



**Rockslide along US Route 60 in Cabell County**  
Photo by WV DOT

# West Virginia Landslide Risk Assessment

## Region 2 – Lincoln, Logan, Mingo, Wayne, Cabell, & Mason counties

FEBRUARY 10, 2022

In support of FEMA HMGP Project



## Executive Summary

The West Virginia Emergency Management Division (WVEMD), Department of Homeland Security (DHS), and Federal Emergency Management Agency (FEMA) have facilitated landslide susceptibility studies and community-based risk assessments in support of local and state hazard mitigation plans. Landslide susceptibility was modeled using a random forest machine learning method. The model used LiDAR-identified landslide locations, topography, soil type, and proximity to roads and streams among many input variables to produce landslide susceptibility grids. Overall, 23,404 landslide points were identified using LiDAR in Region 2. Risk assessment was performed at the sub-county scale and includes results on roads and structures/parcels. This report summarizes risk assessment results by West Virginia planning and development council regions. Results for Region 2 can be integrated into hazard mitigation plans to enhance resilience and protect communities from landslide hazards.

This landslide risk report provides non-regulatory landslide risk information to help local officials, planners, emergency managers, and others better understand their landslide risk, take steps to mitigate those risks, and communicate those risks to citizens and local businesses.

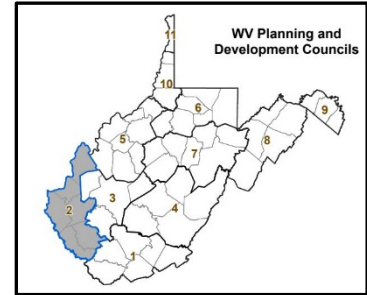
**Road risk analysis** – In Region 2, **Cabell County** has almost 49 miles of road that is susceptible to high/medium probability of landslides. **Lincoln County** has about 63 miles, **Logan County** has 26 miles, **Mason County** has almost 55 miles, **Mingo County** has about 43 miles, and **Wayne County** has almost 104 miles of road prone to high/medium risk for slope failure. Counties were ranked for slope failure risk based on the number of miles that are at risk. One Region 2 county ranks in the Top 20 for highest number of road miles at risk from landslides in the state. Of all 55 counties, Cabell County ranks 38<sup>th</sup>, Lincoln 34<sup>th</sup>, Logan 48<sup>th</sup>, Mason 35<sup>th</sup>, Mingo 44<sup>th</sup>, and Wayne 17<sup>th</sup>. In each county, most of the at-risk roads are in unincorporated areas.

**Structure/Parcel analysis** - **Cabell County** has a total of 772 primary structures with a total appraisal value of \$54,280,453 that are in high/medium susceptibility areas. **Lincoln County** has 383 primary structures with total appraisal value of \$6,053,728 in high/medium susceptibility areas. **Logan County** has 460 primary structures with a total appraisal value of \$8,097,255 in high/medium susceptibility areas. **Mason County** has a total of 260 primary structures with a total appraisal value of \$5,584,064 that are in high/medium susceptibility areas. **Mingo County** has 527 primary structures with total appraisal value of \$3,875,291 in high/medium susceptibility areas. **Wayne County** has 728 primary structures with a total appraisal value of \$17,941,942 in high/medium susceptibility areas. Cabell County ranks in the Top 10 for both the count of at-risk structures and the total value of at-risk structures in the state, ranking 8<sup>th</sup> in both categories. Wayne County ranks in the Top 10 for at-risk structure count (10<sup>th</sup> place), but ranks 22<sup>nd</sup> for total asset value in high/medium risk areas. For the remaining counties, Lincoln ranks 22<sup>nd</sup>, Logan 16<sup>th</sup>, Mason 39<sup>th</sup>, and Mingo 14<sup>th</sup> for total count of at-risk structures in the state. For the value of total assets at high or medium risk of landslides, Lincoln ranks 42<sup>nd</sup>, Logan 36<sup>th</sup>, Mason 45<sup>th</sup>, and Mingo 48<sup>th</sup>.

*This report is for informational purposes related to general emergency services planning. It has not been prepared for, and may not be suitable for legal, design, engineering, or site-preparation purposes. This report cannot substitute for site-specific investigations by qualified practitioners. Landslide risk is complex and continually changing. Although other existing studies or reports may provide more precise and comprehensive information, detailed original site investigations are normally an essential best practice for public safety, sustainability, and financial viability. These other data sources may give results that differ from those in this report.*

## Introduction

West Virginia has been divided into 11 regional and planning development councils to more effectively utilize funding, plan development, and aid cooperation. Landslide risk assessment has been performed in Region 2 for roads and structures/parcels. Roads provide critical service to communities. FEMA recently developed the [community lifelines](#) to enhance their effectiveness in disaster operations and better position themselves to respond to catastrophic incidents. Community lifelines cover seven sectors: Safety and Security; Food, Water, Shelter; Health and Medical; Energy; Communications; Transportation; and Hazardous Material. Roads are classified under Transportation in FEMA community lifelines.



**Figure 1.** Planning and development regions in West Virginia

Landslide risk assessment has been performed to assess high and medium risk road segments and structures/parcels. **This study is suitable for planning-level analysis. The risk analysis for roads should be used in conjunction with site-specific risk analysis performed by WV**

**Department of Transportation.** FEMA's goal is to ensure that communities address natural hazards. A comprehensive plan should acknowledge all hazards that pose a risk and identify steps to avoid these hazards altogether or incrementally reduce a community's exposure to them.

### Community Engagement and Verification:

Review Landslide points identified using LiDAR data in the [WV Landslide Tool](#). Add any missing major landslide points in the web application. A photo of the landslide incident can also be uploaded to the Landslide Tool. Review the susceptibility grid in [WV Landslide](#) or [WV Flood Tool](#). Report any major discrepancies in high/medium landslide susceptible zones.

## About Landslide Risk

Landslides are naturally occurring phenomena that can happen almost everywhere in West Virginia, especially on steep slopes. In its most basic form, a landslide is the movement of soil or rock down a slope. Landslides become hazardous to people and property when they happen in an area where development has occurred, causing losses. Many landslides have relatively little impact on people or property, such as minor road damage, tree throws, or tilting of fences and walls. However, severe landslide damage can topple buildings, destroy roads, disrupt utilities, and cause critical injuries or death.



**Figure 2.** Landslides present a risk to critical infrastructure and public safety (Photo by [WVDOT](#))

## Calculating Landslide Risk

It is not enough to simply identify where landslides may occur. Knowing approximately where a landslide may occur is not the same as understanding the **risk** posed by landslides. The most common method for determining landslide risk, also referred to as vulnerability (the exposure of a given population to harmful effects from a hazard), is to identify the susceptibility of landslide occurrence and then determine the subsequent consequences. In other words:

$$\text{Landslide Risk} = \text{Susceptibility} \times \text{Consequences}$$

Where,

**Susceptibility** = the likelihood of occurrence

**Consequences** = the estimated impacts associated with the occurrence

An area's **landslide susceptibility** is the likelihood that a landslide will occur. The likelihood of a landslide occurring can change based on physical, environmental, or contributing human factors. Factors affecting the likelihood of landslide occurrence in an area include seasonality, weather, climate, slope, human disturbance, and the existence of mitigation structures. The ability to assess the likelihood of landslide occurrence and the level of accuracy for that assessment are enhanced by landslide modeling methodology advancements and more widespread reporting or mapping of landslide occurrence.

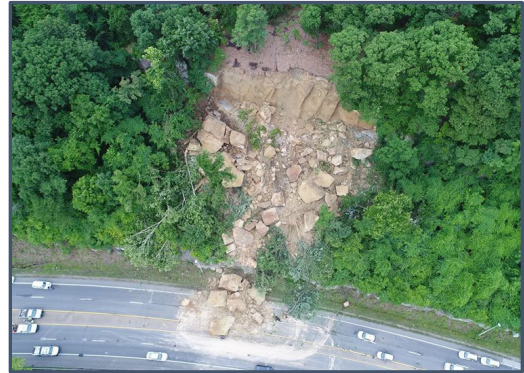
The **consequences of a landslide** are the estimated impacts related to the landslide occurrence. Consequences relate to human activities within an area and how a landslide impacts natural and manmade infrastructures.

## Sources of Data for Landslide Risk Assessments

To assess potential community losses or the consequences portion of the “risk equation”, the following data is typically collected for analysis and inclusion in a landslide risk project:

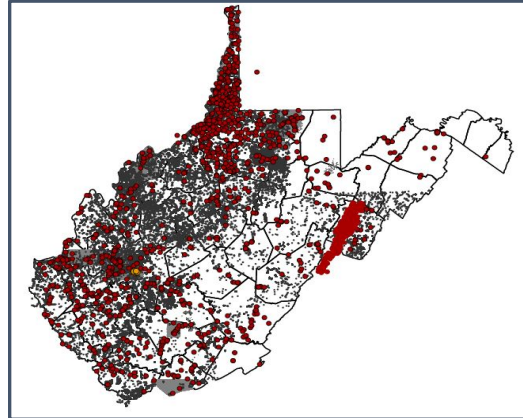
- Locations of past landslide occurrence
- Areas susceptible to landslide occurrence
- Information about local assets or resources at risk from landslide occurrence
- Information about where the risk is most severe

The following sources of incidence information were compiled for the statewide Landslide Risk Project and can be viewed on the [West Virginia Landslide Tool](#). A detailed table showing landslide points and polygons collected in the state can be reviewed [here](#). However, **only high-resolution LiDAR-identified landslide incidence points were used for susceptibility modeling.**



**Figure 3.** The **consequences** of a landslide are often higher in populated areas due to resulting property damage and injury to citizens (Photo by [WVDOT](#))

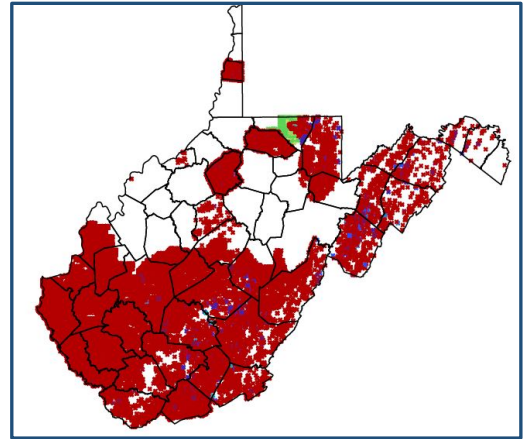
- [WVGES Study](#) - A study by West Virginia Geological and Economic Survey in the 1970s led to a report by Lessing et al. (1976) published as WVGES Environmental Geology Bulletin no. 15. The study mapped 46,330 landslide polygons in 39 7.5-minute quadrangles throughout West Virginia. The study was largely based on air photos taken in the 1960s and 1970s. The [West Virginia GIS Technical Center](#) (WVGISTC) digitized many of these polygons in 2018. Failures were categorized into three broad categories based on original map symbology: older landslides, recent landslides, and rockfalls. Mapping efforts yielded 8,743 landslide polygons from Region 2.



**Figure 4.** [Historical landslides](#) were compiled from several studies to create a comprehensive landslide dataset (Image adapted from the [West Virginia Landslide Tool](#))

- **USGS Study** - The United States Geological Survey completed a multiple-author study between 1975 and 1985 that mapped various failures over 382 7.5-minute quadrangles. The [WVGISTC](#) digitized 41,307 “active or recently active” slope failure polygons in 2018. Mapping efforts yielded 3,265 polygons from Region 2.
- [Landers and Smosna \(1973\)](#) evaluated the damage caused by flooding and slope failure during a 1973 storm event in Kanawha City. From this study, ten landslide points were mapped in the Charleston area.
- **Jacobson et al. (1993)** mapped 3,571 slope failures near the Wills Mountain anticline to evaluate the effects of the November 1985 flood in the upper Potomac and Cheat basins.
- **Kory Konsoer (2008) and Beau Downing (2008)**, as part of their M.S. theses, performed a landslide study in the Horseshoe Run watershed in Tucker County, WV. This research mapped 149 landslide polygons within the watershed and included a statistical analysis to quantitatively assess risk. In 2014, **Yates and Kite** created a landslide inventory in the Bluestone National Scenic River and vicinity. Following this analysis, an inventory of 212 polygons was created for the New River Gorge National River area by the same authors (Yates and Kite, 2016).
- **West Virginia Department of Transportation (WVDOT) database of landslide locations** – The road landslide Inventory (2016) contains 1,406 points where landslides have occurred along roadways. Many of these incident points are no longer visible with LiDAR data, even at the 1-meter scale, either because they are small enough to escape visibility or because the WVDOT has repaired the damage. The database contains 163 landslide points in Region 2 counties.

- High-resolution LiDAR-identified landslide incidence points** - Landslide initiation points were identified and mapped specifically for this project on DEMs created from recent high resolution (1- or 2-m) LiDAR. Trained technicians placed points at the approximate center of the landslide headscarp and classified the failures into one of six general slope failure categories: slide, debris flow, lateral spread, multiple failures, fall, or undetermined. The details of classification can be found [here](#). The nature of the West Virginia landscape and the LiDAR imagery limited mapping to landslides at least 33 feet wide. This approach undercounts small, shallow landslides and slope failures that human agents may have mitigated or removed. Rockfalls, a major landslide risk along roadways, are considerably undercounted in this approach. Overall, 23,404 landslide points were identified in Region 2.

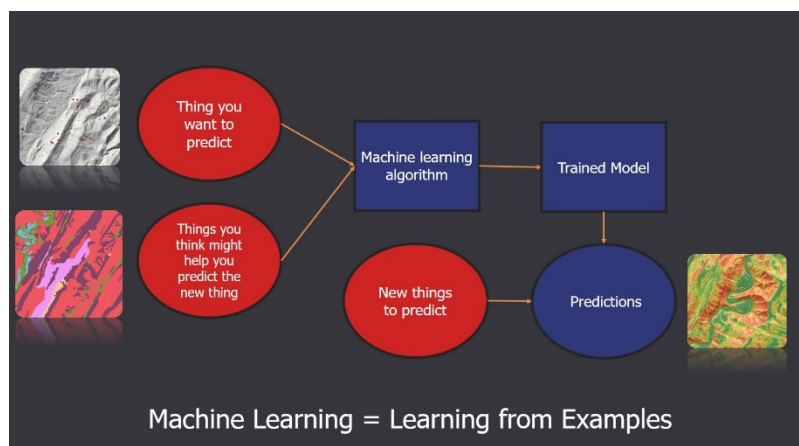


**Figure 5.** [LiDAR-mapped landslide points](#) are dependent upon the presence of 1- or 2-meter LiDAR data (Image from the [West Virginia Landslide Tool](#))

## Landslide Susceptibility Methodology

[Landslide susceptibility](#) has been generated as a grid raster dataset for the state. Much like the pixels in a photo or graphic, a grid is made up of square cells, where each grid cell stores a value representing a landslide susceptibility value. Using Random Forest machine learning methods, landslide incidence was modelled and rendered as a raster grid dataset. In machine learning, a model is generated by learning from examples. Figure 6 shows a simplified diagram of the machine learning model. Modeling starts with two basic variables:

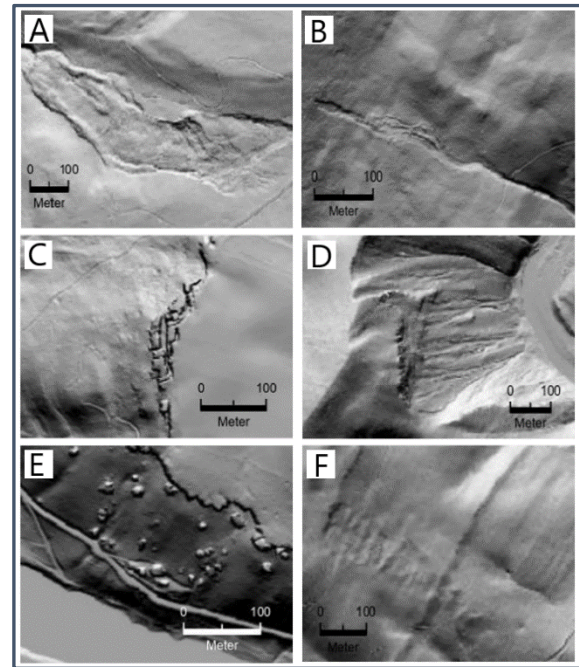
- 1) Response variable you want to predict (example: landslide susceptibility) and,
  - 2) Predictor variables you think might help you predict the new response variable (for example: prior locations of landslide, geology, soil, slope, etc.).
- Then, these predictor variables are run through a machine learning algorithm to train a model. This trained model is used for making predictions. In the end, a new prediction grid is generated (in this case, landslide susceptibility grid).



**Figure 6.** Simplified diagram showing machine learning process for generating landslide susceptibility grid

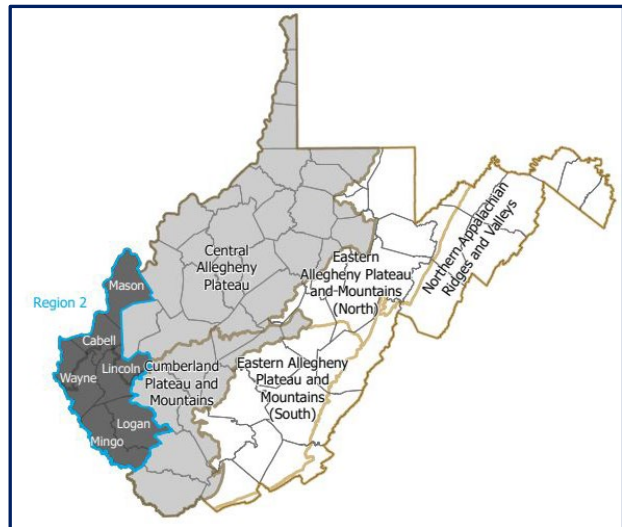
Following is the methodology for landslide susceptibility grids generated using the Random Forest machine learning model:

Landslide locations were mapped throughout West Virginia using light detection and ranging (LiDAR) elevation data products, including [hillshades](#) and [slopes](#). Mapped failure types include slide, debris flow, lateral spread, multiple failures (when several failures were present in a small area, but were too small or close together to map separately), fall, and undetermined failure type (Figure 7). Site characteristics and terrain variables, such as slope, lithology, soil type, and distance to roads and streams, were extracted from the mapped landslide locations. Using a random forest machine learning algorithm, these variables were used as inputs to calculate a probabilistic landslide susceptibility grid. A majority of the mapped landslide locations were used to train the model, and the remaining locations were used to validate the model's accuracy. The resulting grid cells were classified into low, medium, and high susceptibility areas using professional judgement and model statistics. On an average, over 95% of known failure locations were found to occur within the modeled high susceptibility areas ([Maxwell et al., 2020](#)).



**Figure 7.** A) Slide B) Debris Flow C) Lateral Spread D) Multiple Failures E) Fall F) Undetermined

Landslide susceptibility modeling was performed at the [Major Land Resource Area](#) (MLRA) scale. MLRAs are geographic areas defined by the Natural Resources Conservation Service based upon shared characteristics, such as lithology, climate, soils, land uses, and water resources. There are four major MLRAs in West Virginia. Models were generated for each MLRA to take advantage of similarities in physiographic conditions that may influence landslide susceptibility. Two MLRAs are present in Region 2: the **Central Allegheny Plateau** and the **Cumberland Plateau and Mountains**. The Central Allegheny Plateau MLRA covers all of Mason County, northern Cabell County, northwestern Wayne County, and northeastern Lincoln County. The Cumberland Plateau and Mountains MLRA covers southern Cabell County, southeastern Wayne County, southwestern Lincoln County, and all of Mingo and Logan counties (Figure 8).



**Figure 8.** Major land resource areas in West Virginia

Many local factors contribute to landslides and their related losses. Contributing factors can be natural or human induced, but slope and local bedrock geology strongly influences county and community scale landslide incidence. Bedrock control on landslides is relatively consistent throughout individual MLRAs, which are geographically associated with [Land Resource Units](#) (LRUs).

The following paragraphs present detailed MLRA characteristics for Region 2 and a summary of the critical underlying variables that affect landslide susceptibility in this region. A detailed report on these variables can be found [here](#).

### Landscape Characteristics

Region 2 is dominated by rugged topography, nearly flat-lying clastic sedimentary bedrock, and well-drained soils developed in colluvium and residuum. Regolith (unconsolidated material) produced by mining is widely distributed and locally thick in coal-bearing geologic settings. Clastic sedimentary rock types, including sandstone, siltstone, shale, coal, and some limestone dominate the geology of the region. Colluvium (material transported some distance by gravitational processes) and residuum (material weathered in place or nearly in place) are the dominant earth materials in which soils develop in the region. Colluvium, which includes landslide deposits, is generally thin near mountain tops, increasing in thickness farther downslope. Residuum depth varies with rock type and degree of weathering; most rock types in the area produce thin residual soils.

### Landslide Characteristics and Contributing Factors

**Slides** and **slumps** are the most common landslide types in Region 2. They tend to develop when soil moisture and pore pressure are highest. *They are most problematic after prolonged wet seasons, particularly in late winter and early spring when soils are saturated and ground-water tables usually are high throughout the region.* Debris flows initiate as slumps or slides in residuum or colluvium on upper slopes, but may run considerable distances downslope from their source. The most frequent cause of debris flows is heavy rain associated with intense spring and summer storms or late summer and early autumn remnants of tropical cyclones. The high-intensity rainfall events that trigger debris flows tend to produce numerous slope failures in local clusters. Fortunately, large debris flows are uncommon in the region, and they are infrequent even at the most vulnerable Appalachian sites, with recurrence intervals estimated to be hundreds or thousands of years. Rock fall failures are commonly reported in the region, especially on disturbed slopes such as rock cuts along transportation corridors and mine highwalls, but the scope of rock fall susceptibility is not well shown by this landslide inventory. Less common landslide types include multiple failures (tight clusters of small landslides and debris flows that tend to occur during debris flow events) and lateral spreads (clusters of large rock blocks that appear to move rarely).

**Slope:** Analysis of the LiDAR-based landslide mapping of the region reveals that slope steepness may be the most important control over where landslides develop, especially in steep hillslope hollows that allow subsurface moisture, surface-water runoff, and unconsolidated material to accumulate. **In the Cumberland Plateau and Mountains MLRA, about 90 percent of mapped slope failures occurred on slopes greater than 21°. In the Central Allegheny Plateau MLRA, about 80 percent of slope failures initiated on slopes greater than 20°.**

**Geology:** Geology is a universally cited factor in landslide distribution, and this is the case in Region 2. The role of geology on landslides may be complex and indirect. Bedrock units heavily dominated by sandstone, the hardest and most resistant rock type in the region, generally are responsible for the highest-elevation topography in the area and numerous cliffs along major river valleys. The inherent strength of thick sandstone layers makes them more stable than other rock types at any given slope angle. Away from river valleys, upland landscapes associated with heavily sandstone-dominated units tend to be less rugged than landscapes dominated by weaker shale, claystone, or siltstone. On the almost ubiquitous steep slopes that extend across much of the region, weaker bedrock units tend to be more deeply incised and more prone to failure than resistant sandstone units, even if the weak units contain some significant sandstone beds.

**Soil:** Analysis of mapped landslides and the digital NRCS Soil Survey Geographic database (SSURGO) indicate soil parent material and drainage class correlate with landslide susceptibility in Region 2. The majority of landslides were mapped in residuum developed from clastic sedimentary bedrock or in colluvium, parent materials that cover over 85 percent of the area. However, the highest density of mapped landslides occurs in mining regolith. Young, unconsolidated parent materials, like mining regolith, have low inherent strength and may not have been in place long enough to reach equilibrium. Conversely, unless disturbed by human activities or exceptional natural events, colluvium and residuum have developed over thousands of years or more, providing more opportunity to adjust to conditions on the steep rugged landscape. The parent material data convey a clear message that human disturbance, especially coal mining, contributes heavily to landslide susceptibility.

Soil polygons assigned as “well drained” cover over 93 percent of the region, account for over 97 percent of slide initiation points, and have the highest slide susceptibility. This drainage class commonly occurs on steep slopes, so its over-representation in number of slides may reflect a key role of slope as a control of both soil drainage and landslide initiation.

**Other Landslide Factors:** Although many factors influencing slope stability are universal, some aspects of slope stability in Region 2 differ from other areas in West Virginia. Anthropogenic disturbance is significant in the region, especially in urban areas and landscapes underlain by or adjacent to coal-bearing bedrock. Urban and rural development has long been known to enhance landslide susceptibility in West Virginia. Hillslopes underlain by weak bedrock or soil may obtain a significant fraction of their shear strength from tree roots, so intensive clearing for timber harvesting or real estate development may lessen slope strength. Ill-designed or poorly constructed roadways, commercial sites, and housing developments may lead to surface drainage disruptions that cause unprecedented soil saturation and abnormal slope destabilization. The importance of good engineering design, based on slope-stability site analysis by professional geologists and certified civil engineers, cannot be over-emphasized. Neither can the importance of long-term monitoring and maintenance of constructed drainage and retaining structures.

**Landslide Susceptibility E-size maps** for Lincoln, Logan, Mingo, Wayne, Cabell, and Mason counties can be viewed [here](#).

## Risk Assessment

The following datasets have been used in risk assessment study for roads and structures/parcels

- Landslide susceptibility analyses using random forest machine learning algorithms and landslide occurrence locations ([Maxwell et al., 2020](#))
- E-911 site address points inside the floodplain
- Parcel centroids for areas outside the floodplain
- Roads (accessed from WV DOH [website](#))

## Risk Analysis

### Roads

Road risk analysis provides an assessment of landslide risk along roads in West Virginia. **This analysis is suitable only for planning level analysis and should be used in conjunction with site-specific risk analysis performed by WV Department of Transportation.** This “big picture” perspective will benefit the planning of route improvements and lead to more effective landslide risk mitigation for West Virginia roads. The analysis classifies roads into high, medium, and low risk areas. The following methodology was used to assess landslide risk to roads in Region 2.

The statewide landslide susceptibility grid was classified as High (1-0.7), Medium (< 0.7-0.3), and Low (0.3-0) susceptibility. This raster grid was then converted to a vector feature class. Road data from [WV Department of Transportation](#) was used for analysis. For analysis, roads were analyzed for Interstate, US Roads, State, and Other roads (county roads, N/A, state parks, and forests road, FANS, HARP, and Others). Municipal non-state roads, railroads, and trail features were not included in the analysis. Since the road feature class is a line layer, a buffer of four meters was created for the road feature class. A buffer was created to adequately capture the risk for the road feature class as most landslides initiate on the side slopes of roads. An intersection between the buffered road layer and the susceptibility feature class was performed to capture risk information for road segments that overlapped with high and medium susceptibility areas. Finally, the road layer was clipped using the buffer layer to identify high and medium risk road segments for each community.

### Results:

Roads were analyzed at two scales. An overview level analysis was performed on all of the roads without any distinction to get the total risk to the roads in each community. This result was used to rank communities based on the length of susceptible roads. The second set of analyses contains susceptibility details relating to Interstates, US Roads, State Roads, and Others. Railroads and trails were not part of the analysis.

Table 1 shows the total miles of road that are prone to high/medium slope failure risk. The table also shows the rank of landslide susceptibility within the state. **Cabell County** has almost 49 miles of road that is susceptible to high/medium probability of landslides. **Lincoln County** has about 63 miles, **Logan County** has 26 miles, **Mason County** has almost 55 miles, **Mingo County** has about 43 miles, and **Wayne County** has almost 104 miles of road prone to high/medium risk for slope failure. Counties were ranked

for slope failure risk based on the number of miles that are at risk. One Region 2 county ranks in the Top 20 for highest number of road miles at risk from landslides in the state. Of all 55 counties, Cabell County ranks 38<sup>th</sup>, Lincoln 34<sup>th</sup>, Logan 48<sup>th</sup>, Mason 35<sup>th</sup>, Mingo 44<sup>th</sup>, and Wayne 17<sup>th</sup>. In each county, most of the at-risk roads are in unincorporated areas. Figure 9 shows an example of landslide risk along I-64 near Huntington, WV in Cabell County. The road segments susceptible to landslide can be viewed on the [Landslide Tool](#).

# WEST VIRGINIA LANDSLIDE RISK ASSESSMENT- REGION 2

**Table 1.** Road length susceptible to High/Medium Risk of Landslide

Community Name	County	Roads Total (miles)	Roads Total (miles)- High/Medium Risk	Rank <sup>1</sup>
Barboursville	CABELL	44.2	1.1	36
Cabell County*	CABELL	620.5	43.2	42
Huntington**	CABELL	98.7	3.4	9**
Milton	CABELL	18.8	1.1	36
	<b>CABELL</b>	<b>782.2</b>	<b>48.8</b>	<b>38</b>
Hamlin	LINCOLN	9.9	0	189
Lincoln County*	LINCOLN	690.1	62.7	33
West Hamlin	LINCOLN	6.2	0.1	155
	<b>LINCOLN</b>	<b>706.2</b>	<b>62.8</b>	<b>34</b>
Chapmanville	LOGAN	11.1	0.1	155
Logan	LOGAN	4.3	0	189
Logan County*	LOGAN	529.7	25.1	48
Man	LOGAN	14.1	0.7	57
Mitchell Heights	LOGAN	2.1	0.1	155
West Logan	LOGAN	2.3	0	189
	<b>LOGAN</b>	<b>563.6</b>	<b>26</b>	<b>48</b>
Hartford	MASON	3.3	0.6	63
Henderson	MASON	5.1	0.2	127
Leon	MASON	2.6	0.8	47
Mason	MASON	2.7	0	189
Mason County*	MASON	820.4	53.2	35
New Haven	MASON	3.9	0.1	155
Point Pleasant	MASON	8.8	0	189
	<b>MASON</b>	<b>846.8</b>	<b>54.9</b>	<b>35</b>
Delbarton	MINGO	8.9	0.7	57
Gilbert	MINGO	10.2	0.3	100
Kermit	MINGO	6.1	0.8	47
Matewan	MINGO	6.8	0.5	68
Mingo County*	MINGO	516.6	38.3	44
Williamson	MINGO	24.3	2.7	15
	<b>MINGO</b>	<b>572.9</b>	<b>43.3</b>	<b>44</b>
Ceredo	WAYNE	16.2	0.8	47
Fort Gay	WAYNE	4.7	0.4	85
Huntington**	WAYNE	9.1	0.3	9**
Kenova	WAYNE	11.2	0.5	68
Wayne	WAYNE	11.6	0.8	47
Wayne County*	WAYNE	946.5	101	16
	<b>WAYNE</b>	<b>999.3</b>	<b>103.8</b>	<b>17</b>

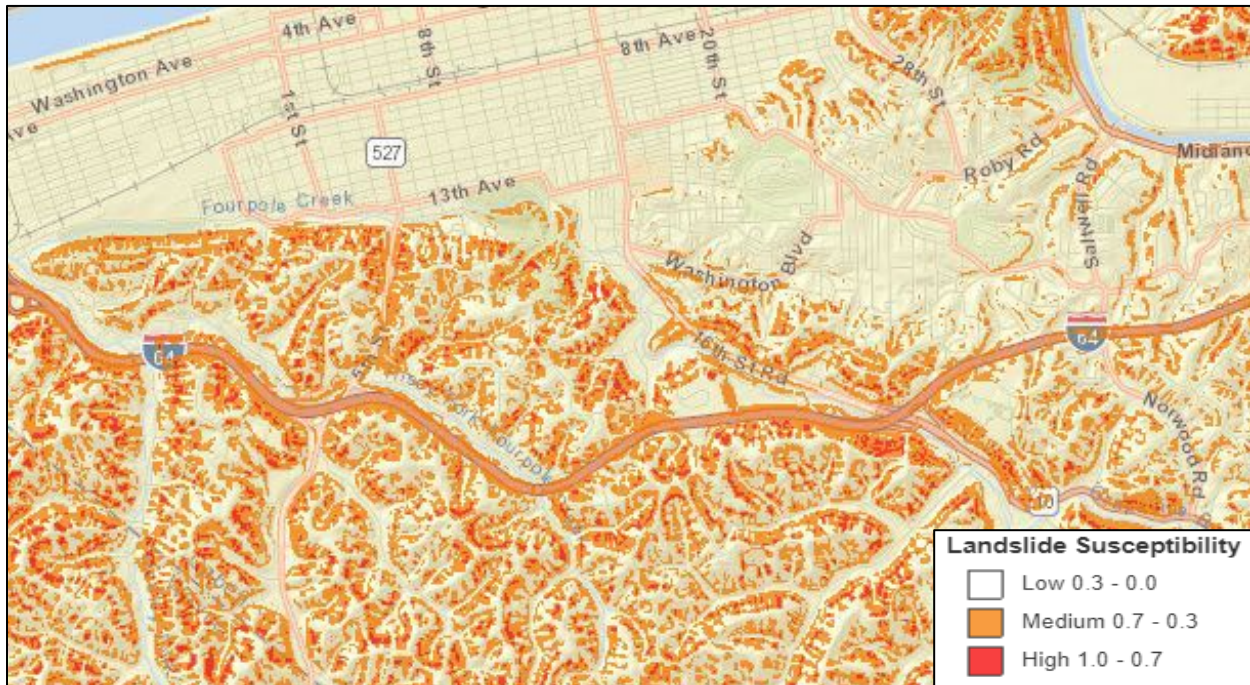
9\*\*: Parts of Huntington in each county represented separately, ranking is based on the sum of values in the city:

Huntington**	CABELL & WAYNE	107.8	3.7	9
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\* Unincorporated

\*\* Split Community

<sup>1</sup> Group Rank on Community Type: County, Unincorporated, Incorporated



**Figure 9.** Landslide Susceptibility near Huntington, WV in Cabell County. Notice high and medium landslide susceptibility areas along I-64. Data can be accessed on [WV Flood Tool](#)

The second set of risk analyses was performed to evaluate the total length of different types of roads in high/medium susceptible areas in each community. Table 2 shows details of different types of roads in high/medium susceptibility zones in each community. In each county, most of the at-risk roads are in the unincorporated areas. In **Cabell County**, the unincorporated area has 43.2 miles of at-risk roads, constituting 88% of at-risk roads in the county; 0.4 miles of Interstate roads; 1.9 miles of US roads; and 1.8 miles of State roads are at-risk. Barboursville and Milton each have 1.1 miles of at-risk roads and the portion of Huntington falling inside Cabell County has 3.4 miles of at-risk roads. **Lincoln County** has 62.7 miles of at-risk roads in unincorporated areas, constituting over 99% of at-risk roads in the county. Unincorporated areas have 0.3 miles of US roads at risk and 4.4 miles of State roads at-risk. West Hamlin has 0.1 miles of roads at risk and Hamlin has no roads at risk. There are no Interstate roads at risk in the county. In **Logan County**, the unincorporated area has 25.1 miles of at-risk roads, constituting 96% of at-risk roads in the county. The unincorporated area has 0.4 miles of US roads and 6.9 miles of State roads at risk. The remaining communities each have less than 1 mile of roads at risk. There are no at-risk roads in the cities of Logan or West Logan. There are no Interstate roads at risk in Logan County. **Mason County** has 53.2 miles of at-risk roads in unincorporated areas, constituting 97% of at-risk roads in the county. Unincorporated areas have 9.1 miles of US roads at risk and 3 miles of State roads at-risk. The remaining communities each have less than 1 mile of at-risk roads. There are no at-risk roads in the cities of Mason or Point Pleasant. No Interstate roads are at risk in Mason County. In **Mingo County**, the unincorporated area has 38.3 miles of at-risk roads, constituting 88% of at-risk roads in the county. The unincorporated area has 14.9 miles US roads at risk and 3.6 miles of State roads at risk. Williamson has 2.7 miles of at-risk roads and the remaining communities each have less than 1 mile of at-risk roads. There are no Interstate roads at risk in the county. **Wayne County** has 101 miles of at-risk roads in

# WEST VIRGINIA LANDSLIDE RISK ASSESSMENT- REGION 2

unincorporated areas, constituting 97% of at-risk roads in the county. Unincorporated areas have 20.1 miles of US roads and 5 miles of State roads at risk. The incorporated communities each have less than 1 mile of road at risk.

**Table 2.** Different road type and length susceptible to High/Medium Risk of Landslide

Community Name	County	Roads Total (miles)	Roads Total (miles)- High/Medium Risk	Interstate Roads High/Medium Risk	US Roads High/Medium Risk	State Roads High/Medium Risk	Other Roads
Barboursville	CABELL	44.2	1.1	0.3	0.3	0	0.5
Cabell County*	CABELL	620.5	43.2	0.4	1.9	1.8	39.1
Huntington**	CABELL	98.7	3.4	0.6	0.6	0.3	1.8
Milton	CABELL	18.8	1.1	0.1	0.9	0	0.1
	<b>CABELL</b>	<b>782.2</b>	<b>48.8</b>	<b>1.4</b>	<b>3.7</b>	<b>2.1</b>	<b>41.5</b>
Hamlin	LINCOLN	9.9	0	0	0	0	0
Lincoln County*	LINCOLN	690.1	62.7	0	0.3	4.4	58
West Hamlin	LINCOLN	6.2	0.1	0	0	0.1	0
	<b>LINCOLN</b>	<b>706.2</b>	<b>62.8</b>	<b>0</b>	<b>0.3</b>	<b>4.5</b>	<b>58</b>
Chapmanville	LOGAN	11.1	0.1	0	0	0	0.1
Logan	LOGAN	4.3	0	0	0	0	0
Logan County*	LOGAN	529.7	25.1	0	0.4	6.9	17.7
Man	LOGAN	14.1	0.7	0	0	0.6	0.1
Mitchell Heights	LOGAN	2.1	0.1	0	0	0	0.1
West Logan	LOGAN	2.3	0	0	0	0	0
	<b>LOGAN</b>	<b>563.6</b>	<b>26</b>	<b>0</b>	<b>0.4</b>	<b>7.5</b>	<b>18</b>
Hartford	MASON	3.3	0.6	0	0	0.6	0
Henderson	MASON	5.1	0.2	0	0.2	0	0
Leon	MASON	2.6	0.8	0	0	0.5	0.3
Mason	MASON	2.7	0	0	0	0	0
Mason County*	MASON	820.4	53.2	0	9.1	3	41.2
New Haven	MASON	3.9	0.1	0	0	0.1	0
Point Pleasant	MASON	8.8	0	0	0	0	0
	<b>MASON</b>	<b>846.8</b>	<b>54.9</b>	<b>0</b>	<b>9.3</b>	<b>4.2</b>	<b>41.5</b>
Delbarton	MINGO	8.9	0.7	0	0.6	0.1	0
Gilbert	MINGO	10.2	0.3	0	0	0	0.3
Kermit	MINGO	6.1	0.8	0	0.4	0	0.4
Matewan	MINGO	6.8	0.5	0	0	0.1	0.4
Mingo County*	MINGO	516.6	38.3	0	14.9	3.6	19.9
Williamson	MINGO	24.3	2.7	0	0.7	0	2
	<b>MINGO</b>	<b>572.9</b>	<b>43.3</b>	<b>0</b>	<b>16.6</b>	<b>3.8</b>	<b>23</b>
Ceredo	WAYNE	16.2	0.8	0.2	0	0	0.6
Fort Gay	WAYNE	4.7	0.4	0	0.3	0	0.1
Huntington**	WAYNE	9.1	0.3	0.3	0	0	0
Kenova	WAYNE	11.2	0.5	0.4	0.1	0	0
Wayne	WAYNE	11.6	0.8	0	0	0.3	0.4
Wayne County*	WAYNE	946.5	101	0	20.1	5	75.7
	<b>WAYNE</b>	<b>999.3</b>	<b>103.8</b>	<b>0.9</b>	<b>20.5</b>	<b>5.3</b>	<b>76.8</b>

Huntington**	CABELL & WAYNE	107.8	3.7	0.9	0.6	0.3	1.8
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\* Unincorporated

\*\* Split Community

### Land Use Landslide Risk

Land use risk analysis provides an assessment of landslide risk to structures/parcels in West Virginia.

**This study is not intended for site-specific analysis or remediation measures and is only suitable for planning-level analysis.** This “big picture” perspective will benefit planning and lead to more effective landslide risk mitigation for West Virginia. The following methodology was used to assess landslide risk to structures/parcels.

Primary structures were extracted for each parcel both inside and outside of the 1% annual chance floodplain in each community. Verified primary structures located inside the 1% annual chance floodplain were used as a point to assess landslide risk within a parcel. For primary structures outside of the floodplain, the following methodology was applied to extract primary structures. This method was used to avoid overestimating the values for each parcel. A spatial join was performed between the site address point and property tax assessment record. To avoid overestimating the appraisal value, the average was calculated by dividing the building appraisal value of the tax assessment record by the number of points located in the parcel. A spatial join was performed between the site addresses and parcels with the average building appraisal value. The output resulted in a site address point feature class representing primary structures attributed to the building appraisal value. These processing steps avoided adding the same building appraisal value multiple times to more than one site address point within a tax parcel.

One notable limitation of this method was that parcels containing no addressing points are assigned a building value of zero (\$0). In addition, the building values for some structures are less than the values recorded in the community-wide building dollar exposure report because for specific parcels the appraisal values may be in neighboring parcels instead of the parcel where the structure is located. This results in building values not being assigned to site address points. Also, some government and other property values do not get pulled in from the statewide assessment database, resulting in lower value of at-risk structures.

### Results:

Structures were analyzed at two scales for each community. An initial overview-level analysis was performed for all of the structures without any distinction to occupancy type. A second analysis was performed for different types of occupancy for high/medium risk of landslide.

Table 3 shows the total count of primary structures in high/medium landslide susceptibility areas. Total asset values were then derived from the 2021 tax assessment database. Each county was ranked for the number of primary structures and the total asset values in high/medium susceptibility areas. **Cabell County** has a total of 772 primary structures with a total appraisal value of \$54,280,453 that are in high/medium susceptibility areas. **Lincoln County** has 383 primary structures with total appraisal value of \$6,053,728 in high/medium susceptibility areas. **Logan County** has 460 primary structures with a total appraisal value of \$8,097,255 in high/medium susceptibility areas. **Mason County** has a total of 260 primary structures with a total appraisal value of \$5,584,064 that are in high/medium susceptibility areas. **Mingo County** has 527 primary structures with total appraisal value of \$3,875,291 in high/medium susceptibility areas. **Wayne County** has 728 primary structures with a total appraisal value of \$17,941,942 in high/medium susceptibility areas.

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Cabell County ranks in the Top 10 for both the count of at-risk structures and the total value of at-risk structures in the state, ranking 8<sup>th</sup> in both categories. Wayne County ranks in the Top 10 for at-risk structure count (10<sup>th</sup> place), but ranks 22<sup>nd</sup> for total asset value in high/medium risk areas. For the remaining counties, Lincoln ranks 22<sup>nd</sup>, Logan 16<sup>th</sup>, Mason 39<sup>th</sup>, and Mingo 14<sup>th</sup> for total count of at-risk structures in the state. For the value of total assets at high or medium risk of landslides, Lincoln ranks 42<sup>nd</sup>, Logan 36<sup>th</sup>, Mason 45<sup>th</sup>, and Mingo 48<sup>th</sup>.

**Table 3.** Structures with High/Medium Risk Landslide Susceptibility

Community Name	County	Total Count	Total Value	Ranking(Count) <sup>1</sup>	Ranking(Value) <sup>1</sup>
Barboursville	CABELL	13	\$3,078,700	81	24
Cabell County*	CABELL	476	\$26,914,249	11	13
Huntington**	CABELL	280	\$24,160,554	8**	8**
Milton	CABELL	3	\$126,950	151	129
	<b>CABELL</b>	<b>772</b>	<b>\$54,280,453</b>	<b>8</b>	<b>8</b>
Hamlin	LINCOLN	0	\$0	195	191
Lincoln County*	LINCOLN	382	\$6,042,394	16	36
West Hamlin	LINCOLN	1	\$11,333	178	188
	<b>LINCOLN</b>	<b>383</b>	<b>\$6,053,728</b>	<b>22</b>	<b>42</b>
Chapmanville	LOGAN	3	\$52,600	151	161
Logan	LOGAN	123	\$2,054,473	16	33
Logan County*	LOGAN	322	\$5,437,382	20	37
Man	LOGAN	0	\$0	195	191
Mitchell Heights	LOGAN	8	\$474,200	111	77
West Logan	LOGAN	4	\$78,600	139	148
	<b>LOGAN</b>	<b>460</b>	<b>\$8,097,255</b>	<b>16</b>	<b>36</b>
Hartford	MASON	4	\$50,750	139	164
Henderson	MASON	6	\$17,100	123	186
Leon	MASON	3	\$43,400	151	169
Mason	MASON	0	\$0	195	191
Mason County*	MASON	238	\$5,342,114	29	38
New Haven	MASON	3	\$30,550	151	176
Point Pleasant	MASON	6	\$100,150	123	141
	<b>MASON</b>	<b>260</b>	<b>\$5,584,064</b>	<b>39</b>	<b>45</b>
Delbarton	MINGO	20	\$39,210	57	171
Gilbert	MINGO	9	\$107,300	104	137
Kermit	MINGO	8	\$139,700	111	125
Matewan	MINGO	4	\$0	139	191
Mingo County*	MINGO	325	\$1,463,565	19	51
Williamson	MINGO	161	\$2,125,517	14	31
	<b>MINGO</b>	<b>527</b>	<b>\$3,875,291</b>	<b>14</b>	<b>48</b>
Ceredo	WAYNE	25	\$886,700	52	53
Fort Gay	WAYNE	16	\$96,250	73	144
Huntington**	WAYNE	4	\$127,100	8**	8**
Kenova	WAYNE	0	\$0	195	191
Wayne	WAYNE	29	\$711,933	49	63
Wayne County*	WAYNE	654	\$16,119,958	5	20
	<b>WAYNE</b>	<b>728</b>	<b>\$17,941,942</b>	<b>10</b>	<b>22</b>

8\*\*: Parts of Huntington in each county represented separately, ranking is based on the sum of values in the city:

Huntington**	CABELL & WAYNE	284	\$24,287,653	8	8
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\* Unincorporated

\*\* Split Community

<sup>1</sup> Group Rank on Community Type: County, Unincorporated, Incorporated

Table 4 shows detailed risk of slope failure based on different occupancy classes. For all Region 2 counties, the **Residential** occupancy class has the highest structure counts and total replacement costs in high/medium landslide susceptibility areas. Replacement costs for the Other occupancy class should be ignored as some government and other property values do not get incorporated in the statewide assessment database, resulting in lower value of at-risk structures.

**Cabell County** has 688 structures in the Residential occupancy class with replacement costs of \$52,838,441, followed by 70 Other structures, and 14 Commercial structures with a total replacement cost of \$877,753. The unincorporated areas of Cabell County have the highest structure counts and corresponding replacements costs in all occupancy classes.

**Lincoln County** has a total of 300 structures in the Residential occupancy class with replacement costs of \$5,631,272, followed by 79 Other structures, and 4 Commercial structures with replacement costs of \$124,100. The unincorporated areas of Lincoln County have the highest structure counts and replacement costs in all occupancy classes. There are no at-risk structures in Hamlin.

**Logan County** has a total of 340 structures in the Residential occupancy class with replacement costs of \$6,775,064, followed by 100 Other structures, and 20 Commercial structures with a replacement cost of \$1,305,234. The unincorporated areas of Logan County have the highest structure counts and corresponding replacement costs in all occupancy classes. There are no at-risk structures in Man.

**Mason County** has a total of 134 structures in the Residential occupancy class with replacement costs of \$2,899,023, followed by 123 Other structures, and 3 Commercial structures with replacement costs of \$24,050. The unincorporated area has the highest structure counts in all occupancy classes and the highest replacement cost in the Residential class, while Point Pleasant has the highest replacement cost in the Commercial class. There are no at-risk structures in the city of Mason.

**Mingo County** has a total of 348 structures in the Residential occupancy class with replacement costs of \$3,354,667, followed by 166 Other structures, and 13 Commercial structures with replacement costs of \$449,245. The unincorporated areas of Mingo County have the highest structure counts in all occupancy classes, but Williamson has the highest replacement costs in the Residential and Commercial classes.

**Wayne County** has a total of 551 structures in the Residential occupancy class with replacement costs of \$16,865,767, followed by 161 Other structures, and 16 Commercial structures with replacement costs of \$539,367. The unincorporated area has the highest structure counts in all occupancy classes and the highest replacement costs in the Residential class, while Ceredo has the highest replacement costs in the Commercial class. There are no at-risk structures in Kenova.

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**Table 4. Types of Structures with High/Medium Risk Landslide Susceptibility**

Community Name	County	RESIDENTIAL OCCUPANCY CLASS		COMMERCIAL OCCUPANCY CLASS		OTHER OCCUPANCY CLASS	
		High/Medium Susceptibility		High/Medium Susceptibility		High/Medium Susceptibility	
		Residential count	Residential-value	Commercial count	Commercial value	Other count	Other value***
Barboursville	CABELL	11	\$3,060,800	1	\$17,900	1	\$0
Cabell County*	CABELL	410	\$25,733,588	12	\$679,253	54	\$501,408
Huntington**	CABELL	265	\$23,945,654	1	\$180,600	14	\$34,300
Milton	CABELL	2	\$98,400	0	\$0	1	\$28,550
	<b>CABELL</b>	<b>688</b>	<b>\$52,838,441</b>	<b>14</b>	<b>\$877,753</b>	<b>70</b>	<b>\$564,258</b>
Hamlin	LINCOLN	0	\$0	0	\$0	0	\$0
Lincoln County*	LINCOLN	299	\$5,619,939	4	\$124,100	79	\$298,356
West Hamlin	LINCOLN	1	\$11,333	0	\$0	0	\$0
	<b>LINCOLN</b>	<b>300</b>	<b>\$5,631,272</b>	<b>4</b>	<b>\$124,100</b>	<b>79</b>	<b>\$298,356</b>
Chapmanville	LOGAN	2	\$52,600	0	\$0	1	\$0
Logan	LOGAN	101	\$1,771,333	2	\$279,040	20	\$4,100
Logan County*	LOGAN	226	\$4,404,130	17	\$1,020,394	79	\$12,857
Man	LOGAN	0	\$0	0	\$0	0	\$0
Mitchell Heights	LOGAN	8	\$474,200	0	\$0	0	\$0
West Logan	LOGAN	3	\$72,800	1	\$5,800	0	\$0
	<b>LOGAN</b>	<b>340</b>	<b>\$6,775,064</b>	<b>20</b>	<b>\$1,305,234</b>	<b>100</b>	<b>\$16,957</b>
Hartford	MASON	4	\$50,750	0	\$0	0	\$0
Henderson	MASON	3	\$0	0	\$0	3	\$17,100
Leon	MASON	3	\$43,400	0	\$0	0	\$0
Mason	MASON	0	\$0	0	\$0	0	\$0
Mason County*	MASON	118	\$2,689,573	2	\$9,900	118	\$2,642,640
New Haven	MASON	2	\$29,300	0	\$0	1	\$1,250
Point Pleasant	MASON	4	\$86,000	1	\$14,150	1	\$0
	<b>MASON</b>	<b>134</b>	<b>\$2,899,023</b>	<b>3</b>	<b>\$24,050</b>	<b>123</b>	<b>\$2,660,990</b>
Delbarton	MINGO	12	\$39,210	0	\$0	8	\$0
Gilbert	MINGO	7	\$107,300	0	\$0	2	\$0
Kermit	MINGO	6	\$139,700	0	\$0	2	\$0
Matewan	MINGO	2	\$0	0	\$0	2	\$0
Mingo County*	MINGO	198	\$1,402,640	11	\$3,045	116	\$57,880
Williamson	MINGO	123	\$1,665,817	2	\$446,200	36	\$13,500
	<b>MINGO</b>	<b>348</b>	<b>\$3,354,667</b>	<b>13</b>	<b>\$449,245</b>	<b>166</b>	<b>\$71,380</b>
Ceredo	WAYNE	19	\$620,000	1	\$265,200	5	\$1,500
Fort Gay	WAYNE	12	\$96,250	0	\$0	4	\$0
Huntington**	WAYNE	3	\$105,700	1	\$21,400	0	\$0
Kenova	WAYNE	0	\$0	0	\$0	0	\$0
Wayne	WAYNE	25	\$665,033	1	\$46,900	3	\$0
Wayne County*	WAYNE	492	\$15,378,783	13	\$205,867	149	\$535,308
	<b>WAYNE</b>	<b>551</b>	<b>\$16,865,767</b>	<b>16</b>	<b>\$539,367</b>	<b>161</b>	<b>\$536,808</b>

Huntington**	CABELL & WAYNE	268	\$24,051,353	2	\$202,000	14	\$34,300
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\* Unincorporated

\*\* Split Community

\*\*\*Other occupancy class value is underreported as assessment value may be absent in assessment database.

## Limitations and Expert Consultation

Landslide susceptibility classifications are based on physical characteristics associated with landslide locations mapped using LiDAR data. The nature of the West Virginia landscape and the LiDAR imagery limited mapping to landslides at least 33 feet wide. This approach undercounts small, shallow landslides and slope failures that may have been mitigated or removed by human agents. LiDAR-mapped landslide locations and landslide susceptibility maps derived from this data are inherently biased against these areas. Additionally, it is not feasible to thoroughly verify the accuracy of each dataset used for mapping and modeling. However, every effort has been made to ensure the integrity of this data.

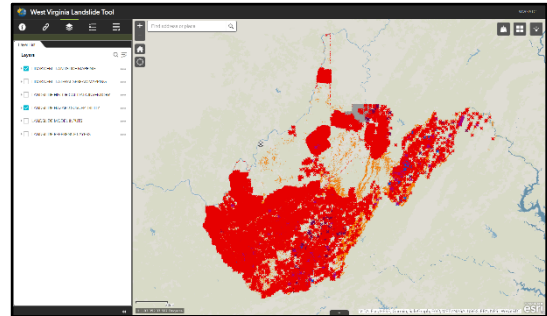
Landslide risk is complex and continually changing. Future mitigation projects or alterations to topography, land use, and climate may render these results inaccurate. Other models, maps, reports, and future site-specific analyses may provide results that differ from those included here.

**This study is NOT intended for regulatory use and is NOT the final authoritative source of all landslide risk data in the community. It should be used in conjunction with other data sources to provide a comprehensive picture of general landslide risk. This report is for informational and planning purposes regarding landslide susceptibility and risk at the county scale. It may not be used to identify susceptibility at site-specific locations.**

To address landslide susceptibility at a sub-county scale, geotechnical evaluations should be performed by professional engineers or geologists. For site-specific investigations, local officials, developers, and property owners should consult slope-stability experts, such as certified professional engineers and qualified geologists. Site-specific evaluations for landslide susceptibility can only be provided by performing detailed site-specific geotechnical studies, including bedrock and soil analyses, core description, physical testing, and slope-stability analyses.

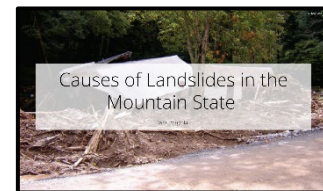
## Outreach Materials

- The West Virginia Landslide Tool** (<http://mapwv.gov/landslide>) is a landslide web mapping application showing landslide incidence data and modeling results. The West Virginia GIS Technical Center created an ArcGIS online map that provides information about landslide susceptibility and landslides mapped throughout West Virginia. The map allows users to display landslide locations mapped by the West Virginia Department of Transportation (WV DOT), West Virginia Geological and Economic Survey (WVGES), United States Geological Survey (USGS), several independent research projects, and landslides mapped using high-resolution elevation data. The public can also add landslide locations to the West Virginia Landslide Tool (<http://www.mapwv.gov/landslide>) by taking a photo of the landslide and uploading it to the application.



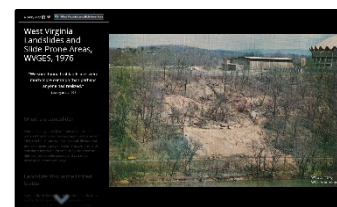
**Figure 10.** [West Virginia Landslide Tool](http://mapwv.gov/landslide)

- Story Maps**
  - Causes of Landslides in Mountain State, West Virginia***  
<https://arcg.is/1SW0Sn> discusses different causes of landslides in the state.



**Figure 11.** Story Map showing causes of landslide

- West Virginia Landslides and Slide Prone Areas, WVGES 1976***  
<https://arcg.is/1KDnvg> discusses landslide risk assessment published in 1976 by the WV Geological and Economic Survey that was funded by the Appalachian Regional Commission.



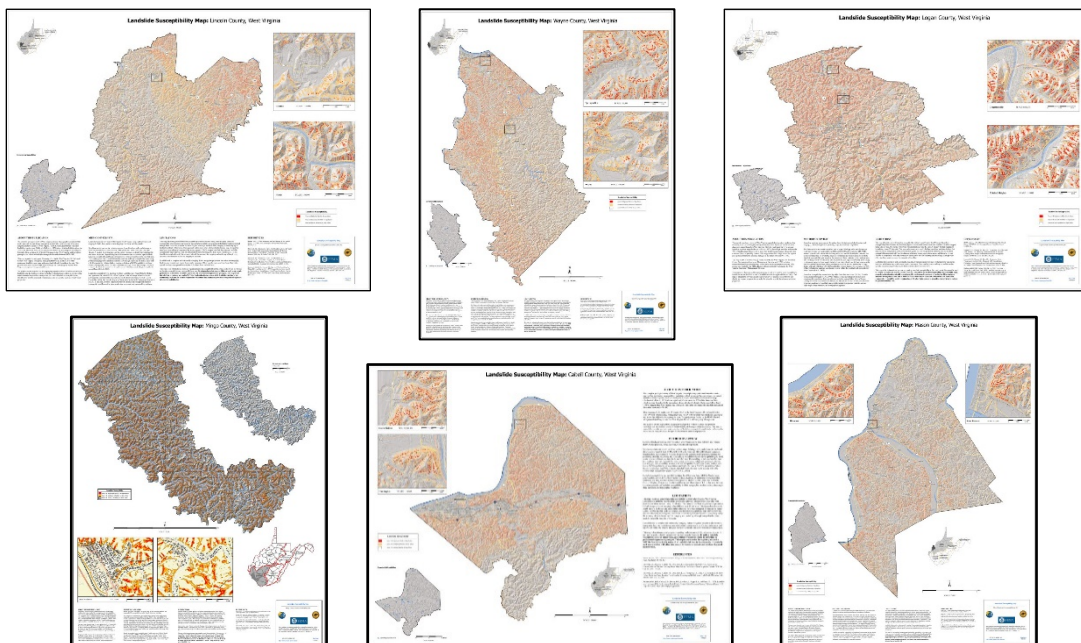
**Figure 12.** WVGES 1976 Study details in Story Map

- **Educational brochures** were developed to provide general information about identifying signs of slope instability and mitigation measures that may help reduce landslide risk at the [community](#) and [individual](#) property levels.



**Figure 13.** Mitigation brochure for community and property owners

- **Landslide susceptibility modelling publications-** Two peer reviewed modelling papers have been published in refereed journals
  - [Slope Failure Prediction Using Random Forest Machine Learning and LiDAR in an Eroded Folded Mountain Belt](#) – Published in journal Remote Sensing
  - [Assessing the Generalization of Machine Learning-Based Slope Failure Prediction to New Geographic Extents](#) – Published in journal International Journal of Geo-Information
- **County Landslide Susceptibility Maps** – Landslide susceptibility maps for Lincoln, Logan, Mingo, Wayne, Cabell, and Mason counties can be viewed and downloaded [here](#).



**Figure 14.** Landslide Susceptibility maps of Lincoln, Logan, Mingo, Wayne, Cabell, and Mason counties

### Statewide Risk Assessment Contacts

Statewide Risk Assessment Technical Support, WVU GIS Technical Center

- Kurt Donaldson ([kurt.donaldson@mail.wvu.edu](mailto:kurt.donaldson@mail.wvu.edu))
- Maneesh Sharma ([maneesh.sharma@mail.wvu.edu](mailto:maneesh.sharma@mail.wvu.edu))
- Eric Hopkins ([Eric.Hopkins@mail.wvu.edu](mailto:Eric.Hopkins@mail.wvu.edu))

WV Emergency Management Division

- Brian Penix, State Hazard Mitigation Project Officer ([Brian.M.Penix@wv.gov](mailto:Brian.M.Penix@wv.gov))
- Tim Keaton, State Hazard Mitigation Planner ([Tim.W.Keaton@wv.gov](mailto:Tim.W.Keaton@wv.gov))
- Kevin Sneed, CTP Coordinator ([Kevin.L.Sneed@wv.gov](mailto:Kevin.L.Sneed@wv.gov))
- Nuvia E. Villamizar, GIS Manager ([nuvia.e.villamizar@wv.gov](mailto:nuvia.e.villamizar@wv.gov))

State NFIP Coordinator, WV Office of the Insurance Commissioner

- Chuck Grishaber ([Charles.C.Grishaber@wv.gov](mailto:Charles.C.Grishaber@wv.gov))