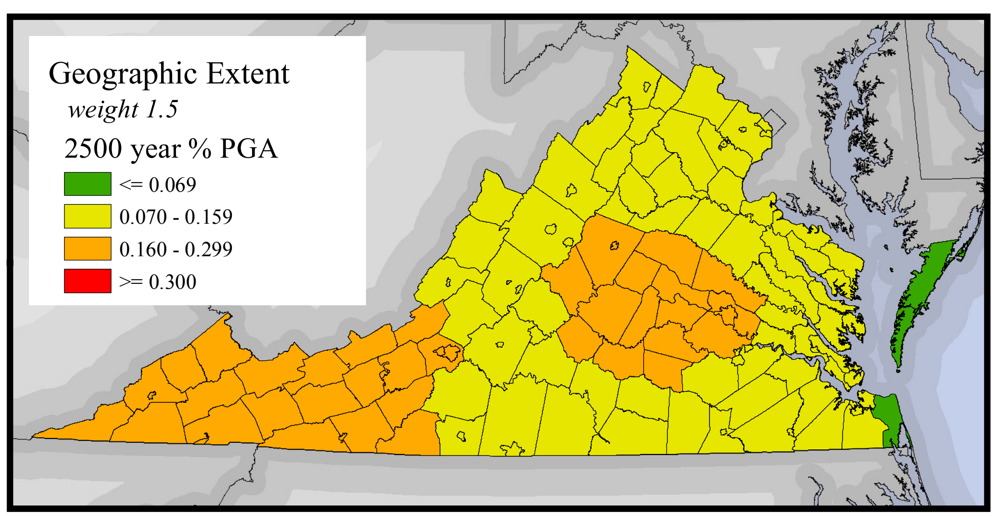


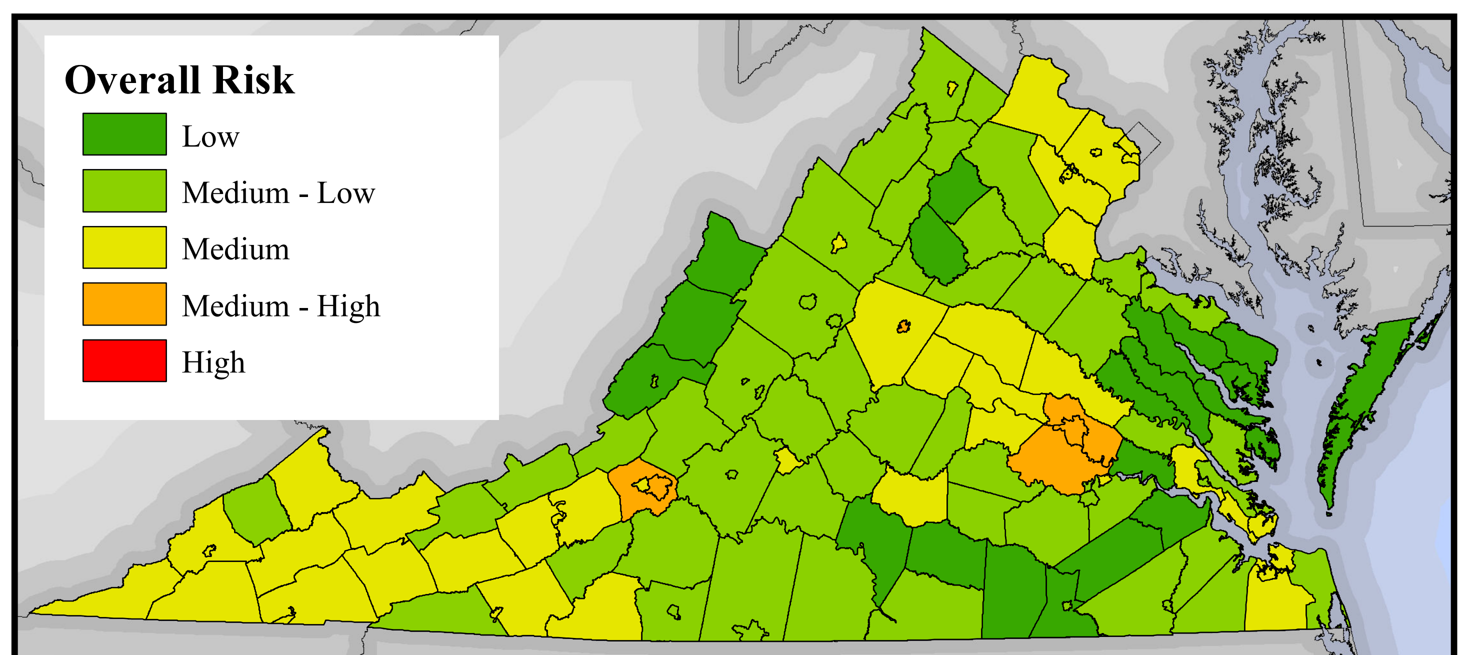












HAZARD RANKING:

A number of factors have been considered in this risk assessment to be able to compare between jurisdictions and hazards. The factors have been added together to come up with the overall total ranking for each hazard.
Some factors were weighted based on imput from the HIRA sub-committee.
Section 3.5 explains each of the factors in detail.

Factors & Weighting Include:
- Population Vulnerability & Density 0.5 weighting
- Injuries & Deaths 1.0 weighting
- Crop & Property Damage 1.0 weighting
- Annualized Events 1.0 weighting
- Geographic Extent 1.5 weighting

DATA SOURCES:
CGIT Ranking Methodology
VGIN Jurisdictional Boundaries
ESRI State Boundaries

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

N W E S

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Table 3.13-12: EMAP Analysis

Subject	Detrimental Impacts
Health and Safety of Public	Local impacts expected to be serious for those who are inside poorly build structures close to the event, and light to moderate in areas with better construction and that are further away from the event.
Health and Safety of Response Personnel	Local impacts expected to be serious for those who are inside poorly built structures close to the event, and light to moderate in areas with better construction and that are further away from the event.
Continuity of Operations	Damage to facilities/personnel in the area of the event may require temporary relocation of some operations.
Property, Facilities, and Infrastructure	Depending on the magnitude of the event, localized impact to facilities, residential properties, and infrastructure in the area of the event may be extensive.
Delivery of Services	Disruption of lines of communication and damage to facilities and/or roads may have considerable impacts on the delivery of services.
The Environment	The Environment may be subject to extensive damage due to secondary effects such as HAZMAT debris, broken utility lines, and movement of soil.
Economic and Financial Condition	Local economy and finances moderately impacted, duration depends on magnitude of event.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery time is not sufficient.

Table was modeled from the Missouri State Hazard Mitigation Plan