4.16 Landslides

4.16.1 Hazard Profile

A landslide is defined as the movement of a mass of rock, debris, or earth down a slope. The term "landslide" encompasses five modes of slope movement: falls, topples, slides, spreads, and flows. These are further subdivided by the type of geologic material (bedrock, debris, or earth). Debris flows (commonly referred to as mudflows or mudslides) and rock falls are examples of common landslide types. In Virginia, heavy rainfall is the major cause of landslides, but they can also be triggered by rapid snow melt or oversteepening of slopes by stream incision. Certain man-made changes to the land, such as slope modification or drainage alteration, can greatly increase the likelihood of landslides.

4.16.1.1 Geographical Location and Extent

Landslides are a major geologic hazard and occur most frequently in the mountainous terrain of Virginia because of the presence of steep slopes and highly fractured bedrock that exists over shallow soils. The lower-relief areas of the Piedmont region also have landslides, but they are often smaller and generated by human disturbance, such as making an over-steepened road cut. The most disastrous landslide events have been associated with heavy rainfall along the steep slopes of the Blue Ridge Mountains and the Appalachians.

4.16.1.2 Magnitude or Severity

Landslides are frequently associated with periods of heavy rainfall. Such landslides tend to worsen the effects of flooding that often accompanies these weather events. In areas burned by forest and brush fires, a lower threshold of precipitation may initiate landslides. Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly.

4.16.1.3 Previous Occurrence

There are very few documented landslides events for the CVPDC area. Historically, major rainfall events have caused the greatest numbers of documented landslides in the Virginia mountains. Hurricane Camille in 1969 stalled over the Blue Ridge Mountains, dropping more than 30 inches of rain in less than eight hours. Flooding and numerous landslides and debris flows occurring in the north of the CVPDC area (Nelson, Amherst, and Rockbridge counties) led to the deaths of more than 150 people, 100 injuries, destruction of more than 100 bridges, and more than $150 million in property damage. This event resulted in the most recorded deaths by a natural hazard in the Commonwealth.

There are two minor landslide events occurring recently recorded in the U.S. Landslide inventory by USGS. On September 19, 2010, a mudslide caused by a downpour knocked out the boiler in Central Virginia Training Center, Madison Heights, Amherst County. On May 18, 2018, heavy rain triggered a mudslide on US Route 460 near the Route 122 interchange and the exit for the National D-day Memorial. It caused traffic jams and at least one lane in Bedford County was shut down.[81]

[81] https://wset.com/news/local/mudslide-on-route-501-in-bedford

4.16.1.4 Relationship to Other Hazards

Floods and landslides are often associated with major tropical storms. In 2004, several organizations, including NOAA, NASA and USGS proposed a research project called the Hurricane–Flood–Landslide Continuum (HFLC), aiming to develop and integrate multidisciplinary tools for practical use in emergency response and disaster mitigation. Figure 4-157 shows the interrelationship (causation, concurrence, *etc.*) between this hazard and other hazards discussed in this plan update.

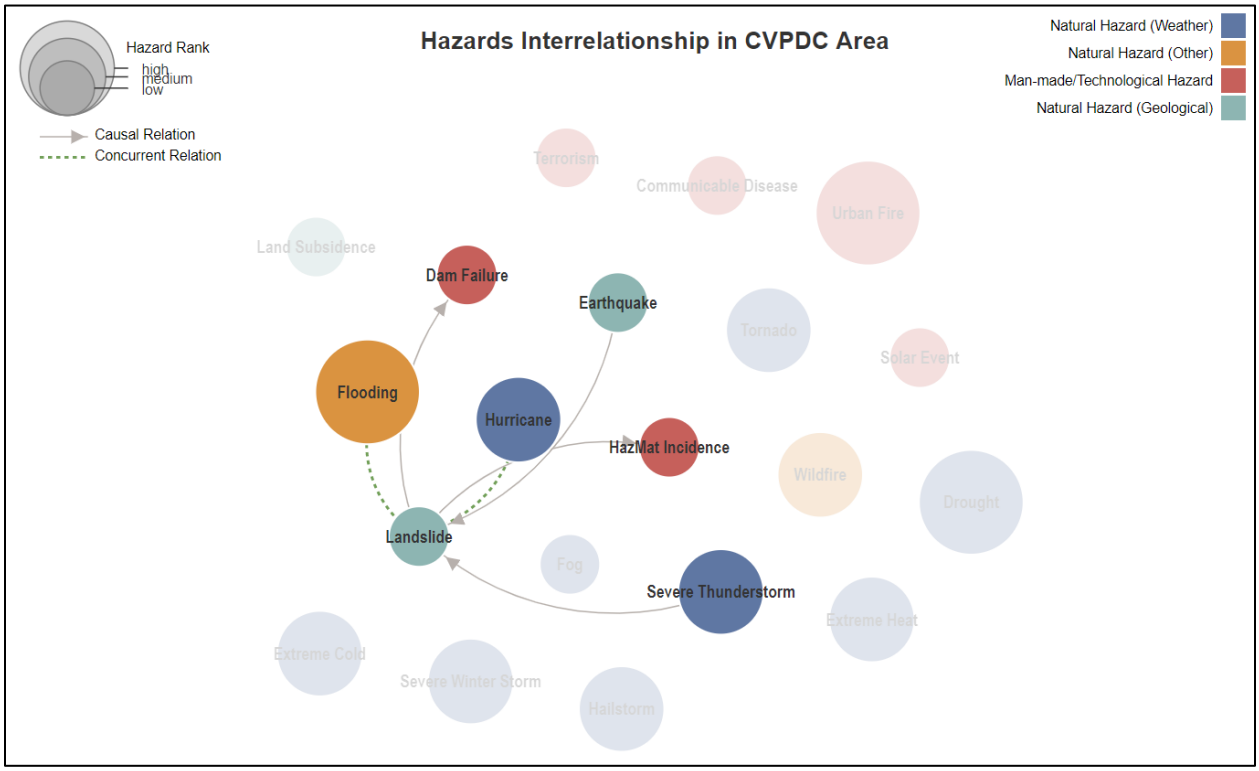

Figure 4-157 Hazards interrelationship

4.16.2 Impact and Vulnerability

Landslides can cause serious damage to highways, buildings, homes, and other structures that support a wide range of economies and activities. In Virginia, landslides can be expected to occur in conjunction with other natural hazards events, such as flooding or a major earthquake (magnitude 6 or larger, according to VA DMME). Several natural and human factors may contribute to or trigger landslides. How these factors interrelate is important in understanding the hazard. The three principal natural factors are topography, geology, and precipitation. The primary trigger for debris flows is heavy rainfall (generally greater than 125–250 mm in 24 hrs.) that results in excess pore-water pressures in relatively thin soil on steep slopes. Areas that are prone to mass movement include areas where landslides have occurred in the past; steep slopes with an angle greater than 25-30 degrees; and oversteepened cuts and fills, particularly due to home and road building.

Expansion of urban development activities contributes to greater risk of damage by landslides. The principal human activities are cut-and-fill construction for highways, construction of buildings and railroads, and mining operations. Research in North Carolina has revealed that about 56 percent of recent

landslides occurred on slopes that had been altered in some way by development.[82] Every landslide, or slope movement is different and unpredictable. Some geological areas are more prone to landslides, such as the bases of steep slopes or hillsides, incised drainages, and mountain streams.[83] Flatter areas away from slope changes tend to be safer from landslides.

Landslide incidence is the percentage of the area involved in landsliding. Susceptibility is defined as the probable degree of the areal response of rocks and soil to natural or artificial cutting or loading of slopes, or to anomalously high precipitation (Wooten *et al*, 2016).

4.16.3 Risk Assessment and Jurisdictional Analysis

4.16.3.1 Landslide Susceptibility

The USGS divides landslide risk into six categories on the national landslide incidence and susceptibility map. These six categories were grouped into three broader categories to be used for the risk analysis and ranking: High (categories 1-3), Moderate (categories 4-5), and Low (category 6). Geographic extent is based off of these groupings (Table 4-153).

Table 4-153 USGS Landslide Risk Category

Risk Level	Description
Risk Level	Description
High Risk	1. High susceptibility to landsliding and moderate incidence. 2. High susceptibility to landsliding and low incidence. 3. High landslide incidence (more than 15% of the area is involved in land sliding).
Moderate Risk	4. Moderate susceptibility to landsliding and low incidence. 5. Moderate landslide incidence (1.5 – 15% of the area is involved in land sliding).
Low Risk	6. Low landslide incidence (less than 1.5% of the area is involved in land sliding).

Mapping and Monitoring of Landslides Using LIDAR

LiDAR, which stands for Light Detection and Ranging, is an active remote sensing method that uses light in the form of a pulsed laser to measure distances to Earth. LiDAR technology has been increasingly used as a way to detect and analyze the phenomenon of natural disasters such as landslides. Very-high resolution digital terrain models (DTM) obtained from airborne LiDAR data, and derivative products (such as contour maps, slope maps, shaded relief images, curvature, and measures of surface roughness) help geologists to map, monitor, and even predict landslides. With advances in computational capabilities and LiDAR acquisition projects in Virginia, the utility of LiDAR provides an efficient yet economic way in visual analysis of the topographic surface, and semi-automatic recognition of morphometric landslide features. The high-resolution LiDAR dataset, once available for the CVPDC, will be valuable to help with landslide preparedness and mitigation planning for the area.

[82] https://www.dmme.virginia.gov/dgmr/landslides.shtml

[83] Frequency and Magnitude of Selected Historical Landslide Events in the Southern Appalachian Highlands of North Carolina and Virginia: https://link.springer.com/chapter/10.1007%2F978-3-319-21527-3_9

The best available landslide data is the USGS landslide overview map of the contiguous United States. This dataset shows areas in the US where large numbers of landslides have occurred and areas which are susceptible to landslides. According to the USGS generalized map of landslide incidence and susceptibility digitized from Godt (1997), the risk of landslides is much higher in western Virginia because of the Appalachian Mountains (Figure 4-158). [84] The CVPDC area falls into the area with an overall high potential for landslides.

The hazard ranking for landslides is based on events reported in the National Climatic Data Center (NCDC) Storm Events database and a generalized geographic extent rating developed from the USGS landslide susceptibility and incidence. It depicts the risk of landslides in general across the entire Virginia by locality. All the jurisdictions in the CVPDC area are located in a high risk zone.

The risk assessment mapping at local level was developed with the Hazus Earthquake model (at Level 1 analysis) using digital elevation models (DEM) and soil data for the area. Landslide susceptibility is characterized by the geologic group, slope angle, and critical acceleration. The acceleration required to initiate slope movement is a complex function of slope geology, steepness, groundwater conditions, type of landsliding, and history of previous slope performance. Please note the DEM used in the assessment is at resolutions of 1 arc-second (about 30 meters). High resolution DEM data (1-3 meter resolution) from LiDAR (Light Detection and Ranging) will be available once the Virginia LiDAR acquisition for Central Virginia is accomplished, and will be used for the next update for this plan.

Landslide susceptibility is measured on a scale of I to X, with X being the most susceptible. The site condition is identified using three geologic groups: strongly cemented (crystalline) rocks; weakly cemented rocks, including sandy soils; and argillaceous rocks (shales). Figure 4-159 indicates landslide prone areas in the CVPDC area. The northern and western areas of the CVPDC area (Amherst county and Bedford county) along the Blue Ridge Mountains are most susceptible to landslides. This landslide location dataset was developed by DMME as an ArcGIS geodatabase. Features are manually identified and entered into the database using a combination of historical storm records, currently available high-resolution terrain data, and several vintages of aerial photography. This dataset (still in draft) is neither an exhaustive inventory nor guarantees the presence or absence of a landslide location in the region. It identifies the presence of historical landslide occurrences in the region at a broad scale.

Transportation corridors through mountainous terrain are often susceptible to rock fall hazards. Highway landslides, rockfalls, and mudslides occur in Virginia and cause delays, damage, injury, and death to users of the routes. Virginia Department of Transportation (VDOT) is currently developing a slope cut inventory and rockfall hazard rating dataset by mid-2021.[85] This information, once available to localities, will allow agencies to develop rockfall hazard rating database to prioritize rock slopes for remediation based on a risk assessment and serve as an indication of risk when developing mitigation strategies in future plan updates.

[84] Landslide incidence and susceptibility polygons were digitized from the original stable-base manuscripts at 1:3,750,000 from U.S. Geological Survey Professional Paper 1183. The data is unsuitable for local planning or actual site selection.

[85] http://vtrc.virginiadot.org/ProjDetails.aspx?id=649

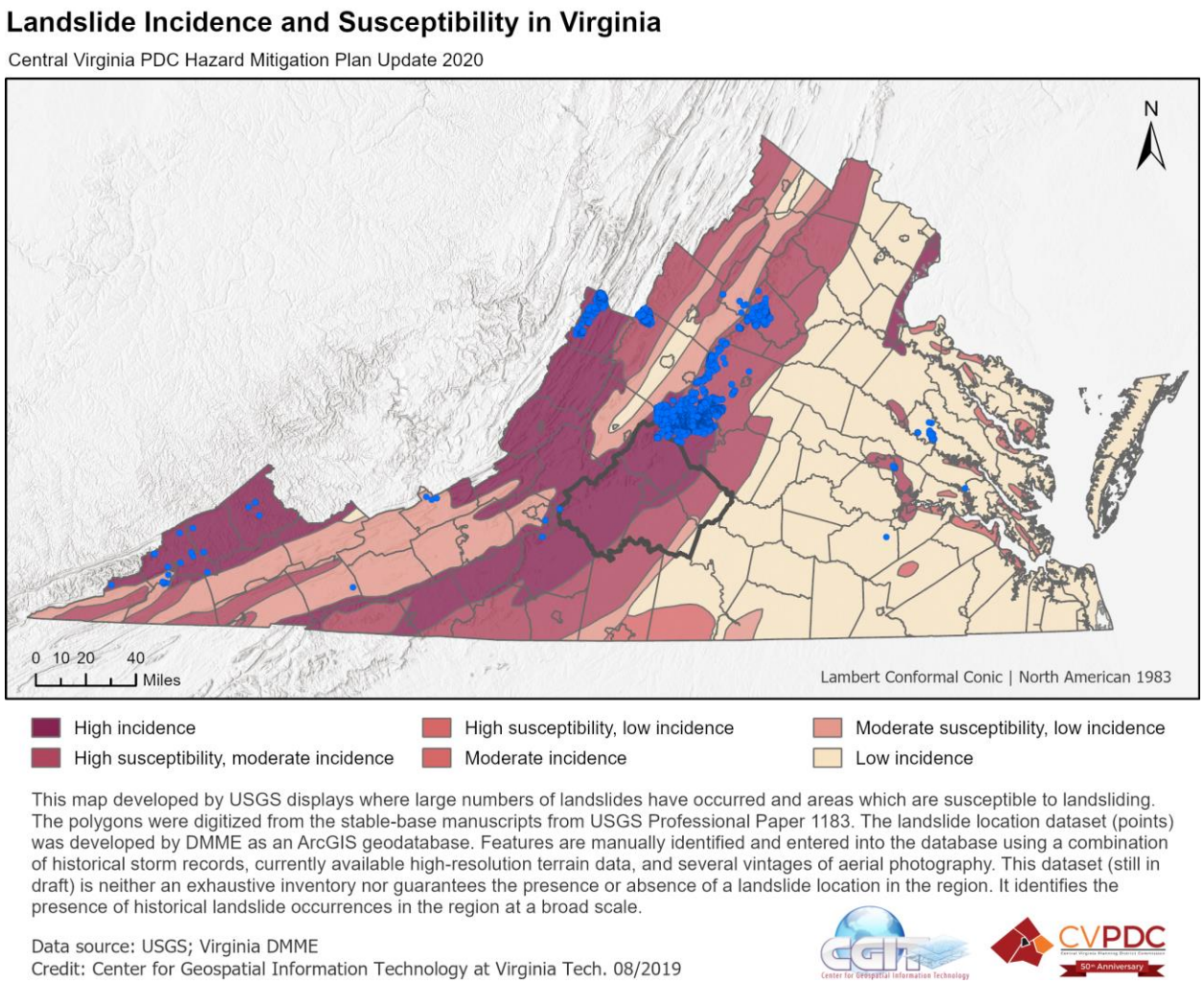

Figure 4-158 Landslide Incidence and Susceptibility in Virginia (Source: USGS)

4.16.3.2 Critical Facility at Risk

The critical facilities at risk were estimated using the landslide susceptibility map. There are 32 facilities in Amherst County, 1 in Appomattox County, 28 in Bedford County, 11 in Campbell County, and 28 in the City of Lynchburg located in high and very high susceptibility areas of landslides (Table 4-154).

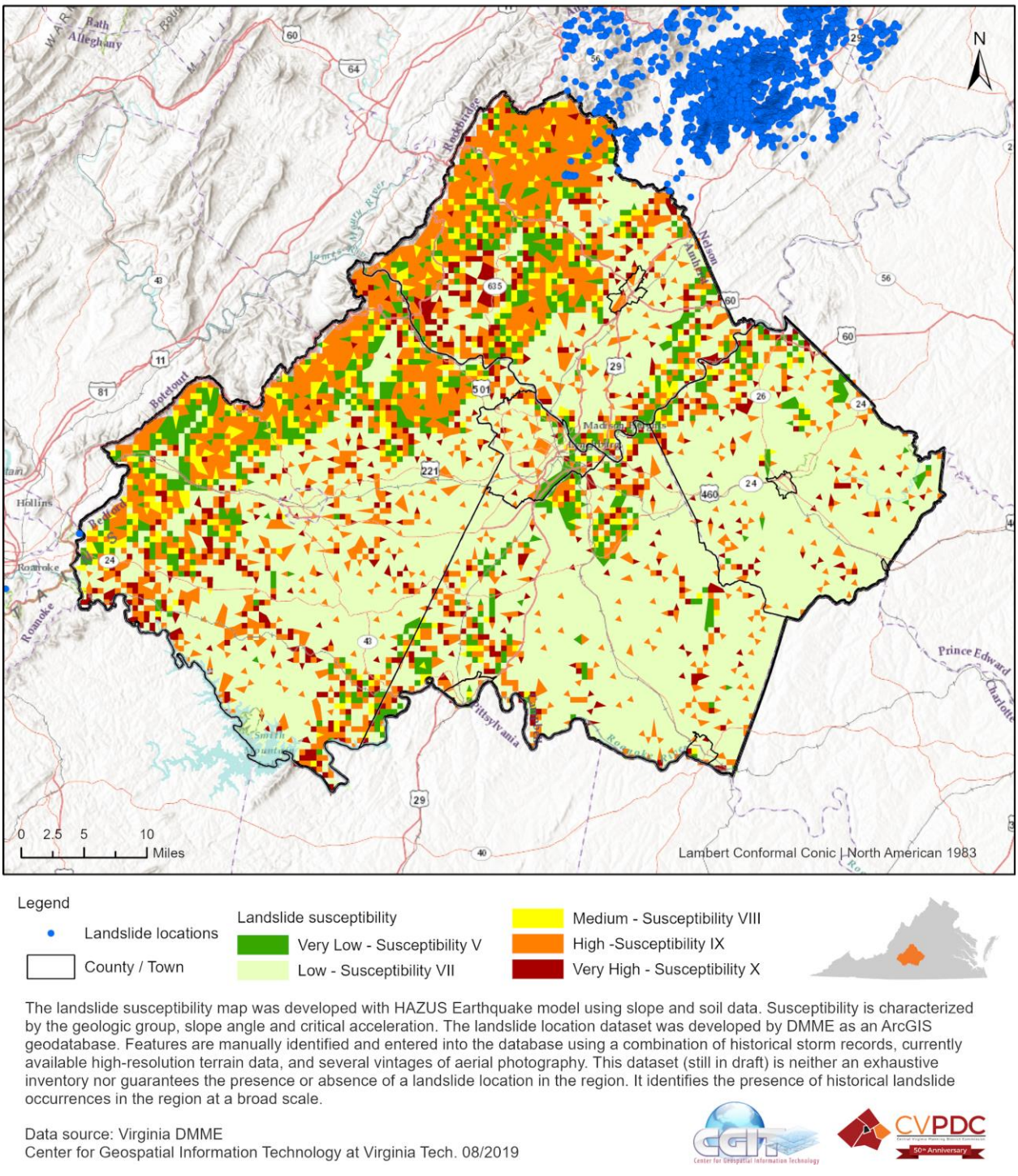

Figure 4-159 Landslides susceptibility estimates in CVPDC Area

Table 4-154 Critical facilities in high and very high susceptibility areas of landslides

Locality	Facility Name	Facility Type	Location	Coordinates
Amherst	BUFFALO RIDGE AIRPORT	Airport		37.6053, -79.0164
Amherst	WYYD - FS - CAPSTAR TX, LLC	Communication Facility		37.5609, -79.1915
Amherst	WZZU - FM - CENTENNIAL LICENSING, LLC	Communication Facility		37.5632, -79.1936
Amherst	WVBE-FM - FM - MEL WHEELER, INC	Communication Facility		37.4501, -79.0748
Amherst	WJJX - FS - CAPSTAR TX, LLC	Communication Facility		37.5609, -79.1915
Amherst	WNRS-FM - FM - STU-COMM, INC	Communication Facility		37.5641, -79.1926
Amherst	Monacan Ancestral Museum	Attractions	2009 Kenmore Rd, Amherst, Va 24521	37.5729, -79.1270
Amherst	Otter Creek Campground	Campground	60851 Blue Ridge Pkwy, Monroe, Va 24574	37.5760, -79.3379
Amherst	Lynchburg/Blue Ridge Parkway KOA	Campground	6252 Elon Rd, Monroe, Va 24574	37.5744, -79.3247
Amherst	Shady Mountain Campground	Campground	Panther Falls Rd, Vesuvius, Va 24483	37.7170, -79.2893
Amherst	GREIF PACKAGING CONTAINERBOARD MILL	HazMat Facility	861 Fibre Plant Rd	37.5107, -78.9101
Amherst	GREIF BROTHERS PACKAGING CORPORATION - RIVERVILLE MILL FIRE BRIGADE AND EMERGENCY MEDICAL SERVICES	Fire Stations	861 Fibre Plant Road	37.5120, -78.9083
Amherst	MONELISON VOLUNTEER FIRE DEPARTMENT	Fire Stations	133 Amer Court	37.4698, -79.1188
Amherst	CENTRAL VIRGINIA TRAINING CENTER POLICE DEPARTMENT	Law Enforcement	521 Colony Road	37.4156, -79.1195
Amherst	JOHNSON SENIOR CENTER INC.	Nursing Home	108-112 Senior Street	37.5791, -79.0572
Amherst	Snowden Hydro Power Plant	Energy Facility	7443 Elon Road	37.5736, -79.3715
Amherst	AMHERST COUNTY ADULT DETENTION CENTER	Detention Facility	219 Riverview Rd	37.4088, -79.0947
Amherst	AMELON ELEMENTARY	Schools	132 Amer Court	37.4700, -79.1175
Amherst	AMHERST COUNTY HIGH	Schools	139 Lancer Lane	37.5700, -79.0585
Amherst	PLEASANT VIEW	Schools	229 Dancing Creek Road	37.6028, -

Locality	Facility Name	Facility Type	Location	Coordinates
	ELEMENTARY			79.2474
Amherst	CENTRAL VIRGINIA TRAINING CENTER	Schools	521 Colony Road	37.4155, -79.1196
Amherst	OLD DOMINION JOB CORPS CENTER	Schools	1073 Father Judge Road	37.5536, -79.1392
Amherst	Sewer Pump Station	Sewer Pump Station	Route 718 / Buffalo River	37.6091, -79.0384
Amherst	Electrical Substation	Electrical Substation		37.6947, -79.0120
Amherst	Electrical Substation	Electrical Substation		37.4062, -79.0772
Amherst	Electrical Substation	Electrical Substation		37.4266, -79.0846
Amherst	Electrical Substation	Electrical Substation		37.5103, -79.2283
Amherst	Electrical Substation	Electrical Substation		37.5637, -79.1928
Amherst	Electrical Substation	Electrical Substation		37.4622, -79.1872
Amherst	AMELON IMMEDIATE CARE	Public Health	200 Amelon Square	37.4681, -79.1166
Amherst	Water Tank	Water Storage Facility	Waugh'S Ferry Road	37.5637, -79.0741
Amherst	Lanum Water Filtration Plant	Wastewater Treatment Plant	1355 Elon Rd	37.4846, -79.1664
Appomattox	Electrical Substation	Electrical Substation		37.5070, -78.7826
Bedford	MILLER AIRPORT	Airport		37.3271, -79.4048
Bedford	HAWK RIDGE AIRPORT	Airport		37.2887, -79.4469
Bedford	WBLT - AM - 3 DAUGHTERS MEDIA, INC.	Communication Facility		37.3475, -79.5234
Bedford	WSLK - AM - SMILE BROADCASTING, LLC	Communication Facility		37.1647, -79.6343
Bedford	WRXT - FM - POSITIVE ALTERNATIVE RADIO, INC	Communication Facility		37.3858, -79.6686
Bedford	WSET-TV - DT - WSET INCORPORATED	Communication Facility		37.3151, -79.6348
Bedford	MOORMAN MARINA	Campground	1510 Moorman Rd, Goodview	37.2232, -79.7753
Bedford	TRI-COUNTY MARINA	Campground	1261 Sunrise Loop, Lynch Station	37.0595, -79.4468
Bedford	ISLE OF PINES SUBDIVISION	Campground	Across From 3930 Isle Of	37.0998, -

Locality	Facility Name	Facility Type	Location	Coordinates
	CAMPGROUND		Pines Drive	79.6246
Bedford	THE WOODS ADVENTURE & CONFERENCE RETREAT (LEASED)	Campground	1336 Simmons Mill Rd, Thaxton	37.3073, -79.6844
Bedford	TUCK-A-WAY CAMPGROUND	Campground	1312 Sunrise Loop, Lynch Station	37.0605, -79.4484
Bedford	SAFETY-KLEEN SYSTEMS	HazMat Facility	16090 Stewartsville Road	37.2727, -79.8138
Bedford	BLUE RIDGE WOOD PRESERVING INCORPORATED	HazMat Facility	1220 Hendricks Store Road	37.1622, -79.6325
Bedford	MONETA VOLUNTEER FIRE DEPARTMENT STATION 1	Fire Stations	12737 North Old Moneta Road	37.1868, -79.6134
Bedford	Bedford Solar	Energy Facility	1477 Draper Rd.	37.3351, -79.4810
Bedford	Smith Mountain Dam Hydro Plant	Energy Facility	Route 1, Penhook	37.0413, -79.5356
Bedford	FOREST MIDDLE	Schools	100 Ashwood Drive	37.3693, -79.3096
Bedford	Forest Middle School Pump Station	Sewer Pump Station		37.3707, -79.3107
Bedford	Pump Station #2	Sewer Pump Station		37.3504, -79.5224
Bedford	Lift Station	Sewer Pump Station		37.0985, -79.5831
Bedford	Electrical Substation	Electrical Substation		37.5411, -79.3978
Bedford	Mill Lane Ground Tank, 5,000,000 gallon	Water Storage Facility	Mill Lane	37.4490, -79.2456
Bedford	Huntingwood Tank, 2,000,000 gallon	Water Storage Facility	Walnut Hollow Road	37.4454, -79.2753
Bedford	Water Pump Station - 1 (Woods Landing Pump Station)	Water Booster Pump Station	Woods Landing On The James	37.4969, -79.2465
Bedford	Water Pump Station - 3 (Deerwood Well House)	Water Booster Pump Station	Mountain View Shores Water System Improvements	37.0667, -79.5411
Bedford	IVY CR Tank	Water Storage Facility	Ivy Cr Tank	37.4205, -79.3045
Bedford	Cascade Forest LT 14 B-2 Water tank	Water Storage Facility	Cascade Forest Lt 14 B-2	37.2786, -79.8101
Bedford	BP #665-05 TANK 100% COMP FOR 2006	Water Storage Facility	574 High Point Road	37.1271, -79.6431
Campbell	WODI - AM - THE RAIN BROADCASTING, INC.	Communicatio n Facility		37.0384, -78.9420

Locality	Facility Name	Facility Type	Location	Coordinates
Campbell	Walnut Hill	Historic Site	129 Johnson Mountain Rd	37.2088, -79.3079
Campbell	Avoca Museum	Attractions	1514 Main St, Altavista, Va 24517	37.1300, -79.2697
Campbell	ABBOTT LABORATORIES - ROSS PRODUCTS DIVISION	HazMat Facility	1516 Main St, Altavista	37.1333, -79.2658
Campbell	RUSTBURG HIGH	Schools	1671 Village Highway	37.2766, -79.0849
Campbell	Lawyers Road Pump Station	Sewer Pump Station		37.3138, -79.1947
Campbell	Electrical Substation	Electrical Substation		37.4259, -79.0374
Campbell	Otter River Water Tank	Water Storage Facility	9625 Leesville Road	37.2109, -79.2992
Campbell	Rt 24 Finished Pump Station	Water Booster Pump Station	5 Blackwater Rd, Evington, Va 24550	37.2348, -79.2367
Campbell	BROOKNEAL TOWN - STAUNTON RIVER	Wastewater Treatment Plant	Radio Rd	37.0376, -78.9391
Campbell	Otter River Water Treatment Plant	Wastewater Treatment Plant	9605 Leesville Rd	37.2113, -79.2988
Lynchburg	WLLL - AM - HUBBARD'S ADVERTISING AGENCY, INC.	Communication Facility		37.4070, -79.2322
Lynchburg	Legacy Museum of African American History	Attractions	403 Monroe St	37.4142, -79.1543
Lynchburg	Maier Museum of Art	Attractions	1 Quinlan St	37.4393, -79.1699
Lynchburg	Old City Cemetery	Attractions	301 Monroe St	37.4149, -79.1565
Lynchburg	Historic Sandusky Foundation - Civil War Museum	Attractions	757 Sandusky Dr	37.3803, -79.1963
Lynchburg	CENTRAL VIRGINIA COMMUNITY COLLEGE	College		37.3589, -79.1844
Lynchburg	WESTROCK CONVERTING COMPANY	HazMat Facility	1801 Concord Turnpike	37.4032, -79.1277
Lynchburg	LYNCHBURG FIRE DEPARTMENT STATION 4 - BIRCH STREET	Fire Stations	410 Birch Street	37.4343, -79.1647
Lynchburg	Surgery Center of Lynchburg	Public Health	2401 Atherholt Road	37.4087, -79.1776
Lynchburg	CENTRAL VIRGINIA COMMUNITY COLLEGE POLICE	Law Enforcement	3506 Wards Road	37.3589, -79.1845

Locality	Facility Name	Facility Type	Location	Coordinates
Lynchburg	CARRINGTON, THE	Nursing Home	2406 Atherholt Road	37.4083, -79.1758
Lynchburg	AVANTE AT LYNCHBURG	Nursing Home	2081 Langhorne Road	37.4130, -79.1824
Lynchburg	THE ELMS OF LYNCHBURG	Nursing Home	2249 Murrell Road	37.4077, -79.1725
Lynchburg	Reusens Dam Hydro Plant	Energy Facility	4300 Hydro Street	37.4630, -79.1867
Lynchburg	HOLY CROSS REGIONAL CATHOLIC SCHOOL	Schools	2125 Langhorne Rd	37.4125, -79.1778
Lynchburg	JAMES RIVER DAY SCHOOL	Schools	5039 Boonsboro Rd	37.4446, -79.2268
Lynchburg	NEW VISTAS SCHOOL	Schools	520 Eldon St	37.3987, -79.1724
Lynchburg	LAUREL REGIONAL SPECIAL EDUCATION CENTER	Schools	401 Monticello Avenue	37.4044, -79.1798
Lynchburg	HERITAGE ELEMENTARY	Schools	501 Leesville Road	37.3622, -79.2083
Lynchburg	HERITAGE HIGH	Schools	3020 Wards Ferry Road	37.3609, -79.2059
Lynchburg	SANDUSKY ELEMENTARY	Schools	5828 Apache Lane	37.3808, -79.2037
Lynchburg	WILLIAM M. BASS ELEMENTARY	Schools	1730 Seabury Avenue	37.3918, -79.1410
Lynchburg	CROSSROADS / SINGLE POINT OF ENTRY	Schools	405 Cabell Street	37.4227, -79.1467
Lynchburg	CENTRAL VIRGINIA GOVERNOR'S SCHOOL	Schools	3020 Wards Ferry Road	37.3609, -79.2059
Lynchburg	Electrical Substation	Electrical Substation		37.4062, -79.1339
Lynchburg	Electrical Substation	Electrical Substation		37.4345, -79.1653
Lynchburg	Electrical Substation	Electrical Substation		37.4620, -79.1889
Lynchburg	LYNCHBURG CITY SEWAGE TREATMENT	Wastewater Treatment Plant	2301 Concord Tpke	37.3968, -79.1141

4.16.4 Probability of Future of Occurrences

There is no simple, universal methodology for determining the probability and vulnerability to landslides and the available data provides only the broadest indications of areas that could expect a landslide (Virginia DGMR). The best predictors of future landslides are past landslides, because they tend to occur in the same places. Landslides, like other geologic hazards, are very complex and require someone with geologic expertise to conduct a geotechnical study. The impact and extent of the damage will greatly hinge

on where the landslide occurs. The largest danger from landslides and debris flows occurs in areas of high relief or abrupt changes in topography, especially areas susceptible to slope failure initiated by sustained and/or heavy rain events.

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