COMMONWEALTH OF VIRGINIA
DEPARTMENT OF ENERGY
GEOLOGY AND MINERAL RESOURCES PROGRAM

LANDSLIDE SUSCEPTIBILITY MAP OF NELSON AND ALBEMARLE COUNTIES, VIRGINIA

FOR SHALLOW TRANSLATIONAL SLOPE MOVEMENT DURING A 5-INCH (125-MM) OR GREATER RAINFALL EVENT

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GEOLOGIC HAZARDS MAP SERIES 3
SLOPE MOVEMENT HAZARD MAPS OF
ALBEMARLE AND NELSON COUNTIES, VIRGINIA
SHEET 2 of 3, VERSION: September 20, 2024

EXPLANATION

MAP FEATURES

Roads

Primary roads

Secondary roads

Blue Ridge Parkway & Skyline Drive

Rivers

Rivers and Streams

Lakes

Political Boundaries

County boundary

Slope Movement Initiation Zones

Debris or earth blowout

Debris or earth flow

Debris or earth slide and flow

Debris or earth slide

Note: Locations of slope movement initiation zones shown on this map sheet depict only shallow translational movements on unmodified slopes. These locations were used to calibrate the results of the slope stability model (this map). For a comprehensive listing and locations of the types of slope movements and deposits identified and/or field verified in the study area, see Sheet 1 (Slope Movement and Slope Movement Deposits Map).

SLOPE MOVEMENT DEFINITIONS

Materials

debris - A soil that contains a significant proportion of coarse material; 20 to 80 percent of the particles are larger than coarse sand (0.08 inches or 2 millimeters), with the remainder finer than 0.08 inches of 2 millimeters.

earth - A soil in which more than 80 percent of the particles are smaller than 0.08 inches (2 millimeters).

Mechanisms

blowout - A type of slope failure in which water and soil bursts forth from the ground and then proceeds downslope as overland flow. These are possibly caused by excessive pore water pressure.

flow - A type of slope movement in which the water content in the displaced mass is sufficient for the material to liquify and behave as a viscous fluid.

slide - A type of slope movement failure in which the material is displaced along a well-defined, typically planar or curvi-planar failure surface. Where the geometry of the failure surface is not known, the term slide is applied. Where known, the slide is classified as rotational or translational.

Note: Definition of blowout from Hack and Goodlet (1960); unless referenced otherwise, the above definitions are in general accordance with Cruden and Varnes (1996) and Jackson (1997).

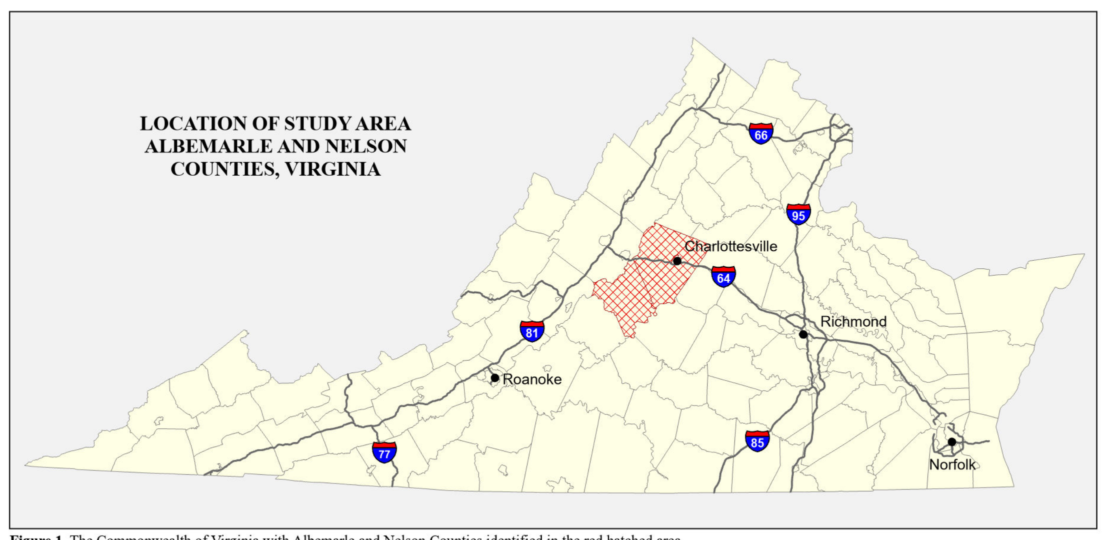


Figure 1. The Commonwealth of Virginia with Albemarle and Nelson Counties identified in the red hatched area.

Table 1. Susceptibility zone definitions, parameter ranges, and possible stabilizing or destabilizing factors. Parameters were delineated using a weighted analysis of soil, rock, and topographic inputs in ArcPro. See Table 3 for more information.

Map Color Code	Predicted Susceptibility Zone [1]	Parameter Index Range [2]	Calibration Parameters	Possible Influence of Stabilizing or Destabilizing Factors [3]
	High Hazard	7 - 8	Majority of soil/rock and topographic parameters overlap	Stabilizing factors required for stability
	Moderate Hazard	5 - 6	Some soil/rock and topographic parameters overlap	Destabilizing factors are not required for instability
	Low Hazard	0 - 4	Few soil/rock and topographic parameters overlap	Significant destabilizing factors are required for instability

Explanatory notes for Table 1:

[1] **Predicted Susceptibility Zone.** This column designates the predicted susceptibility zone for the initiation of shallow translational landslides on unmodified (i.e., natural or undisturbed) slopes.

[2] **Parameter Index Range.** The parameter index is a numerical representation of the relative hazard for shallow translational slope movement initiation. The integer value is computed at each point on a 5-foot digital elevation model grid. The parameter index is a dimensionless number generated by summing five weighted rasters generated from soil, geological, and topographic information for the study area (see Table 3). The breaks in the ranges of values for the parameter index categories were calculated based on the relative density of landslides in each category.

[3] **Possible Influence of Stabilizing or Destabilizing Factors.** Stabilizing factors include increased soil strength, root strength, or improved drainage. Destabilizing factors include increased wetness or loading, loss of root strength, or oversteepening of the slope.

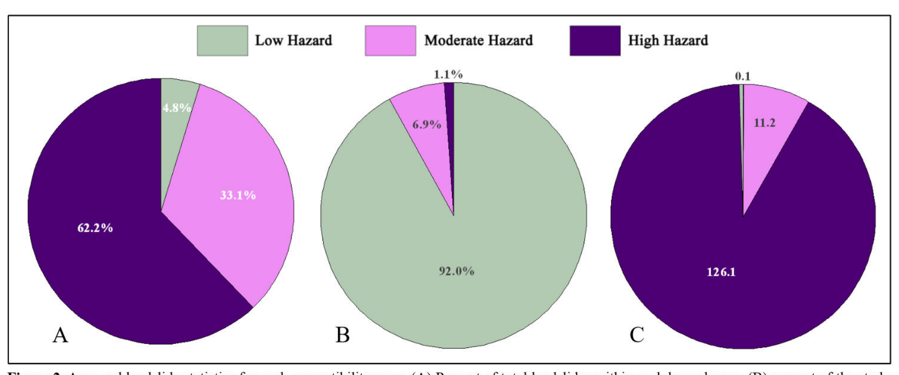
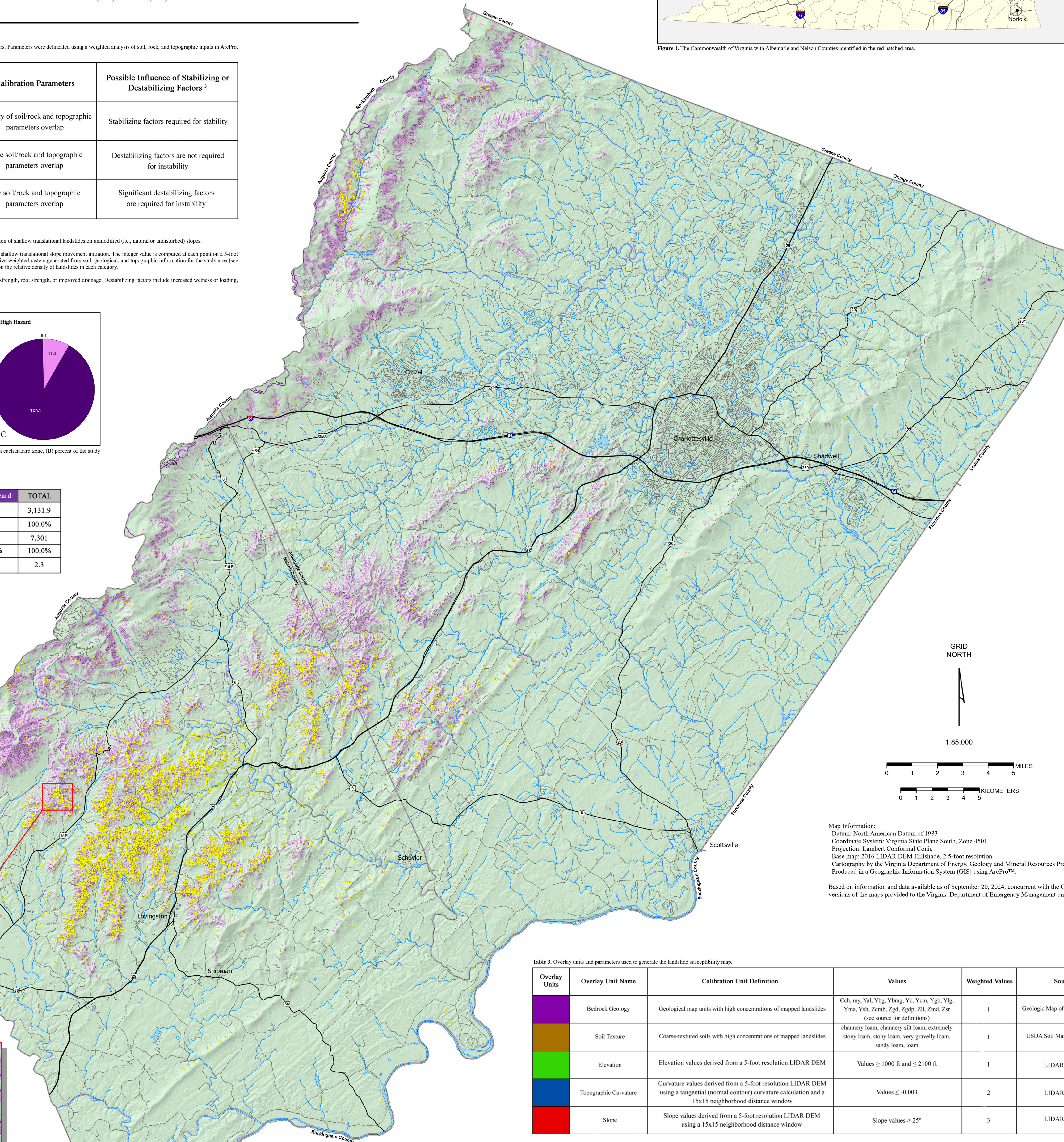
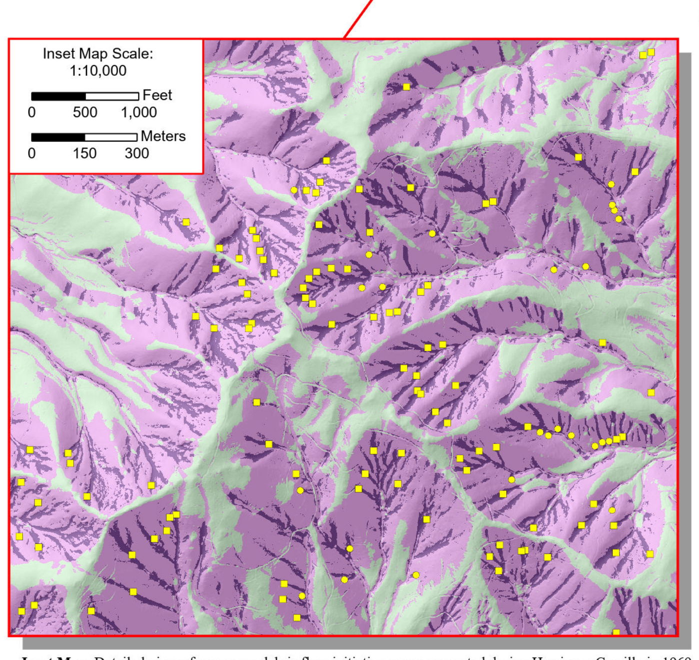


Figure 2. Area and landslide statistics for each susceptibility zone. (A) Percent of total landslides within each hazard zone, (B) percent of the study area within each hazard zone, (C) landslides per km² within each hazard zone.

Table 2. Statistical summary for each susceptibility zone in Albemarle and Nelson counties.

	Stable	Moderate Hazard	High Hazard	TOTAL
Area (km^2)	2,880.8	215.1	36.0	3,131.9
% of Region	92.0%	6.9%	1.1%	100.0%
Number of Landslides	348	2,413	4,540	7,301
% of Slides	4.8%	33.1%	62.2%	100.0%
Landslides/km^2	0.1	11.2	126.1	2.3





Inset Map. Detailed view of numerous debris flow initiation zones generated during Hurricane Camille in 1969 on the landslide susceptibility map. Most of these debris flows initiated in areas identified as high or moderate hazard (see Table 1). Ground disturbing activities in areas identified as purple (high hazard) or pink (moderate hazard) may reduce the stability of the slope and make them more susceptible to failure during a heavy rainfall event.

Map Information:
Datum: North American Datum of 1983
Coordinate System: Virginia State Plane South, Zone 4501
Projection: Lambert Conformal Conic
Base map: 2016 LIDAR DEM Hillshade, 2.5-foot resolution
Cartography by the Virginia Department of Energy, Geology and Mineral Resources Program
Produced in a Geographic Information System (GIS) using ArcPro™.

Based on information and data available as of September 20, 2024, concurrent with the GIS versions of the maps provided to the Virginia Department of Emergency Management on this date.

Table 3. Overlay units and parameters used to generate the landslide susceptibility map.

Overlay Units	Overlay Unit Name	Calibration Unit Definition	Values	Weighted Values	Source
	Bedrock Geology	Geological map units with high concentrations of mapped landslides	Ꞓch, my, Yal, Ybg, Ybmg, Yc, Ycm, Ygb, Ylg, Yma, Ysh, Zcmb, Zgd, Zgdp, Zll, Zmd, Zsr (see source for definitions)	1	Geologic Map of Virginia (2021)
	Soil Texture	Coarse-textured soils with high concentrations of mapped landslides	channery loam, channery silt loam, extremely stony loam, stony loam, very gravelly loam, sandy loam, loam	1	USDA Soil Map (2013, 2019)
	Elevation	Elevation values derived from a 5-foot resolution LIDAR DEM	Values ≥ 1000 ft and ≤ 2100 ft	1	LIDAR DEM
	Topographic Curvature	Curvature values derived from a 5-foot resolution LIDAR DEM using a tangential (normal contour) curvature calculation and a 15x15 neighborhood distance window	Values ≤ -0.003	2	LIDAR DEM
	Slope	Slope values derived from a 5-foot resolution LIDAR DEM using a 15x15 neighborhood distance window	Slope values ≥ 25°	3	LIDAR DEM

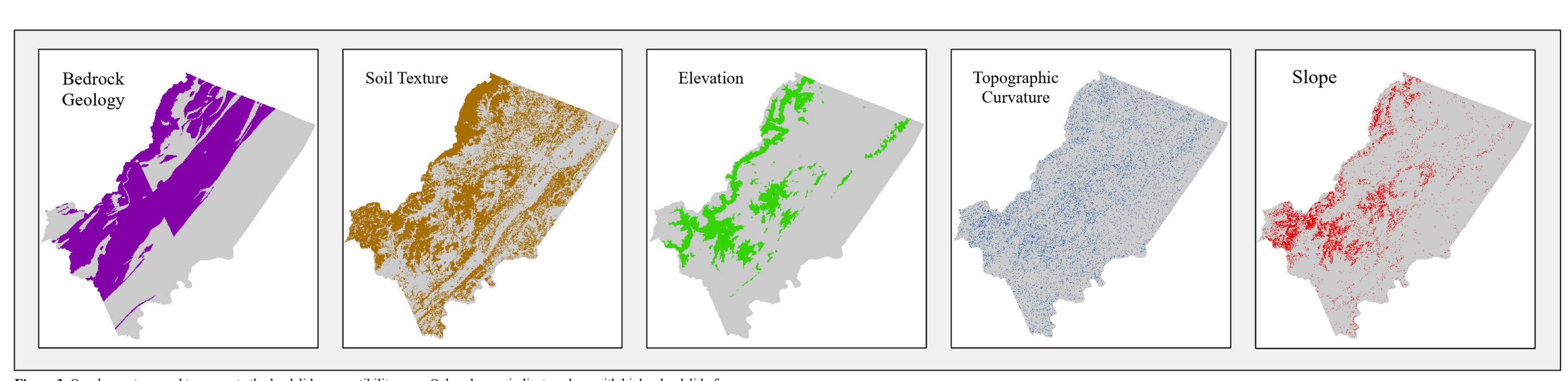


Figure 3. Overlay rasters used to generate the landslide susceptibility map. Colored areas indicate values with higher landslide frequency.

OVERVIEW OF THE LANDSLIDE SUSCEPTIBILITY MAP

Background and Purpose

The Geology and Mineral Resources Program of the Virginia Department of Energy has produced slope movement hazard maps for Albemarle and Nelson Counties (Figure 1) to provide the public and local and state government agencies with descriptions and locations where slope movements have occurred, or are likely to occur, and the general areas at risk from these slope movements. The locations of previous slope movements and their deposits are important because slope movements often reoccur in the same general areas, and typically deposit material in areas where there are pre-existing slope movement deposits.

The slope movement hazard map series for Albemarle and Nelson Counties, Virginia, consists of three maps: Geologic Hazards Map Series 3 (GHMS-3), Sheets 1, 2, and 3, that are designed to be used in conjunction with each other. Brief descriptions of this map (Sheet 2) and accompanying maps follow.

1. Sheet 1, Slope Movement and Slope Movement Deposits Map, shows the extent and distribution of known historical slope movements (all types) and pre-existing slope movement deposits.

2. Sheet 2 (this map), Slope Stability Map, shows where naturally occurring, shallow, translational slope movements (e.g., debris flows) may begin on otherwise undisturbed slopes in response to a major rainfall event.

3. Sheet 3, Map of Known and Potential Debris Flow Pathways, shows where debris flows may travel if they were to occur.

These printed maps are smaller scale representations of digital spatial data that have been created for use in a Geographic Information System (GIS). The Geology and Mineral Resources Program slope movement hazard map products are not intended to be a substitute for a detailed, site-specific analysis by a qualified geologist or engineer.

Landslide Susceptibility Map (Geologic Hazards Map Series 3, Sheet 2)

This color-coded map is symbolized using the supplied Susceptibility_Map.lyrx ESRI layer file and shows the predicted susceptibility zones (high hazard, moderate hazard, and low hazard) for the potential initiation of shallow, translational slope movements (i.e., debris/earth flows, and debris/earth slides) in response to approximately 5-6 inches (125-154 millimeters) or more rainfall within a 24-hour period. This rainfall rate is based on historical evidence of debris flow generating storm events in the Southern Appalachians (Eschner and Patric, 1982; Neary and Swift, 1987; Wieczorek et al., 1996; Witt, 2005) and is the approximate minimum threshold for triggering numerous debris/earth flows and slides on slopes not modified by human activities such as excavations and/or embankments. The map does indicate, however, those areas where modifications to the ground can lead to instability. Local conditions (i.e. vegetation, soil, geology) may dictate that a percentage of the precipitation may runoff rather than directly enter the shallow groundwater system as recharge. In this case, a greater amount of rainfall could be required to produce the 5-inches of recharge necessary to generate numerous shallow landslides.

Debris flows make up 78% of the landslides identified in Albemarle and Nelson Counties. Throughout the southern Appalachians, debris flows have resulted in the greatest number of landslide fatalities and damage of all reported landslide types (Wooten et al., 2016). In Nelson County, 124 people perished due to landslides (primarily debris flows) on the night of August 19-20, 1969 when the remnants of Hurricane Camille tore through the region.

Table 1 provides definitions and additional information related to the predicted susceptibility zones and the corresponding predictive index ranges. Table 2 and Figure 2 provide the statistical summary of slope movements for each susceptibility zone. The susceptibility map forecasts where shallow translational slope movements are more likely to initiate during a high intensity rainfall event, given the input values and assumptions used in the analysis. In Virginia, debris/earth flows and debris/earth slides typically originate on steep slopes (those greater than 25 degrees or 47 percent) where thin (usually less than 6 foot- or 2 meter-thick) permeable soil overlies relatively low permeability layers such as bedrock. This data layer is intended to indicate the distribution of high and moderate hazard areas where further slope stability analysis and assessment, including field verification, may be appropriate prior to undertaking ground disturbing activities.

Map Production

This map was produced using the ESRI ArcPro 3.1 geoprocessing tools to calculate the final weighted overlay raster used as the susceptibility map. Topographic raster data was derived from a 5-foot resolution digital elevation model LIDAR grid. Polygon soil data was derived from digital soil surveys for Nelson and Albemarle Counties (U.S. Department of Agriculture, 2013, 2019). Generalized polygon bedrock geology data was then imported from the digital Geologic Map of Virginia (Witt et al., 2021). Selected polygon and raster data values (see Table 3) were converted to a simplified raster where selected values were converted to cells with integer values of “1” and all others to “0”. Slope and curvature raster values were weighted by 3 and 2 respectively and then all rasters were summed to produce the final susceptibility raster. The final output raster has cell values that range between 0 and 8. Low values indicate where few input parameters overlap while high numbers indicate where many input parameters overlap. The output raster values were then assigned into three susceptibility zones (high, moderate, and low) based on the calculated parameter value ranges and known slope movement occurrences. Table 3 gives basic information on parameters used in the susceptibility calculation.

Model Calibration

The parameter adjustment process was performed using 7,301 known shallow, translational slope movements (e.g., debris flows and debris slides) that occurred on unmodified slopes (i.e., those without obvious ground disturbance). Topographic, soil, and geologic values were compared to the 7,301 landslide initiation locations to identify significant factors associated with greater landslide incidence. Initial topographic rasters for elevation, slope, curvature and elevation were derived from the 5-foot resolution LIDAR data. Landslide frequency was found to be greater on slopes with elevations between 1,000-2,100 feet, slopes ≥ 25-degrees, and curvature values ≤ -0.003 or concave slopes. Landslide locations were evenly distributed between values for aspect (0-360) and thus aspect was discarded as a significant contributor to landslide initiation for the susceptibility model.

Soil parameter values were derived from the Albemarle and Nelson soil survey map units for each of the landslide initiation locations and included soil depth, hydraulic conductivity, soil texture, and Unified soil classification (ASTM, 1985). Values for root cohesion, soil cohesion, and soil friction angle were estimated for each soil unit using values derived from Hales et al. (2009) and Hammond et al. (1992). Ultimately, soil texture, the relative proportion of sand, silt, and clay and larger particles in the soil, was found to contribute significantly to landslide initiation and used in the susceptibility overlay model. A similar process was used to identify bedrock geologic units with higher landslide frequency. The specific soil and geological map units used in the susceptibility model are identified in Table 3.

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