

A Landslide Risk Assessment Project for the Mountain State of West Virginia

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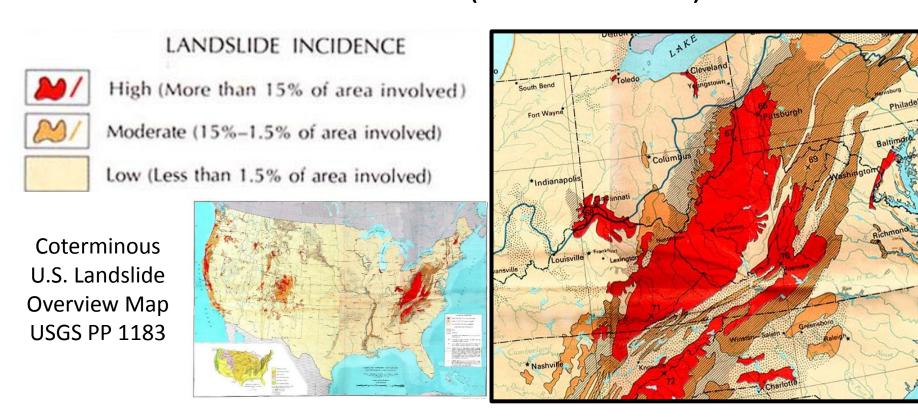
Session # 41 "T25. Geologic Hazards: Hazard Maps, Risk Analysis and Reduction, and Long-term Landscape Evolution

115th Annual Meeting GSA Cordilleran Section, Portland, Oregon Booth 50, Exhibit Hall B, Oregon Convention Ctr. 9 AM-3:30 PM, 17 May 2019

Funded by FEMA Hazard Mitigation Grant Program & WV Division of Homeland Security and Emergency Preparedness

Why West Virginia Landslides?

- Landslides = #2 West Virginia Hazard (FEMA).
- West Virginia = 11.2% of 1973-1983 Landslide Damage
 in 48 States (Brabb, 1984, USGS OF 84-486).
- West Virginia = #1 in Per Capita Landslide Damage.
- ~75% of West Virginia Has "High Landslide Incidence" No Other State Has >25% (USGS PP 1183).



Project Highlights

West Virginia GIS Technical Center Began FEMA-supported Statewide Landslide Risk Assessment in Summer 2018.

Long-Term Goals:

- Comprehensive Ongoing Statewide Landslide Inventory.
- Interactive Web-based App for Graphically Displaying & Collecting Landslide Information.
- Landslide Models for Specific WV Regions.
- County-Level Landslide Susceptibility Maps.
- Local Landslide Risk Reports to Inform Emergency Preparedness & Hazard Mitigation Planning.
- Public & Stakeholder Outreach.
- Update State Hazard Mitigation Plan.

Initial Steps:

- Launched Statewide Landslide Inventory.
- >75,000 Previously Identified Landslides.
- > 10 Disparate Sources: Disparate Data.
- Landslide Mapping Protocol for QL2 LiDAR DEMs
- >3,000 Newly Mapped Landslides.
- Updates as West Virginia QL2 LiDAR DEMs Arrive.
- **Digital Topography**, Hill-Shade, & Slope-Shade Layers.
- Lithology & Soil Parent Material Maps.
- West Virginia Landslide Bibliography.
- ESRI Story Maps on Case Studies & General Hazard.

Landslide Incidence Modelling Inputs:

- Geology (Stratigraphic Units & General Lithologies).
- Soils (Parent Material & Drainage Class).
- Topography.
- Transportation Infrastructure.
- Flow-Accumulation Generated Stream Networks.

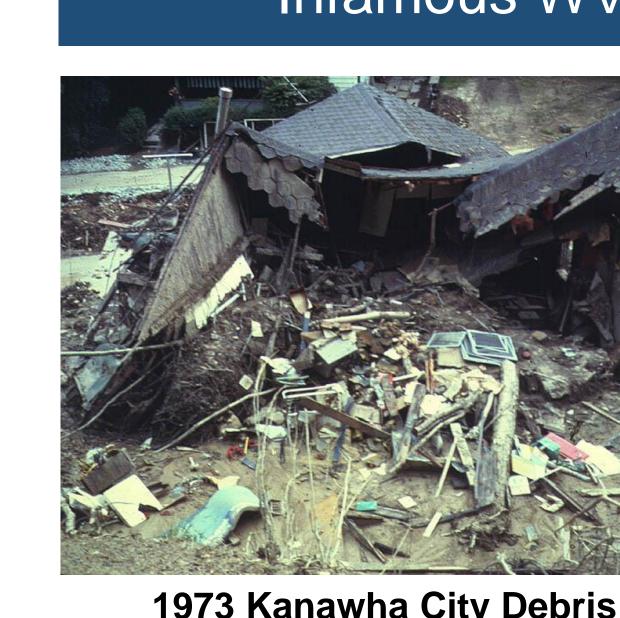
Key Factors in Regional Slope Instability:

- Anthropogenic Activities.
- Quaternary River Rerouting & Valley Incision.
- Pleistocene Periglacial Instability.
- Bedrock **Dip** vs. Slope Orientation.

Landslide Risk:

• Address in Years 2-3 (after Incidence & Susceptibility).

Infamous WV Landslides



Landslide Incidence

West Virginia Landslide Project

Elevation Change

West Virginia Landslides Project December 2018

Slope (degrees)

Generalized Bedrock Lithologies

Generalized Soils

Central Allegheny

Appalachian Ridges

Funding from FEMA Hazard Mitigation Grant Program and

West Virginia Landslide Project

Residuum, Calcareous Clastic

Major Land Resource Area (MLRA) - USDA

Residuum, Limestone

Residuum, Metamorphic/

Old Alluvium

Created by WVGISTC: 12/19/2018

1976 WVGES (n= 42,277)

> Jacobson, Wills Mountain Anticlilne (n= 3,571)





2015 Yeager Airport \$18 Million (AP Photo)

Landslide Classification for Mapping WV

Arm-Chair Thoughts - J.S. Kite Draft Version 0.1, Feb 2019

		Material before Failure (Engineering Criteria)			
Failure Motion		Bedrock S		oil	
General Motion	Type of Motion	Rock	Debris (>20% larger than sand)	Earth (<20% larger than sand	
Falling	Fall	Rock Fall	Debris Fall	Earth Fall	
	Topple (Falling Over)	Rock Topple	Debris Topple	Earth Topple	
	Collapse * (Roof Failure into Large Void Space)	Rock Collapse	Debris Collapse	Earth Collapse	
Sliding	Slide (Translational Sliding along Planar Surface)	Rock Slide	Debris Slide	Earth Block Slide	
	Slump (Rotational Sliding along Concave Surface)	Rock Slump	Debris Slump	Earth Slump	
Flowing	Lateral Spread	Rock Lateral Spread	Debris Lateral Spread	Earth Lateral Spread	
	Creep * (Slow Downslope Creep)	Rock Creep	Debris Creep	Earth Creep	
	Flow (Viscous Channel Flow)	Rock Flow	Debris Flow	Earth Flow	
	Avalanche (Very Rapid Flow over Compressed Air)	Rock Avalanche	Debris Avalanche	Earth Avalanche	
Complex	Common W. Va. Examples	Rock Spread-Slide	Debris Slide-Flow	Earth Slump-Flow	

Modified from Campbell, RH, Varnes, DJ, Fleming, RW, Hampton, MA, Prior, DB, Sangrey, DA, Nichols, DR, & Brabb, EE, 1985,

- andslide classification for identification of mud flows and other landslides: **USGS Open-File Report 85-276**, p A1-A24.
- Asterisk * Denotes Landslide Type Not in USGS Open-File Report 85-276.
- Italicized Landslides Not Mapped Because Types Are Difficult to Recognize, Rare Statewide, or Outside Project Scope.
- Some Debris Flows Have Been Labelled Debris Avalanches, But Central Appalachian Debris Avalanches Are Very Rare.

Reality Check After Mapping Trials – Draft Version 0.2, March 2019, Revised 4 June 2019

		Material before Failure (Engineering Criteria)		
Failure Motion		Bedrock Soil		
General Motion	Type of Motion	Rock	Debris = Default Material in WV	
Falling	Fall	Rock Fall	Rare & Difficult to Discern	
	Topple (Falling Over)			
	Collapse * (Roof Failure into Large Void Space)	Karst & Mine Subsidence Outside Project Scope		
	Slide (Translational Sliding along Planar Surface)	Oli de		
Sliding	Slump (Rotational Sliding along Concave Surface)	Slide		
	Lateral Spread	Lateral Spread	Rare & Difficult to Discern	
	Creep * (Slow Downslope Creep with No Slip Surface)	Creep Not Discernable from Stable Slope		
Flowing	Flow (Rapid Viscous Channel Flow)	Very Rare	Debris Flow	
	Avalanche (Very Rapid Flow over Compressed Air)	True Avalanches Are Very Rare in Central Appalachians		
Complex	Multiple Motion Types - e.g. Multiple Small Failures	Multiple Failures		
Undifferentiated	Failure Process Unclear from Available Data	Undifferentiated Slope Failure		

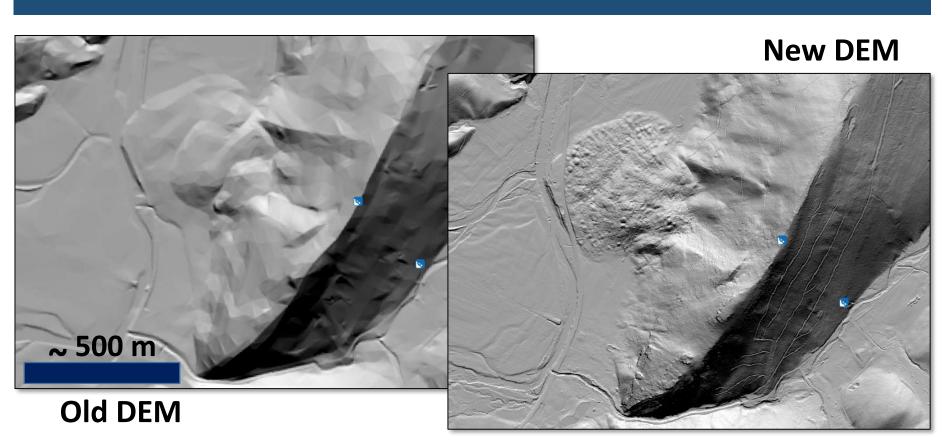
Modified from Version 0.1 Based On Multiple Operator Mapping Efforts..

- Landslide Identification Biased to Head Scarp Morphology.
- LiDAR-based Dems Will Not Allow Debris vs. Earth Differentiation, & May Not Allow Soil-Rock Differentiation
- Consistent Translational Slide vs. Rotational Slump Differentiation Is Unlikely

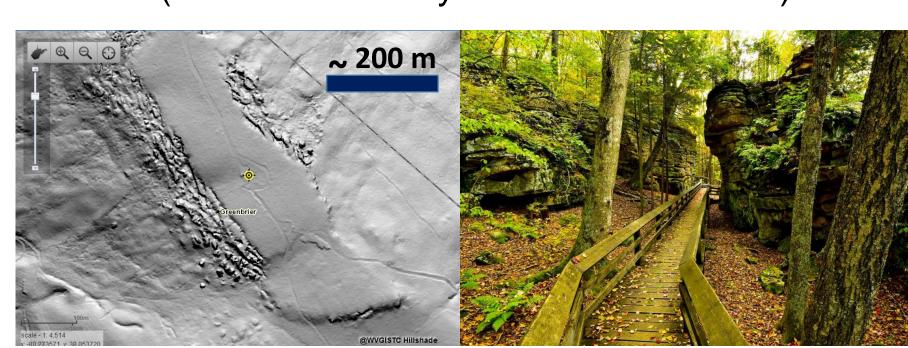


70 Ton Boulder, Morgantown, 1994 (S. Kite Photo)

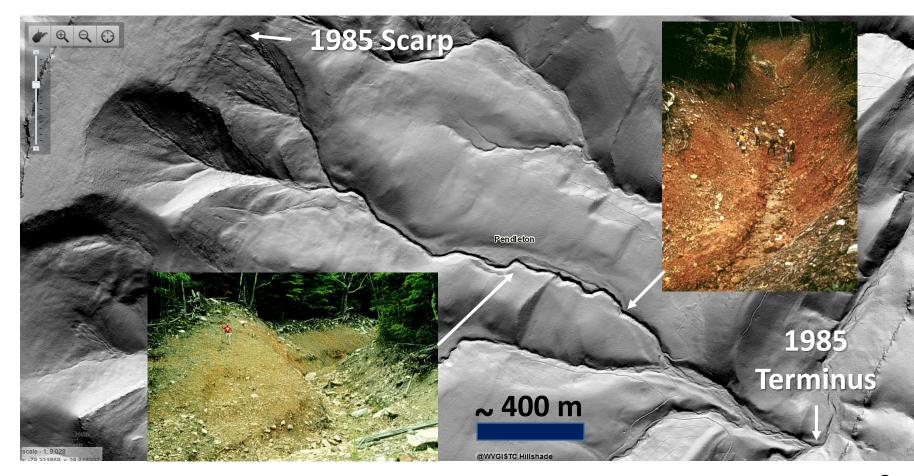
Landslides on QL2 LiDAR DEMs



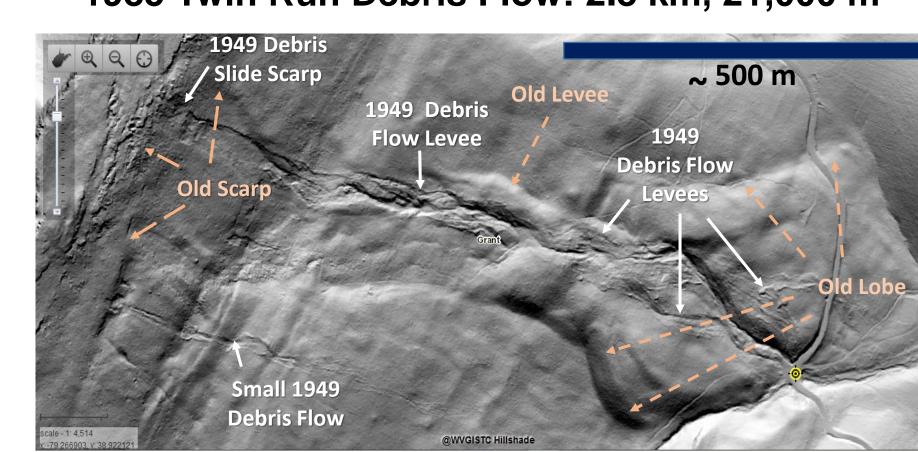
10 Foot Photo-Based DEM vs. 1 Meter LiDAR DEM (Vertical Accuracy: 305 cm vs. 6.7 cm)



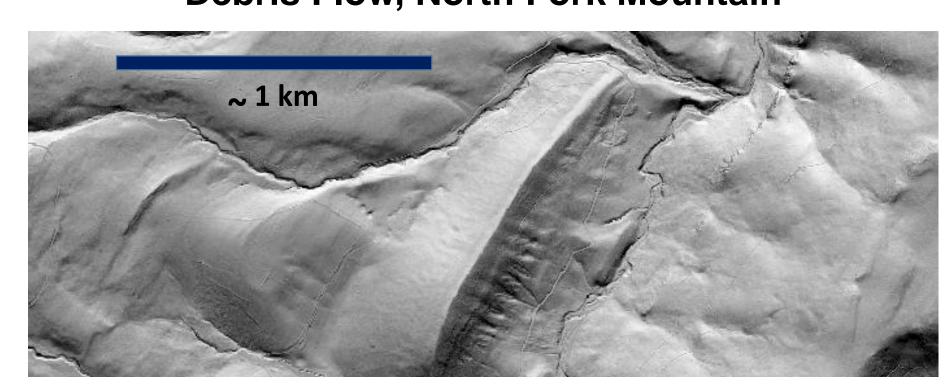
Rock Lateral Spreads - Beartown Rock Cities



1985 Twin Run Debris Flow: 2.8 km, 21,000 m³



Huge Prehistoric Failure Over-Ridden by 1949
Debris Flow, North Fork Mountain



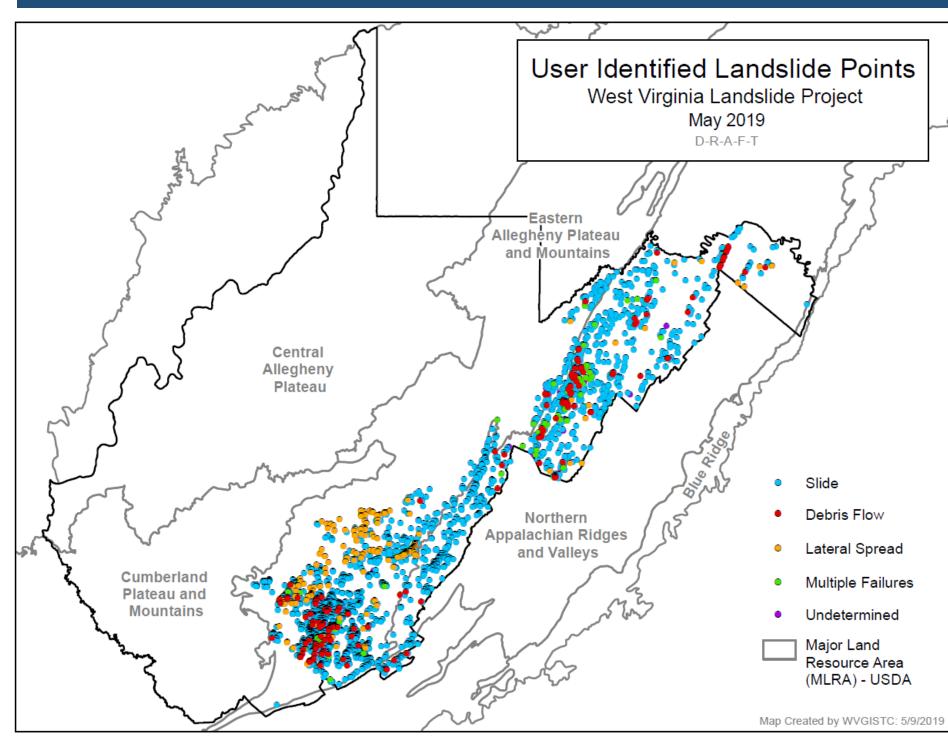
Complex Multiple Small 1985 Debris Flows, Slides, & Blow Outs, Big Mountain

West Virginia University DEPARTMENT OF GEOLOGY AND GEOGRAPHY

FEMA QL2 LIDAR December 2018 DRAF-T DELIVERD Selection III 3DEP North (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP Central (Fall 2018 (Spring 2019 Flight)*) 2018 FEMA Region III 3DEP LIDAR (Collected 11/2017, Expected Delivery 3/2019) 2018 FEMA Region III 3DEP WW Northeast (Collevered) 2018 FEMA Region III 3DEP WW Northeast (Collevered) 2018 FEMA Region III 3DEP 2018 FEMA Region III 3DEP WW Northeast (Collevered) 2018 FEMA Region III 3DEP WY Northeast (Collevered)

Find Best-Available Elevation Sources for West Virginia at www.mapwv.gov/floodtest/docs/WV FloodTool ElevationSource Metadata.pdf

Results to Date



From WVGISTC Landslide App https://www.mapwv.gov/landslide

Failure Movement	Number of Mapped Slides	% of Mapped Slides
Slide	2,624	84.8
Fall	0	0.0
Debris Flow	177	5.7
Lateral Spread	201	6.5
Multiple Failures	74	2.4
Undetermined	20	0.6
Total	3,096	100.0

Salient Points:

- West Virginia Landslide Incidence Is Nearly Ubiquitous.
- NRCS Major Land Resource Areas (MLRAs) & LiDAR
 DEMs Show Need for Updating Physiographic Maps.
- Regional Variations Exist in Slope Failure Types:
- Appalachian Plateaus (Nearly Flat-lying Bedrock):
 Debris Slumps, Debris Slides, Rock Falls, Short Runout Debris Flows, & Rock Lateral Spreads.
- Ridges & Valleys: (Folded Bedrock):
- Debris Slumps, Debris Slides, Rock Falls, Long-Runout Debris Flows, & Huge Planar Rock Slides.
- (1) Human Activity, (2) Late Cenozoic Geologic History,
 & (3) Bedrock Geology Influence Spatial Distribution of Landslides (Debatably in This Order).