Landslide along Kanawha County Route-5/3
Photo by WV DOT

West Virginia Landslide Risk Assessment

Region 3 – Putnam, Kanawha, Clay, & Boone counties

FEBRUARY 9, 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, 14,669 landslide points were identified using LiDAR in Region 3. 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 3 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 3, **Boone County** has about 17 miles of road that is susceptible to high/medium probability of landslides. **Clay County** has almost 85 miles, **Kanawha County** has about 152 miles, and **Putnam County** has about 64 miles of road prone to high/medium risk of slope failure. Counties were ranked for slope failure risk based on the number of miles that are at risk. One Region 3 county ranks in the Top 5 for highest number of road miles at risk from landslides in the state. Of all 55 counties, Boone County ranks 53rd, Clay 25th, Kanawha 4th, and Putnam 33rd. In each county, most of the at-risk roads are in unincorporated areas.

Structure/Parcel analysis - **Boone County** has a total of 300 primary structures with a total appraisal value of $13,109,525 that are in high/medium susceptibility areas. **Clay County** has 330 primary structures with a total appraisal value of $4,619,880 in high/medium susceptibility areas. **Kanawha County** has 5,751 primary structures with a total appraisal value of $399,596,198 in high/medium susceptibility areas. **Putnam County** has 575 primary structures with a total appraisal value of $38,146,493 in high/medium susceptibility areas. Boone County ranks 33rd for total number of at-risk structures and 27th for total at-risk replacement costs in the state. Clay County ranks 28th for total number of at-risk structures and 47th for total at-risk replacement costs. **Kanawha County ranks 1st for both total number of at-risk structures and highest at-risk replacement costs in the entire state.** Putnam County ranks 12th for number of at-risk structures and 10th for total at-risk replacement costs.

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 3 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.

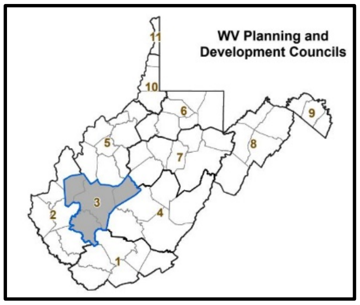

Figure 1. *Planning and development regions in West Virginia*

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:

Landslide Risk = Susceptibility x Consequences

Where,

Susceptibility = the likelihood of occurrence
Consequences = the estimated impacts associated with the occurrence

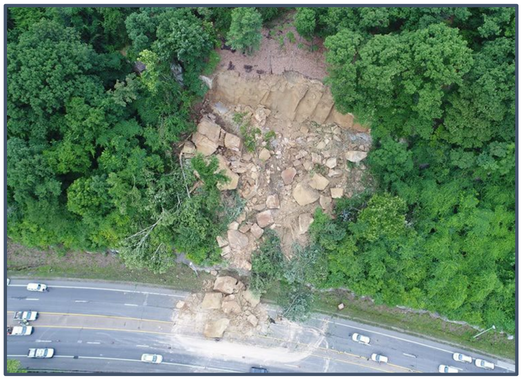

Figure 3. *The **consequences** of a landslide are often higher in populated areas due to resulting property damage and injury to citizens (Photo by WVDOT)*

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**.

- **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 14,256 landslide polygons from Region 3.

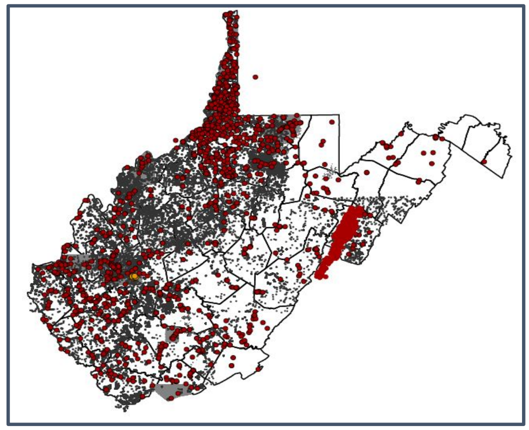

Figure 4. *Historical landslides were compiled from several studies to create a comprehensive landslide dataset (Image adapted from the West Virginia Landslide Tool)*

- **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 4,295 polygons from Region 3.

- **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 143 landslide points in Region 3 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, 14,669 landslide points were identified in Region 3.

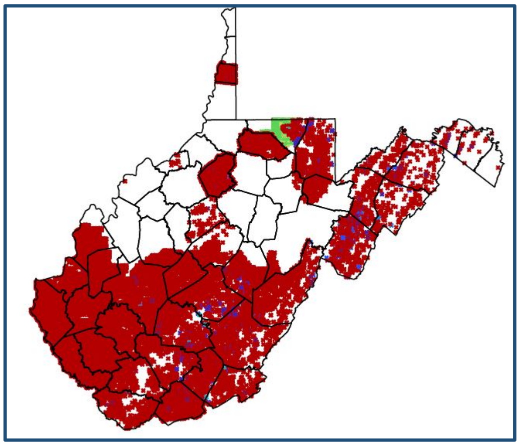

Figure 5. *LiDAR-mapped landslide points are dependent upon the presence of 1- or 2-meter LiDAR data (Image from the West Virginia Landslide Tool)*

Landslide Susceptibility Methodology

Landslide susceptibility has been generated as a raster grid 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:

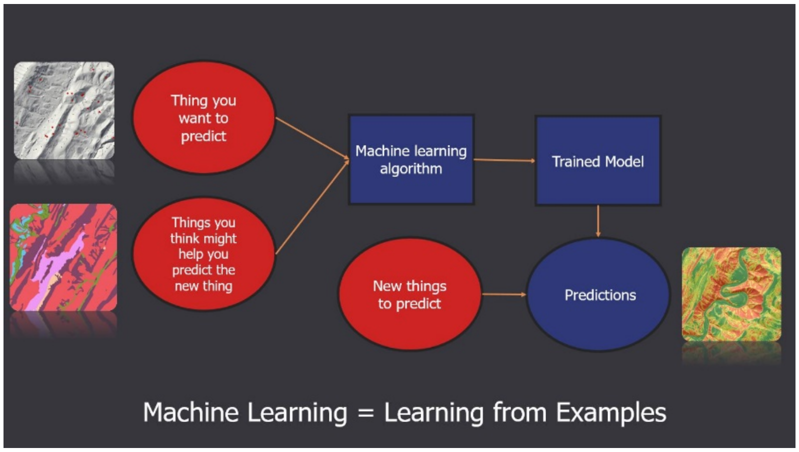

Figure 6. *Simplified diagram showing machine learning process for generating landslide susceptibility grid*

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).

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 slopeshades. 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).

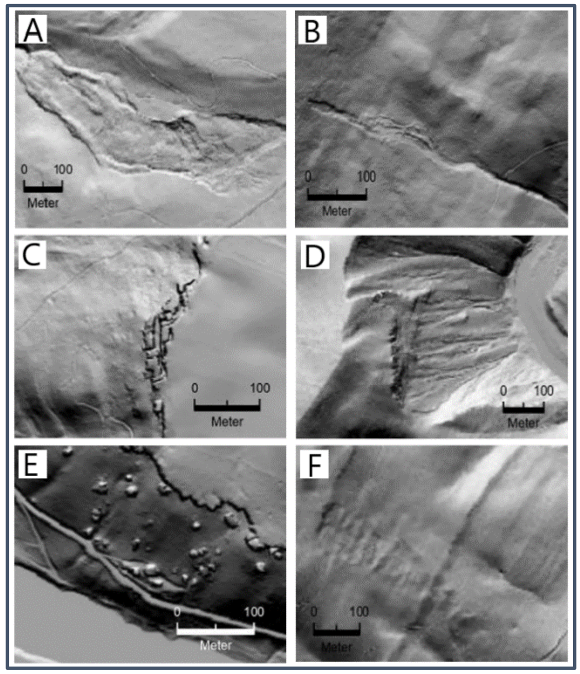

Figure 7. *A) Slide B) Debris Flow C) Lateral Spread D) Multiple Failures E) Fall F) Undetermined*

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 3: the **Central Allegheny Plateau** and the **Cumberland Plateau and Mountains**. The Central Allegheny Plateau MLRA covers all of Putnam County, northwestern Kanawha County, and northern Clay County. The Cumberland Plateau and Mountains MLRA covers southeastern Kanawha County, southern Clay County, and all of Boone County (Figure 8).

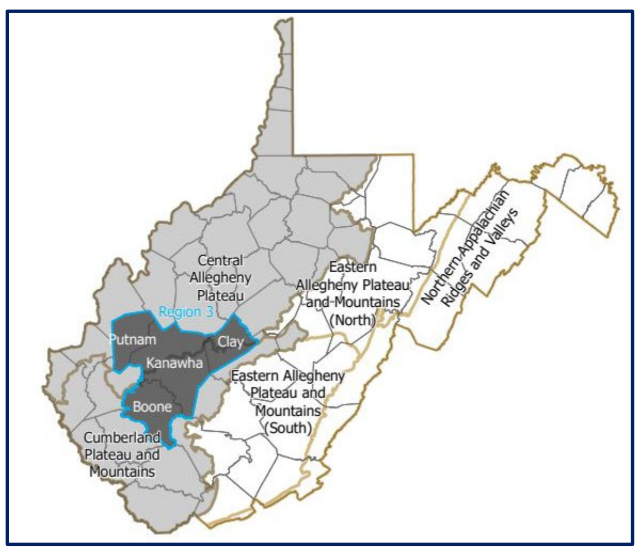

Figure 8. *Major land resource areas in West Virginia*

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 3 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 3 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 MLRA. 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 3. 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 3. 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 3. 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 3 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 Putnam, Kanawha, Clay, and Boone 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 3.

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 road feature class as most landslides initiate on the side slopes of roads. An intersection between the buffered road layer and 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 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. Railroad 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**. Boone County** has about 17 miles of road that is susceptible to high/medium probability of landslides. **Clay County** has almost 85 miles, **Kanawha**

County has about 152 miles, and **Putnam County** has about 64 miles of road prone to high/medium risk of slope failure. Counties were ranked for slope failure risk based on the number of miles that are at risk. One Region 3 county ranks in the Top 5 for highest number of road miles at risk from landslides in the state. Of all 55 counties, Boone County ranks 53rd, Clay 25th, Kanawha 4th, and Putnam 33rd. In each county, most of the at-risk roads are in unincorporated areas. Figure 9 shows an example of landslide risk near Charleston, WV in Kanawha County. The road segments susceptible to landslide can be viewed on the Landslide Tool.

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

Community Name	County	Roads Total (miles)	Roads Total (miles)- High/Medium Risk	Rank[1]
Boone County*	BOONE	413.8	17.3	51
Danville	BOONE	8.1	0	189
Madison	BOONE	10.1	0.1	155
Sylvester	BOONE	1.4	0	189
Whitesville	BOONE	2.9	0	189
	BOONE	**436.3**	**17.4**	**53**
Clay	CLAY	7.3	1.8	24
Clay County*	CLAY	528.9	82.8	24
	CLAY	**536.2**	**84.6**	**25**
Belle	KANAWHA	7.6	0.1	155
Cedar Grove	KANAWHA	5.5	0.1	155
Charleston	KANAWHA	154.4	9.2	1
Chesapeake	KANAWHA	11.9	0.5	68
Clendenin	KANAWHA	10	2.2	20
Dunbar	KANAWHA	17.4	0.5	68
East Bank	KANAWHA	1.3	0	189
Glasgow	KANAWHA	1.7	0	189
Handley	KANAWHA	2.4	0.2	127
Kanawha County*	KANAWHA	1415.2	135.3	5
Marmet	KANAWHA	7.5	0.2	127
Montgomery**	KANAWHA	3.4	0.2	100**
Nitro**	KANAWHA	17.6	0.4	42**
Pratt	KANAWHA	3.3	0	189
Smithers**	KANAWHA	0.2	0	189**
South Charleston	KANAWHA	46.8	2.8	12
St. Albans	KANAWHA	18.9	0.8	47
	KANAWHA	**1725.1**	**152.5**	**4**
Bancroft	PUTNAM	0.9	0.1	155
Buffalo	PUTNAM	8.4	0.3	100
Eleanor	PUTNAM	3.7	0	189
Hurricane	PUTNAM	32.2	0.4	85
Nitro**	PUTNAM	8.4	0.5	42**
Poca	PUTNAM	3.3	0.2	127
Putnam County*	PUTNAM	682.9	62.1	34
Winfield	PUTNAM	4.4	0.1	155
	PUTNAM	**744.2**	**63.7**	**33**

100**, 42**, 189**: Parts of Montgomery, Nitro, & Smithers in each county represented separately, ranking is based on the sum of values in the city:

Montgomery**	FAYETTE & KANAWHA	6.8	0.3	100
Nitro**	KANAWHA & PUTNAM	26	0.9	42
Smithers**	FAYETTE & KANAWHA	8.8	0	189

* Unincorporated
** Split Community
[1] Group Rank on Community Type: County, Unincorporated, Incorporated

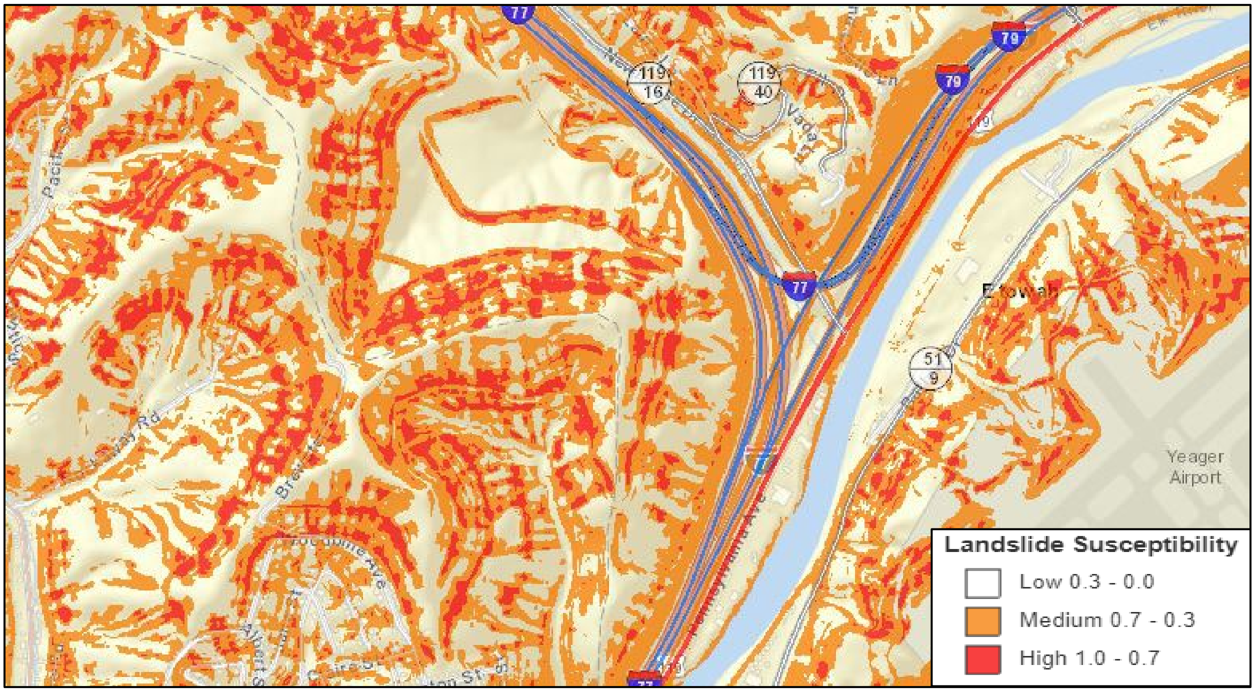

Figure 9. *Landslide Susceptibility near Charleston, WV in Kanawha County. Notice high and medium landslide susceptibility areas along I-77 and I-79 and surrounding Yeager Airport. Data can be accessed on WV Flood Tool*

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 **Boone County**, the unincorporated area has about 17 miles of at-risk roads, constituting 99% of at-risk roads in the county; 0.1 miles of US roads; and 2.6 miles of State roads are at-risk. Madison has 0.1 miles of at-risk roads. There are no at-risk roads in the remaining Boone County communities. There are no Interstate roads at risk in the county. **Clay County** has almost 83 miles of at-risk roads in unincorporated areas, constituting 98% of at-risk roads in the county. Unincorporated areas have 1.9 miles of Interstate roads at-risk and 7.3 miles of State roads at-risk. The town of Clay has 1.8 miles of at-risk roads. There are no US roads at risk in the county. In **Kanawha County**, the unincorporated area has about 135 miles of at-risk roads, constituting 89% of at-risk roads in the county. The unincorporated area has 4.1 miles of Interstate roads, 7.3 miles of US roads, and 7.4 miles of State roads at risk. **Charleston has 9.2 miles of at-risk roads and ranks 1st among incorporated communities in the state for number of at-risk road miles.** Clendenin has 2.2 miles of roads at risk, South Charleston has 2.8 miles, and the remaining incorporated communities have less than 1 mile each. There are no at-risk roads in East Bank, Glasgow, Pratt, and Smithers. In **Putnam County**, the unincorporated area has 62.1 miles of at-risk roads, constituting 97% of at-risk roads in the county. The incorporated communities each have less than 1 mile of roads at risk. There are no at-risk roads in Eleanor.

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
Boone County*	BOONE	413.8	17.3	0	0.1	2.6	14.5
Danville	BOONE	8.1	0	0	0	0	0
Madison	BOONE	10.1	0.1	0	0	0.1	0
Sylvester	BOONE	1.4	0	0	0	0	0
Whitesville	BOONE	2.9	0	0	0	0	0
	BOONE	**436.3**	**17.4**	**0**	**0.1**	**2.7**	**14.5**
Clay	CLAY	7.3	1.8	0	0	0.9	0.9
Clay County*	CLAY	528.9	82.8	1.9	0	7.3	73.7
	CLAY	**536.2**	**84.6**	**1.9**	**0**	**8.2**	**74.6**
Belle	KANAWHA	7.6	0.1	0	0	0	0.1
Cedar Grove	KANAWHA	5.5	0.1	0	0	0	0
Charleston	KANAWHA	154.4	9.2	1.3	1	1.3	5.6
Chesapeake	KANAWHA	11.9	0.5	0.5	0	0	0
Clendenin	KANAWHA	10	2.2	0	0.2	0.4	1.6
Dunbar	KANAWHA	17.4	0.5	0.3	0	0	0.2
East Bank	KANAWHA	1.3	0	0	0	0	0
Glasgow	KANAWHA	1.7	0	0	0	0	0
Handley	KANAWHA	2.4	0.2	0	0	0.2	0
Kanawha County*	KANAWHA	1415.2	135.3	4.1	7.3	7.4	116.5
Marmet	KANAWHA	7.5	0.2	0.1	0	0	0.1
Montgomery**	KANAWHA	3.4	0.2	0	0	0.1	0
Nitro**	KANAWHA	17.6	0.4	0.1	0	0.1	0.2
Pratt	KANAWHA	3.3	0	0	0	0	0
Smithers**	KANAWHA	0.2	0	0	0	0	0
South Charleston	KANAWHA	46.8	2.8	0.4	0.2	0.4	1.8
St. Albans	KANAWHA	18.9	0.8	0	0	0	0.8
	KANAWHA	**1725.1**	**152.5**	**6.8**	**8.7**	**9.9**	**126.9**
Bancroft	PUTNAM	0.9	0.1	0	0	0	0.1
Buffalo	PUTNAM	8.4	0.3	0	0	0	0.3
Eleanor	PUTNAM	3.7	0	0	0	0	0
Hurricane	PUTNAM	32.2	0.4	0	0	0.2	0.2
Nitro**	PUTNAM	8.4	0.5	0.2	0	0	0.3
Poca	PUTNAM	3.3	0.2	0	0	0.2	0
Putnam County*	PUTNAM	682.9	62.1	0.2	4	3.6	54.3
Winfield	PUTNAM	4.4	0.1	0	0	0	0.1
	PUTNAM	**744.2**	**63.7**	**0.4**	**4**	**4**	**55.3**

Montgomery**	FAYETTE & KANAWHA	6.8	0.3	0	0	0.2	0
Nitro**	KANAWHA & PUTNAM	26	0.9	0.3	0	0.1	0.5
Smithers**	FAYETTE & KANAWHA	8.8	0	0	0	0	0

* 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 and 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 in the rest of the area outside of 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. **Boone County** has a total of 300 primary structures with a total appraisal value of $13,109,525 that are in high/medium susceptibility areas. **Clay County** has 330 primary structures with a total appraisal value of $4,619,880 in high/medium susceptibility areas. **Kanawha County** has 5,751 primary structures with a total appraisal value of $399,596,198 in high/medium susceptibility areas. **Putnam County** has 575 primary structures with a total appraisal value of $38,146,493 in high/medium susceptibility areas. Boone County ranks 33rd for total number of at-risk structures and 27th for total at-risk replacement costs in the state. Clay County ranks 28th for total number of at-risk structures and 47th for total at-risk replacement costs. **Kanawha County ranks 1st for both total number of at-risk structures and highest**

at-risk replacement costs in the entire state. Putnam County ranks 12th for number of at-risk structures and 10th for total at-risk replacement costs.

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

Community Name	County	Total Count	Total Value	Ranking(Count)[1]	Ranking(Value)[1]
Boone County*	BOONE	271	$12,244,492	24	24
Madison	BOONE	20	$607,283	57	66
Whitesville	BOONE	4	$45,550	139	168
Danville	BOONE	5	$212,200	129	107
Sylvester	BOONE	0	$0	195	191
	BOONE	**300**	**$13,109,525**	**33**	**27**
Clay County*	CLAY	290	$3,563,047	22	43
Clay	CLAY	40	$1,056,833	38	48
	CLAY	**330**	**$4,619,880**	**28**	**47**
Kanawha County*	KANAWHA	2328	$111,609,824	1	2
Montgomery**	KANAWHA	2	$7,500	164**	189**
Belle	KANAWHA	4	$141,400	139	124
Cedar Grove	KANAWHA	5	$119,986	129	130
Charleston	KANAWHA	2411	$199,300,285	1	2
Chesapeake	KANAWHA	0	$0	195	191
Clendenin	KANAWHA	80	$1,938,517	25	34
Dunbar	KANAWHA	106	$6,612,534	18	15
East Bank	KANAWHA	4	$61,200	139	156
Glasgow	KANAWHA	1	$27,900	178	179
Marmet	KANAWHA	11	$117,900	89	131
Nitro**	KANAWHA	36	$3,292,100	37**	20**
Pratt	KANAWHA	0	$0	195	191
St. Albans	KANAWHA	140	$11,023,433	15	11
South Charleston	KANAWHA	620	$65,291,219	4	4
Handley	KANAWHA	3	$52,400	151	162
Smithers**	KANAWHA	0	$0	178**	190**
	KANAWHA	**5751**	**$399,596,198**	**1**	**1**
Nitro**	PUTNAM	8	$140,200	37**	20**
Bancroft	PUTNAM	10	$56,100	94	158
Buffalo	PUTNAM	0	$0	195	191
Hurricane	PUTNAM	17	$2,181,700	69	30
Eleanor	PUTNAM	8	$1,037,500	111	49
Winfield	PUTNAM	1	$169,100	178	114
Putnam County*	PUTNAM	531	$34,561,893	7	7
Poca	PUTNAM	0	$0	195	191
	PUTNAM	**575**	**$38,146,493**	**12**	**10**

164**,189**,37**,20**,178**,190**: Parts of Montgomery, Nitro, & Smithers in each county represented separately, ranking is based on the sum of values in the city:

Montgomery**	KANAWHA & FAYETTE	2	7500	164	189
Nitro**	KANAWHA & PUTNAM	44	3432300	37	20
Smithers**	KANAWHA & FAYETTE	1	500	178	190

* Unincorporated

** Split Community

[1] Group Rank on Community Type: County, Unincorporated, Incorporated

Table 4 shows detailed risk of slope failure based on different occupancy classes. For most Region 3 counties, the **Residential** occupancy class has the highest structure count and total replacement cost in high/medium landslide susceptibility areas. In Boone County, structures in the Commercial occupancy class have a higher replacement cost than the Residential class, even though the structure count is far lower. 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 a lower value of at-risk structures.

Boone County has 187 structures in the Residential occupancy class with replacement costs of $4,589,804, followed by 92 Other structures, and 21 Commercial structures with a total replacement cost of $8,439,787. The unincorporated areas of Boone County have the highest structure counts and corresponding replacements costs in all occupancy classes. There are no at-risk structures in Sylvester.

Clay County has a total of 236 structures in the Residential occupancy class with replacement costs of $3,454,713, followed by 85 Other structures, and 9 Commercial structures with replacement costs of $185,500. The unincorporated area has the highest structure count and replacement cost in the Residential class, while the town of Clay has the highest structure count and replacement cost in the Commercial class.

Kanawha County has a total of 5,204 structures in the Residential occupancy class with replacement costs of $389,742,542, followed by 488 Other structures, and 59 Commercial structures with replacement costs of $4,371,328. Charleston has the highest structure count and replacement cost in the Residential class, while the unincorporated portion of Kanawha County has the highest structure count and replacement cost in the Commercial class. There are no at-risk structures in Chesapeake, Pratt, and Smithers.

Putnam County has 451 structures in the Residential occupancy class with replacement costs of $36,862,999, followed by 121 Other structures, and 3 Commercial structures with a total replacement cost of $190,300. The unincorporated areas of Putnam County have the highest structure counts and corresponding replacements costs in all occupancy classes. There are no at-risk structures in Buffalo and Poca.

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***
Boone County*	BOONE	165	$3,728,471	21	$8,439,787	85	$76,234
Madison	BOONE	14	$606,533	0	$0	6	$750
Whitesville	BOONE	3	$42,600	0	$0	1	$2,950
Danville	BOONE	5	$212,200	0	$0	0	$0
Sylvester	BOONE	0	$0	0	$0	0	$0
	BOONE	**187**	**$4,589,804**	**21**	**$8,439,787**	**92**	**$79,934**
Clay County*	CLAY	210	$3,128,780	4	$9,700	76	$424,567
Clay	CLAY	26	$325,933	5	$175,800	9	$555,100
	CLAY	**236**	**$3,454,713**	**9**	**$185,500**	**85**	**$979,667**
Kanawha County*	KANAWHA	1966	$108,266,308	36	$2,097,972	326	$1,245,544
Montgomery**	KANAWHA	2	$7,500	0	$0	0	$0
Belle	KANAWHA	4	$141,400	0	$0	0	$0
Cedar Grove	KANAWHA	3	$79,086	2	$40,900	0	$0
Charleston	KANAWHA	2276	$196,056,706	12	$1,813,429	123	$1,430,150
Chesapeake	KANAWHA	0	$0	0	$0	0	$0
Clendenin	KANAWHA	59	$1,842,617	7	$95,900	14	$0
Dunbar	KANAWHA	103	$6,612,534	0	$0	3	$0
East Bank	KANAWHA	3	$61,100	0	$0	1	$100
Glasgow	KANAWHA	1	$27,900	0	$0	0	$0
Marmet	KANAWHA	7	$117,900	0	$0	4	$0
Nitro**	KANAWHA	34	$3,289,600	0	$0	2	$2,500
Pratt	KANAWHA	0	$0	0	$0	0	$0
St. Albans	KANAWHA	136	$11,019,300	0	$0	4	$4,133
South Charleston	KANAWHA	607	$62,168,191	2	$323,128	11	$2,799,900
Handley	KANAWHA	3	$52,400	0	$0	0	$0
Smithers**	KANAWHA	0	$0	0	$0	0	$0
	KANAWHA	**5204**	**$389,742,542**	**59**	**$4,371,328**	**488**	**$5,482,327**
Nitro**	PUTNAM	6	$136,300	0	$0	2	$3,900
Bancroft	PUTNAM	7	$56,100	0	$0	3	$0
Buffalo	PUTNAM	0	$0	0	$0	0	$0
Hurricane	PUTNAM	16	$2,181,700	0	$0	1	$0
Eleanor	PUTNAM	8	$1,037,500	0	$0	0	$0
Winfield	PUTNAM	1	$169,100	0	$0	0	$0
Putnam County*	PUTNAM	413	$33,282,299	3	$190,300	115	$1,089,293
Poca	PUTNAM	0	$0	0	$0	0	$0
	PUTNAM	**451**	**$36,862,999**	**3**	**$190,300**	**121**	**$1,093,193**

Montgomery**	KANAWHA & FAYETTE	2	$7,500	0	$0	0	$0
Nitro**	KANAWHA & PUTNAM	40	$3,425,900	0	$0	4	$6,400
Smithers**	KANAWHA & FAYETTE	1	$500	0	$0	0	$0

* 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.

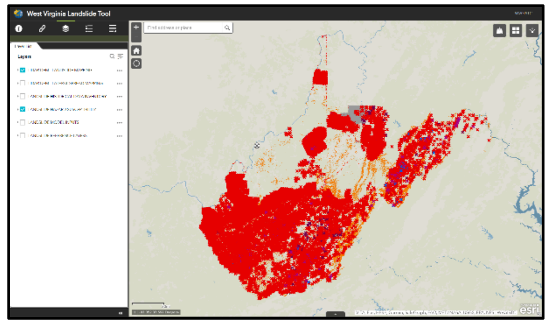

Figure 10. *West Virginia Landslide Tool*

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

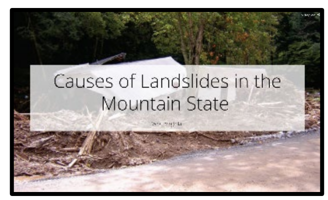

Figure 11. *Story Map showing causes of landslide*

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

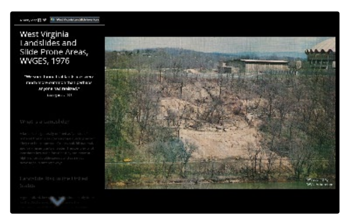

Figure 12. *WVGES 1976 Study details in Story Map*

- **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 Putnam, Kanawha, Clay, and Boone counties can be viewed and downloaded here.

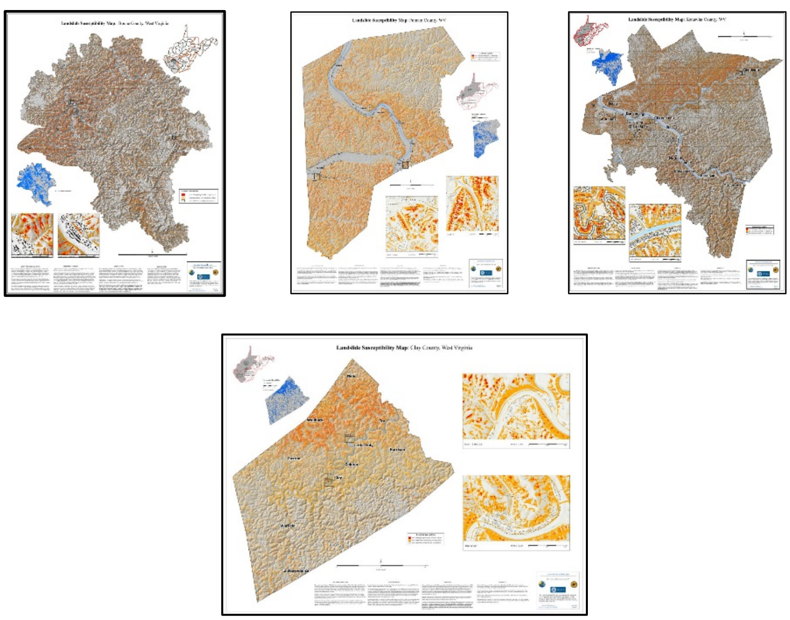

Figure 14. *Landslide Susceptibility maps of Putnam, Kanawha, Clay, and Boone counties.*

Statewide Risk Assessment Contacts

Statewide Risk Assessment Technical Support, WVU GIS Technical Center
- Kurt Donaldson (kurt.donaldson@mail.wvu.edu)
- Maneesh Sharma (maneesh.sharma@mail.wvu.edu)
- Eric Hopkins (Eric.Hopkins@mail.wvu.edu)

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

State NFIP Coordinator, WV Office of the Insurance Commissioner
- Chuck Grishaber (Charles.C.Grishaber@wv.gov)