Yeager Airport, 12 March 2015
Charleston Daily Mail Photo

Building a Landslide Inventory for West Virginia: Step 1 in Statewide Risk Assessment

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Not a Geological Survey

Session T160: Landslide Inventories, Hazard Assessments, and Risk Reduction

Paper 150-2: https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/337478

1:45 - 2:00 PM, Monday, 23 September 2019

Revised 8 October 2019

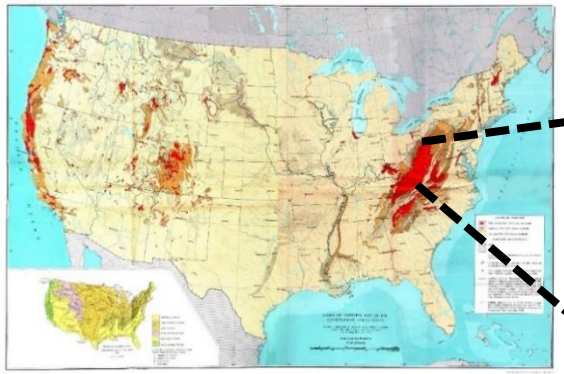
224A North Building, Phoenix Convention Center

2018-2021 Effort Funded by FEMA Hazard Mitigation Grant Program & WV Division of Homeland Security and Emergency Preparedness

Why Assess West Virginia Landslide Risk?

- **Landslides = #2 West Virginia Hazard** (FEMA).
- **West Virginia = 11.2% of 1973-1983 Landslide Damage in 48 States**
  - **#1 in *Per Capita* Landslide Damage** (Brabb, 1984, USGS OF 84-486).
- **~70 % of West Virginia = "High Landslide Incidence"**
  - ***No Other State >25%* (USGS PP 1183).**

Coterminous U.S. Landslide Overview Map USGS PP 1183

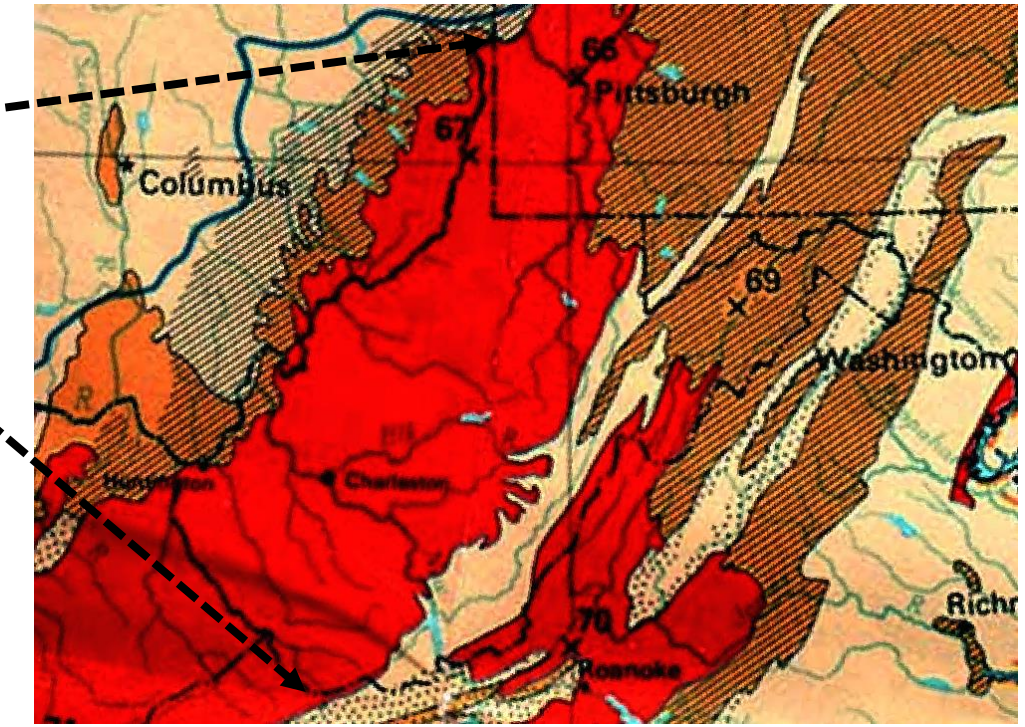


LANDSLIDE INCIDENCE

High (More than 15% of area involved)

Moderate (15%–1.5% of area involved)

Low (Less than 1.5% of area involved)



West Virginia Physiography & NRCS MLRAs

Existing Physiographic Maps Inadequate for WV Landslide Project

MLRA Boundaries Better

Provinces & Subdivisions

Appalachian Plateaus

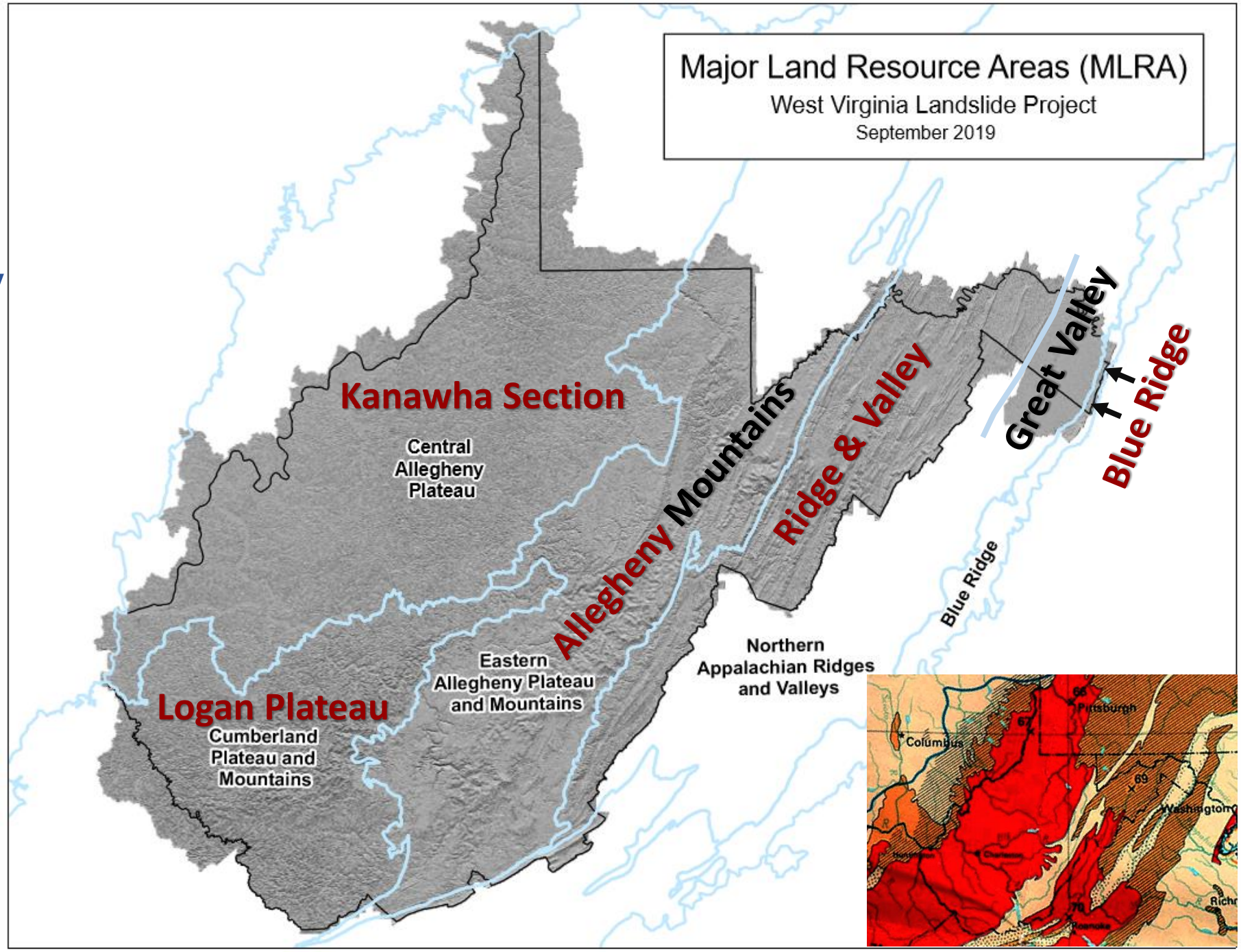
- Kanawha Section
- Logan Plateau
- Allegheny Mountains

Valley & Ridge

- Ridge & Valley
- Great Valley

Blue Ridge

Red = Highly Landslide-Prone



West Virginia Statewide Landslide Risk Assessment

Long-Term Goals:

- **Landslide Inventory (Focus of Talk)**
  - **Step 1A: Compile Statewide Inventory from Pre-Existing Landslide Maps**

    ~93,000 Previously Identified Landslides *(Revised from > 75,000 in GSA Presentation)*
    - **Disparate Sources: Disparate Landslide Data**

Purpose	What Was Mapped	Available Tools	Base "Map"
Basic Science	Landslide Polygon	Field Work	1:62,500 topo
Resource Management	Initiation Point	Image Interpretation	1:24,000 topo
Disaster Documentation	Impact Point	GPS	DEMs
Site Mitigation	Material & Mechanics	LiDAR	Road Mileage

  - **Step 1B: New Landslide Mapping from LiDAR-Based DEMs**
- ***Too Many Other Landslide Risk Assessment Goals for a GSA Talk***
  - ***Modelling-Based Landslide Susceptibility Maps***
  - ***Local Landslide Risk Reports for Hazard Mitigation Planning***

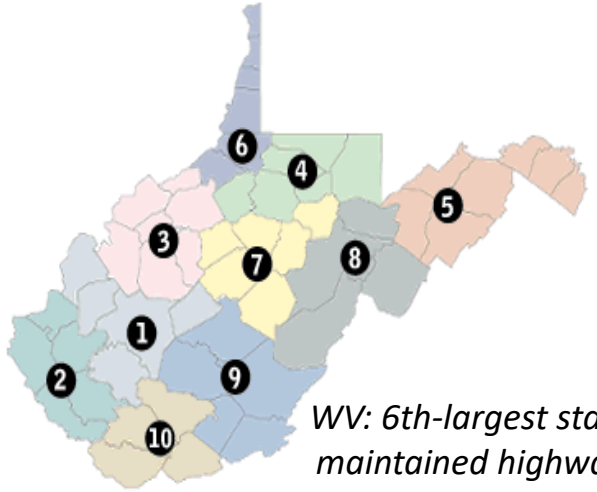
West Virginia Landslide Inventory

Landslide Impact Points

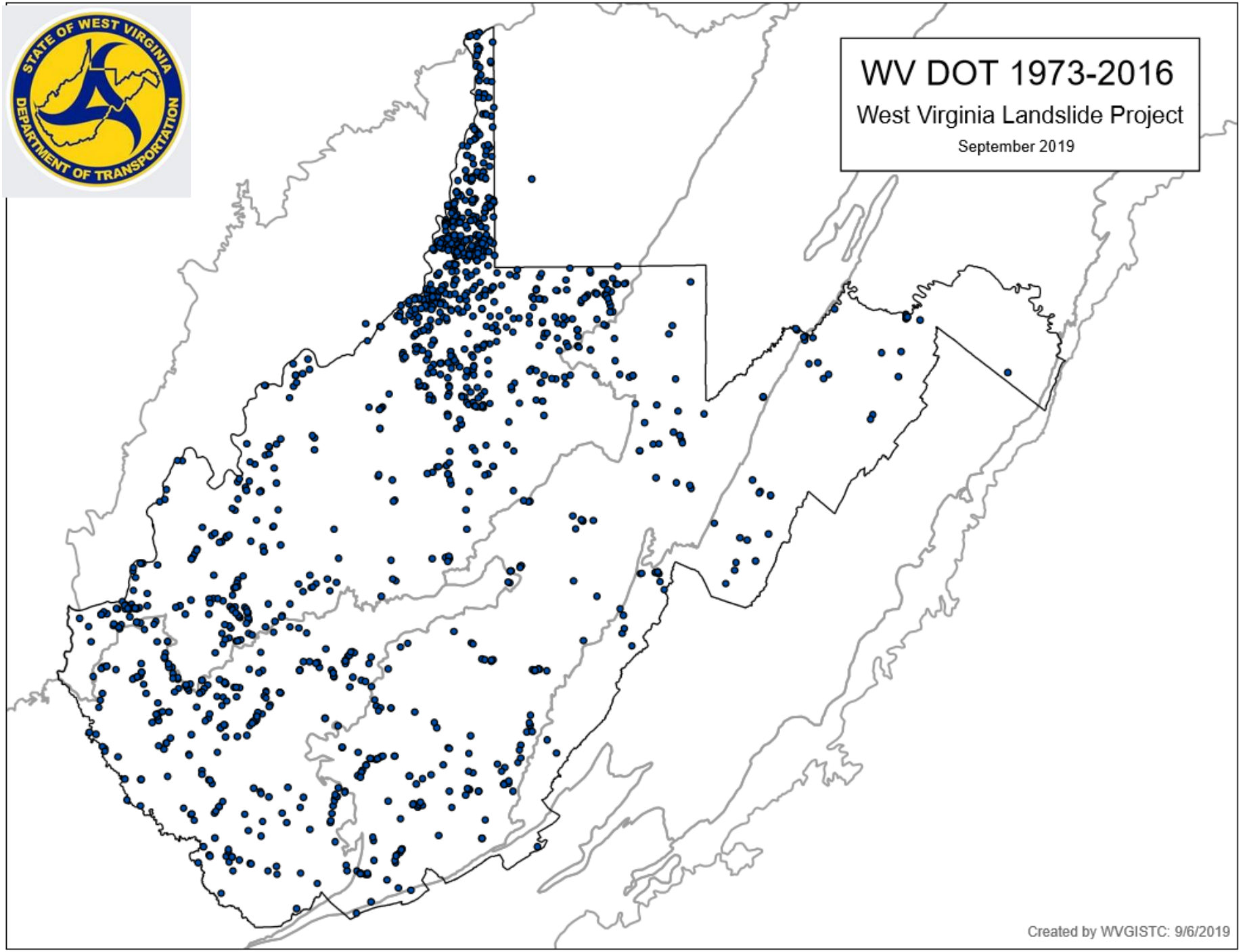
WV Division of Highways
Landslide Database

1,406 Recent Landslides

Biased to Road Network & DoH District Involvement



WV: 6th-largest state maintained highway network in US



West Virginia Landslide Inventory

Air-Photo & Field Based Landslide Polygon Maps

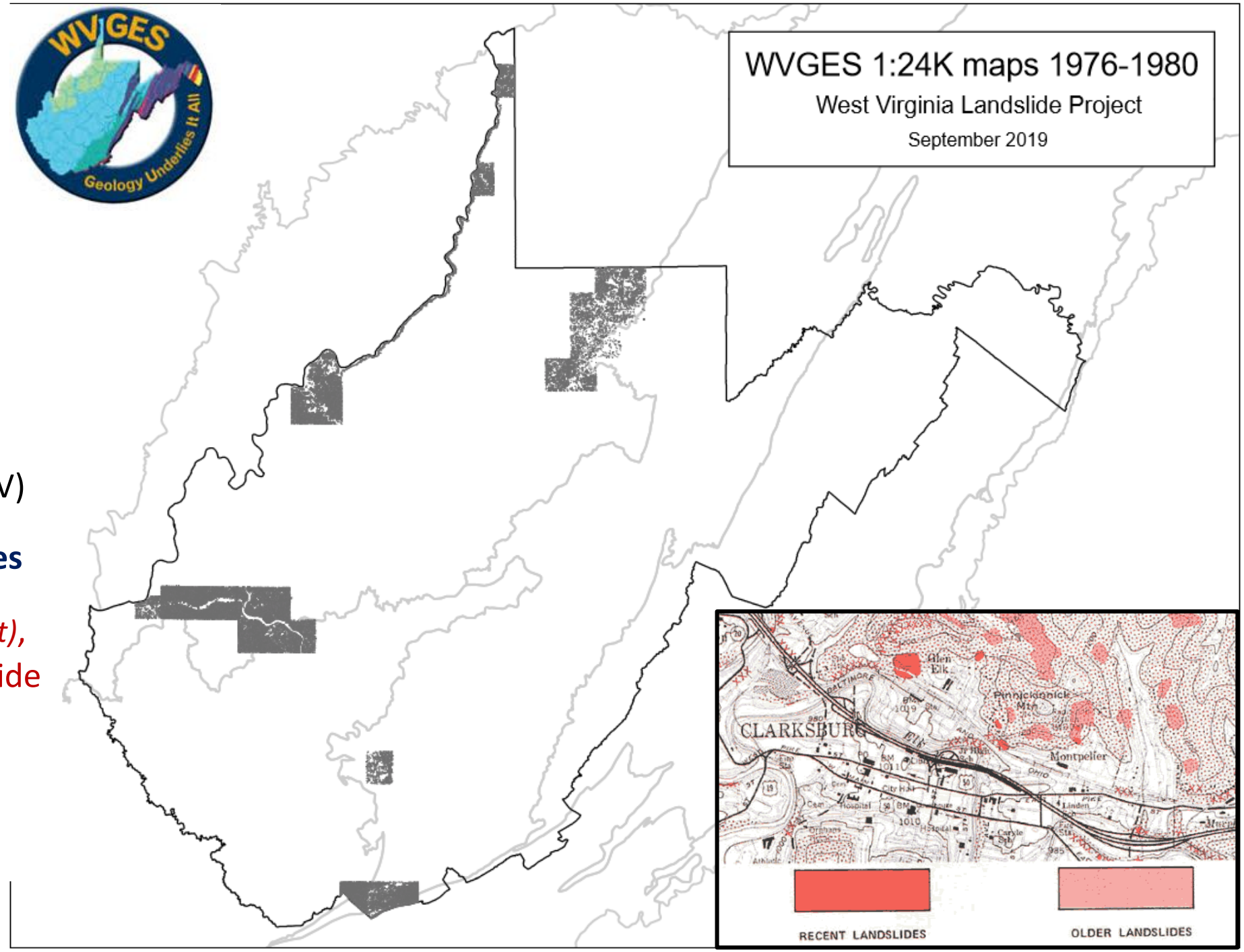
WV Geological & Economic Survey (Lessing et al.)

39 maps 1:24,000 (~8 % of WV)

46,330 Recent & Older Slides

If Representative *(probably not)*, ~600,000 Landslides Statewide

Biased to Urban Areas with Known Landslide Risk



West Virginia Landslide Inventory

Air-Photo & Field Based Landslide Polygon Maps

U.S. Geological Survey 1978-1985 (8 Different Mappers)

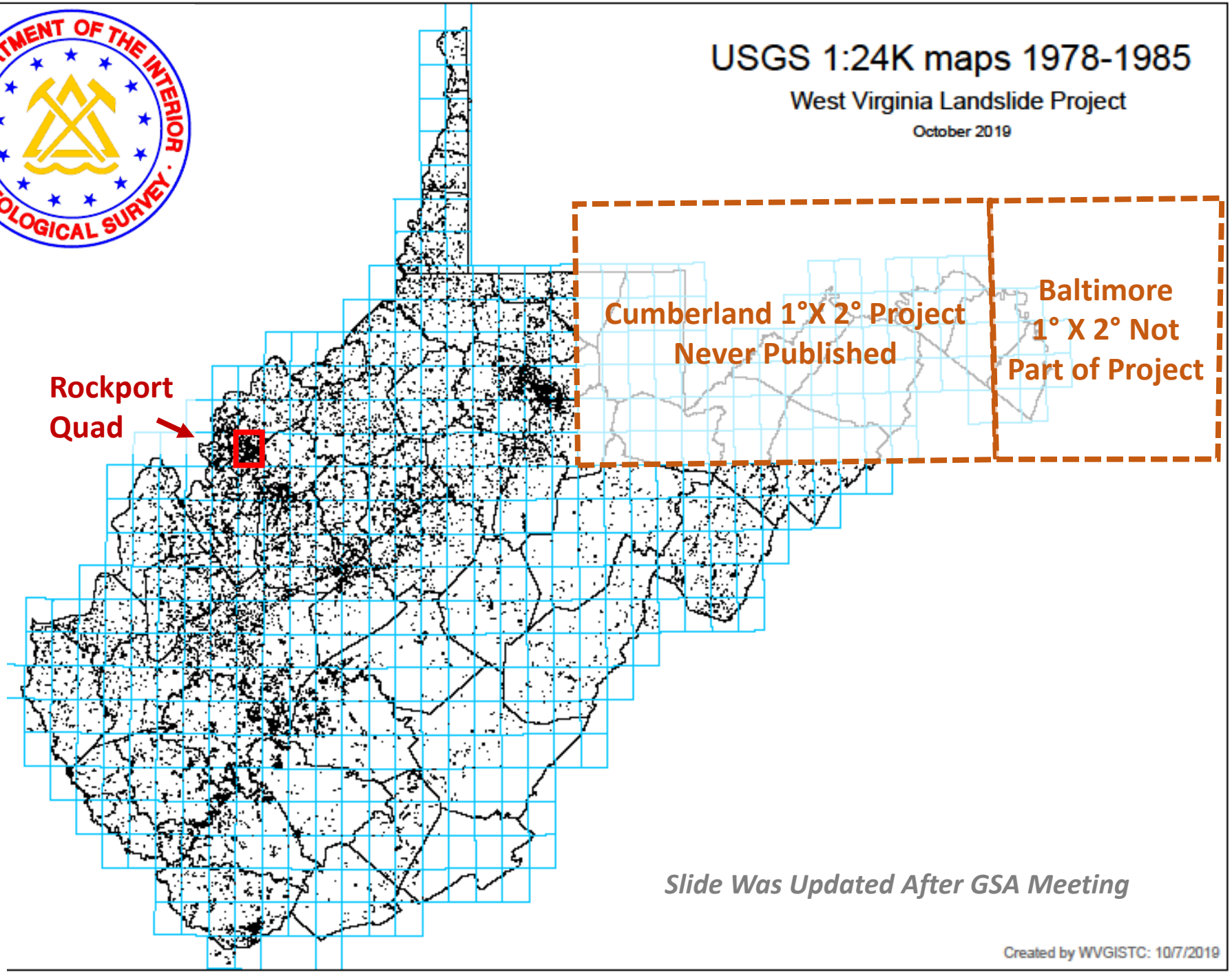
382 (of 496) 1:24,000 Quads (~75 % of WV)

41,307 Active or Recently Active Landslides

Not Digitized into Inventory:

- **Combined Old & New Landslides**
- **Old Landslides**
- **Areas Susceptible to Landsliding**

Biased by Varied Mapper Styles & Varied Land Cover



USGS Landslide Mapping 1978-1985

South Central 1/9th Rockport, WV 7.5 Minute Quad

Hackman, Robert J., and Thomas, Roger E., 1978, Landslides and related features, Ohio, West Virginia, and Pennsylvania; Clarksburg 1 degree by 2 degrees sheet: U.S. Geological Survey Open-File Report OF-78-1056, (1:24,000 scale, 121 maps), https://doi.org/10.3133/ofr781056, https://ngmdb.usgs.gov/Prodesc/proddesc_54933.htm

Based on B&W (1960 & 1976) and IR (1973) Aerial Photos + Field Checked (1976-1977)

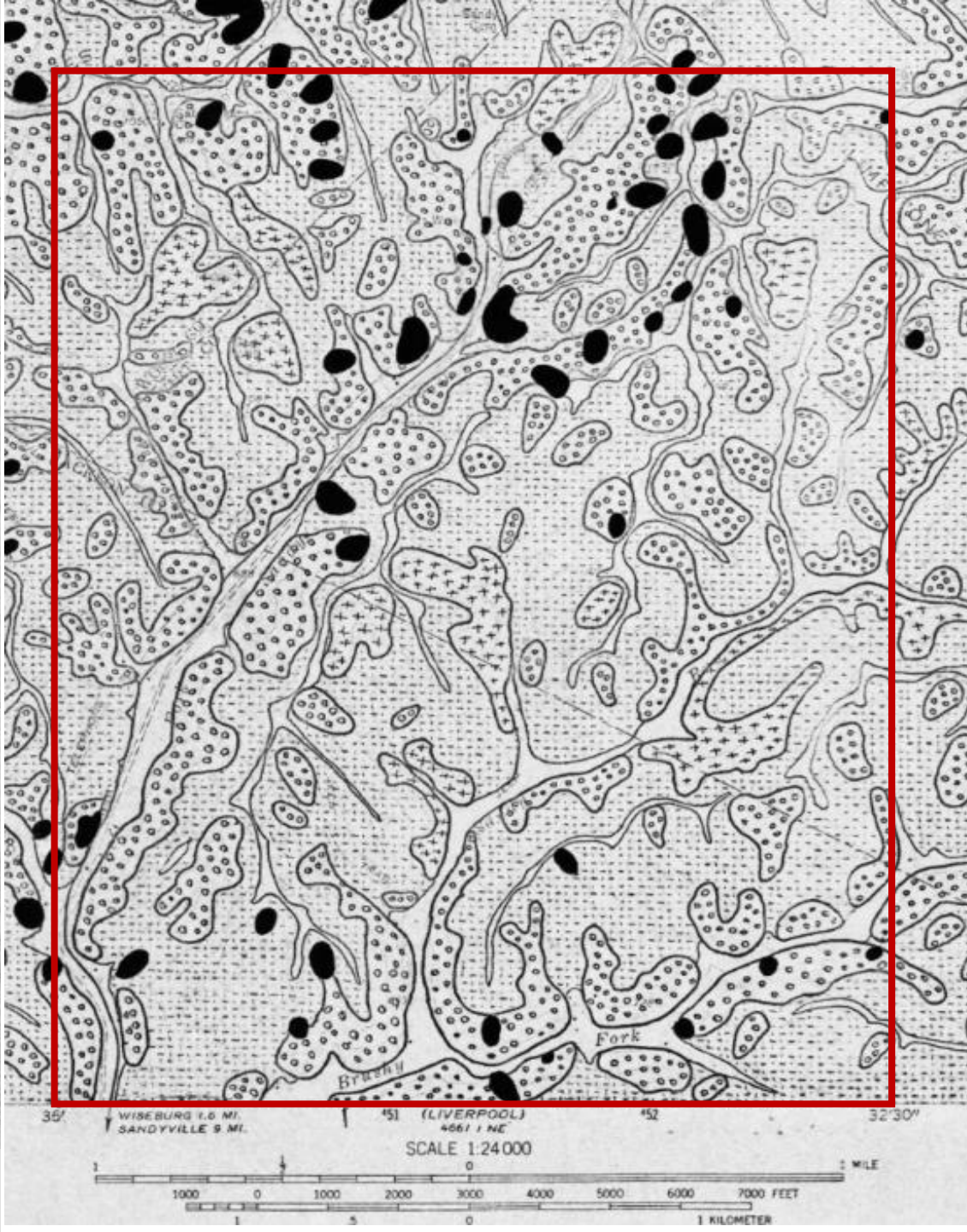
ACTIVE OR RECENTLY ACTIVE LANDSLIDE
Complex landslide composed of earthflow, debris slide, earth and rock slump. Identified from historical records, and from scars, debris and other field evidence. Ground extremely unstable; sliding accelerated by excavation, loading and changes in drainage conditions. May include areas with several active slides too small to be shown separately. Questioned where doubtful.

OLD LANDSLIDE
Area of extensive hummocky ground caused by earthflow and earth and rock slump. Lacks clear evidence of active sliding. Relatively stable in natural, undisturbed state, generally not affected by small structures properly sited in areas away from the edge of the toe; can be reactivated by extensive, rapid excavation, loading, and changes in ground water and surface water conditions. Area of old landslide probably includes recent ones not identified from field evidence or otherwise documented. Upslope boundary of landslide generally defined by modified scarp, but downslope (toe) may be gradational and not well defined. Questioned where doubtful.

COMBINATION LANDSLIDE
Area of recent and old slides in which individual slides are not identified.

SOIL AND ROCK SUSCEPTIBLE TO LANDSLIDING
Soil and rock similar to that involved in landslides elsewhere in map area; primarily areas underlain by claystone, mudstone and shale associated with other rock types. Rock weathers rapidly on exposure forming clayey soil highly susceptible to sliding. Includes coves (U-shaped, shallow valleys) containing thick layers of clayey soil that are very susceptible to sliding where excavation breaks continuity of slope and where overloaded by artificial fill.

AREAS LEAST PRONE TO LANDSLIDES
Map areas in which no patterns or symbols are shown; primarily valley floors, ridge tops and broad benches; modification by excavation and fill may lead to local landslides.



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Based on B&W (1960 & 1976) and IR (1973) Aerial Photos + Field Checked (1976-1977)

Biased by a 495 mm (19 ½ inch) 2 hr 10 min Rainfall, 18 Jul 1889

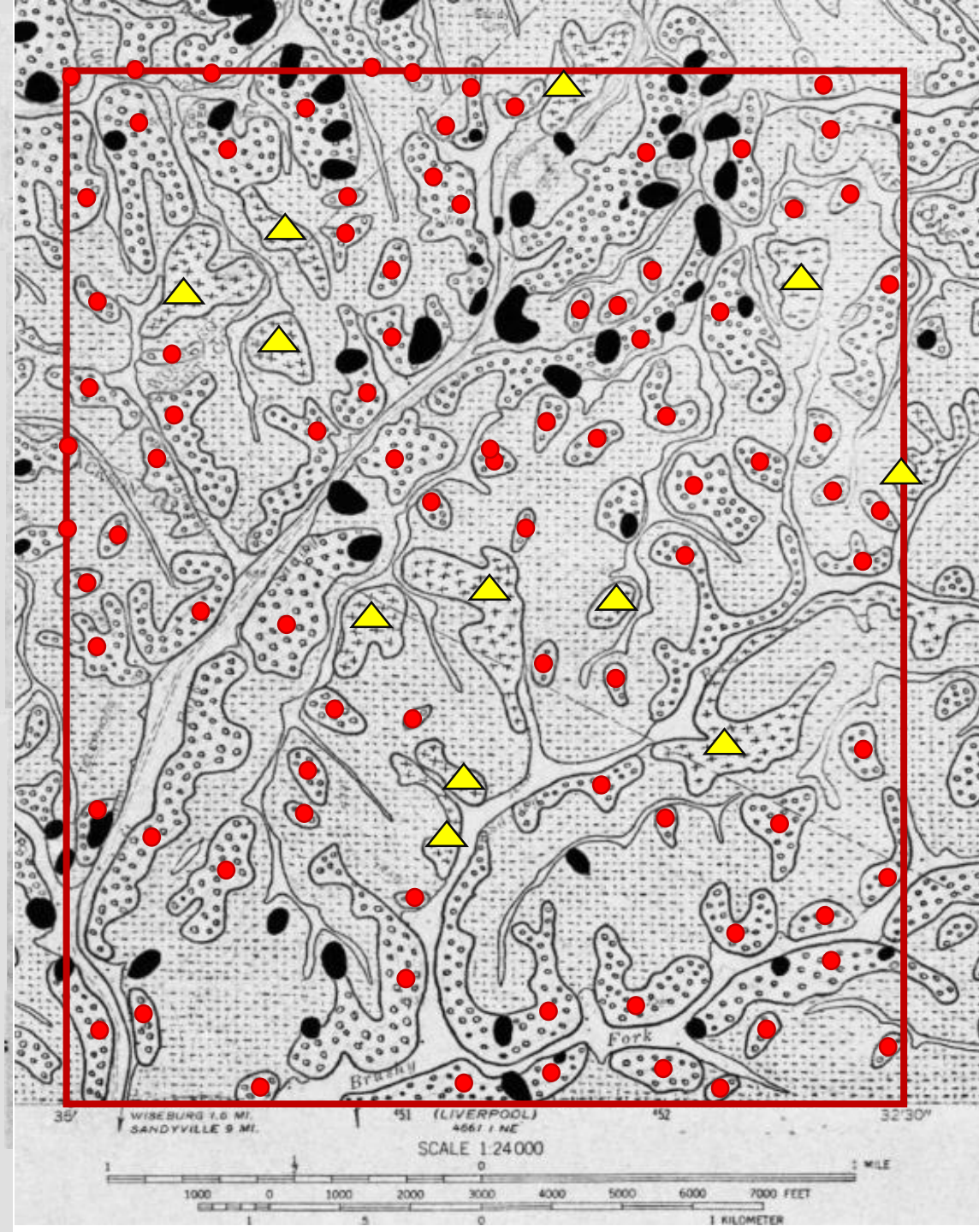
Active or Recently Active Landslide: 47 small polygons – ***Only Landslides in WV GIS TC Inventory (Sept 2019)***

Old Landslide: 88 large polygons – *Not in Inventory*

Combination (Old & New) Landslide: 12 large polygons – *Not in Inventory*

Soil & Rock Susceptible to Landsliding: huge polygons covering ~ half of area – *Not in Inventory*

Areas Least Susceptible to Landsliding: thin polygons - floodplains & ridge crests



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Implications:

- **Inventory is Missing >2/3** of **USGS Slides**
- **If 147 Slides** per 1/9th Quad Is Typical *(Probably Not),* **WV Could Have >600,000 Slides!**

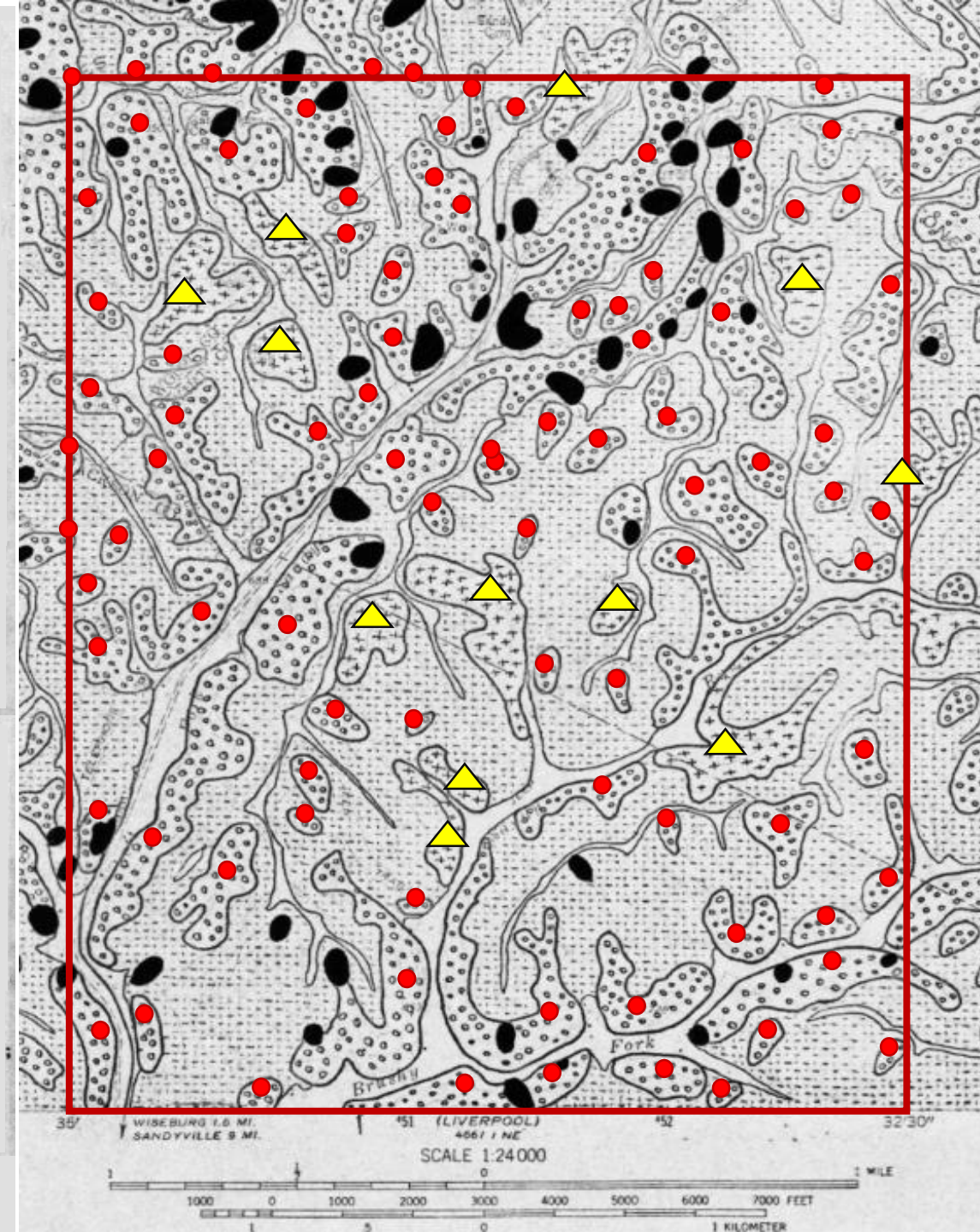
Active or Recently Active Landslide: 47 small polygons – *Only Landslides in WV GIS TC Inventory (Sept 2019)*

Old Landslide: 88 Large Polygons – *Not in Inventory*

Combination (Old & New) Landslide: 12 Large Polygons – *Not in Inventory*

Soil & Rock Susceptible to Landsliding: Huge Polygons Covering ~ Half of Area – *Not in Inventory*

Areas Least Susceptible to Landsliding: *Not Much!* - Floodplains & Ridge Crests



Other Landslide Inventory Data

Field Mapped Polygons

Landers & Smosna WVGES (Fatal 1973 Debris Flows)

Air-Photo & Field Based Landslide Initiation Points

Jacobson et al. USGS (GIS Mapping 1985 "Flood")

Schneider (1973 UT–K PhD on 1969 "Debris Slides")

DEM Based Landslide Polygons

Konsoer & Downing (2008 WVU MS Theses-USGS EDMAP)

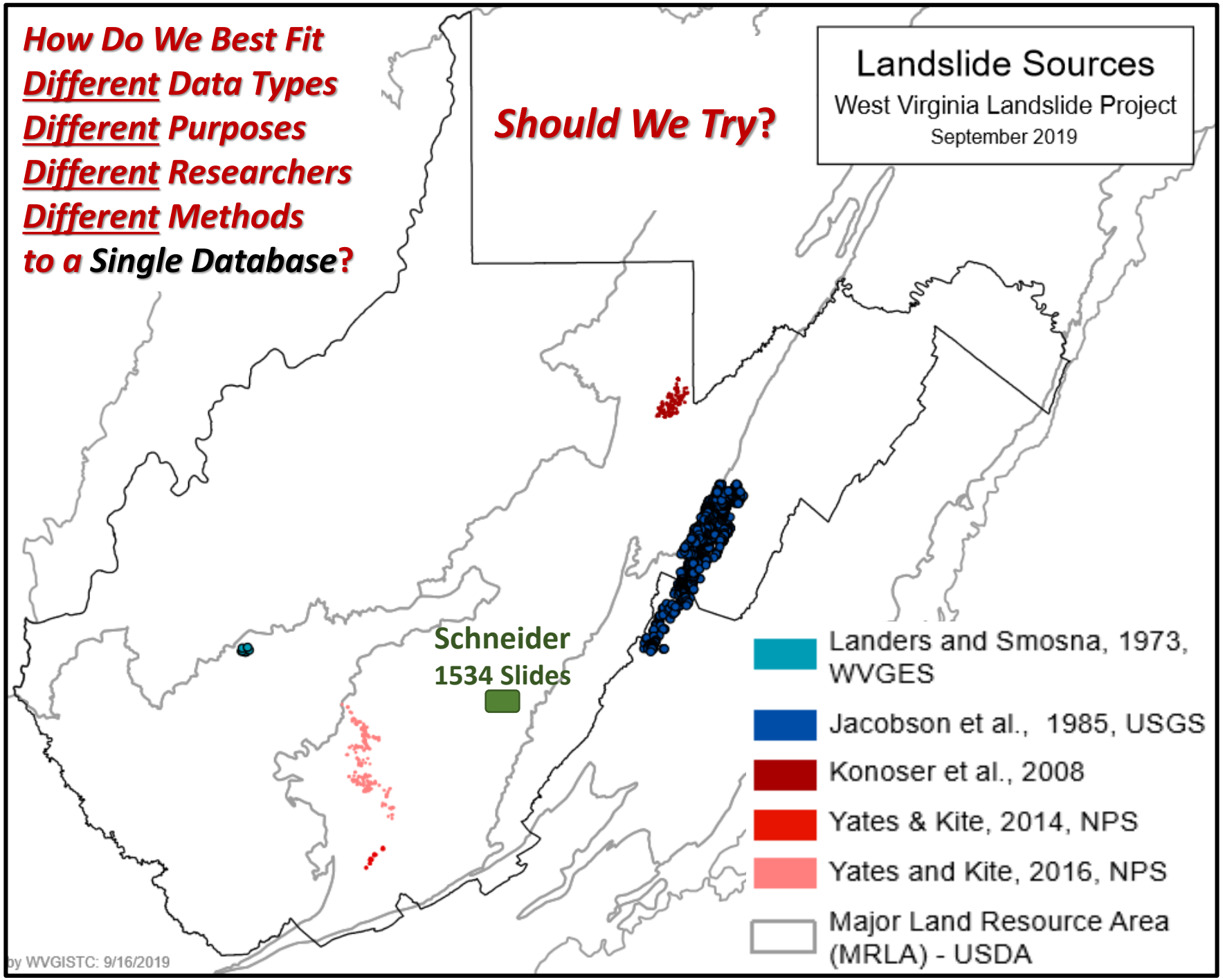
Yates & Kite, NPS 1:10,000 Mapping (2014, 2016)

Other Sources We Could Add

Geotechnical Projects, Media Reports, Landslide Reporting App

How Do We Best Fit Different Data Types Different Purposes Different Researchers Different Methods to a Single Database?

Should We Try?

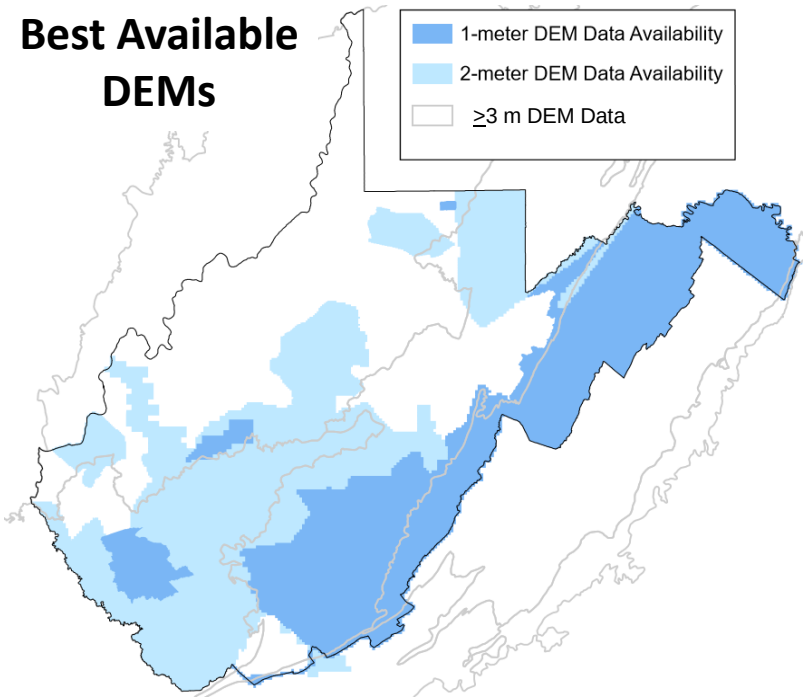


West Virginia Landslide Mapping

New Landslide Mapping by WV GIS TC

- Landslide **Mapping Protocol** for QL2 LiDAR 1 m DEMs
- **Hill-Shade** Base Map Layer (Best Available Statewide)
- **Slope-Shade** Layers (1 m DEM Areas Only)
- **LiDAR Is Crucial**
  - **Good** Coverage in **Eastern West Virginia**
  - **Update as QL2 1 m DEMs Arrive**
  - **QL2 1 m DEMs for *All WV Unlikely by June 2021***
  - **May Map on QL3/QL4 2 m DEMs Where QL2 LiDAR is Unlikely before Project Ends**
  - Many Areas **Only 3 m DEMs – ~ Worthless** for Mapping

Best Available DEMs



Find Best-Available Elevation Sources for West Virginia at
www.mapwv.gov/floodtest/docs/WV_FloodTool_ElevationSource_Metadata.pdf

Reality Check After Mapping Trials – *Revised 4 June 2019*

Failure Motion		Material before Failure (Engineering Criteria)	
		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*	
Sliding	Slide (Translational Sliding along Planar Surface)	Slide	
	Slump (Rotational Sliding along Concave Surface)		
Flowing	Lateral Spread	Lateral Spread	*Rare & Difficult to Discern*
	***Creep** * (Slow Downslope Creep with No Slip Surface)*	*Creep Not Discernable from Stable Slope*	
	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	

- Landslide **Identification Biased to Head Scarp** Morphology.
- **DEMs Will Not Allow Differentiation of Debris *vs.* Earth** or **Soil vs. Rock**.
- Consistent **Translational Slide vs. Rotational Slump Differentiation Is Unlikely**.

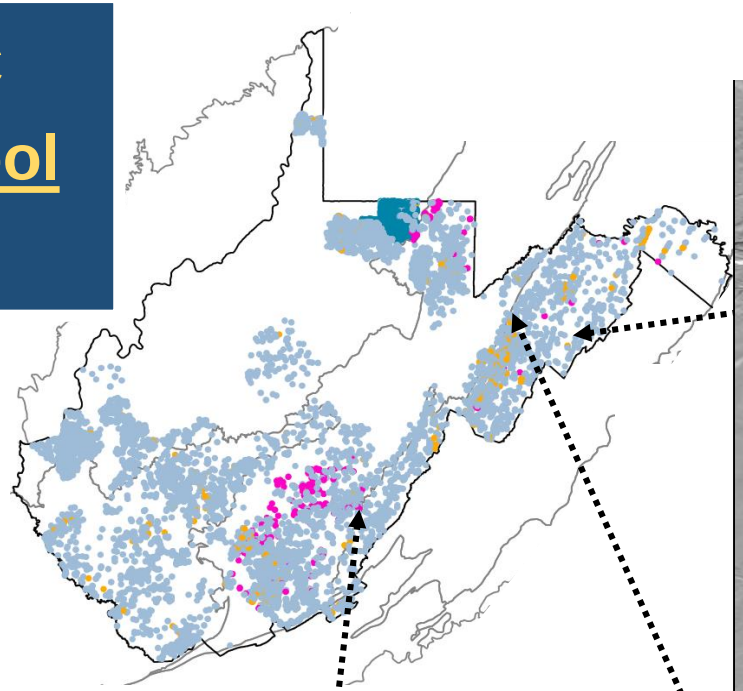
WV GIS TC Landslide Tool Images

Search:

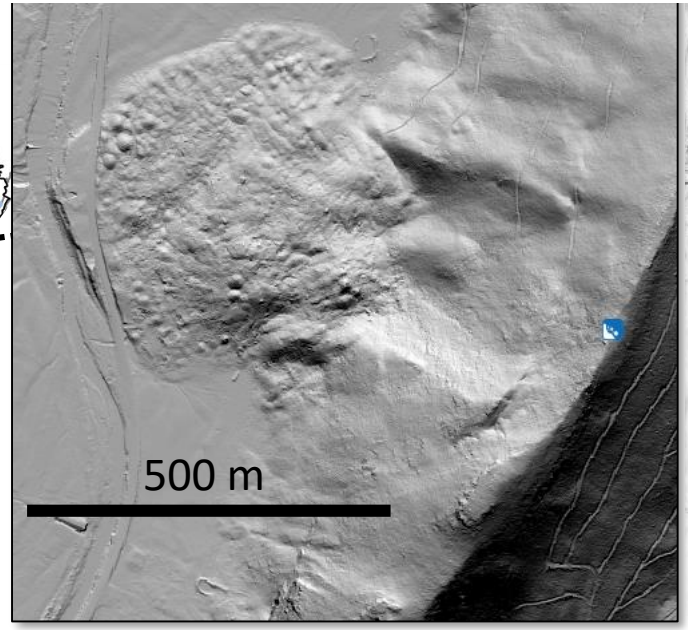
WV Landslide Tool

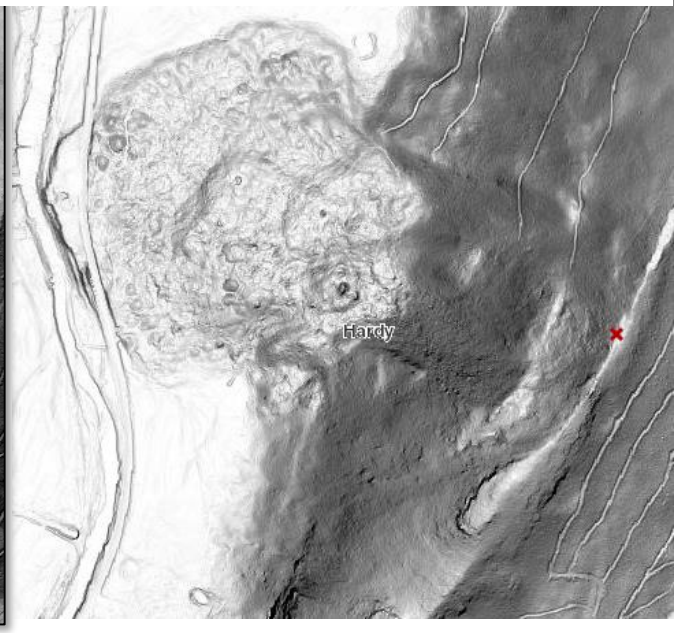
Public Access Coming Soon

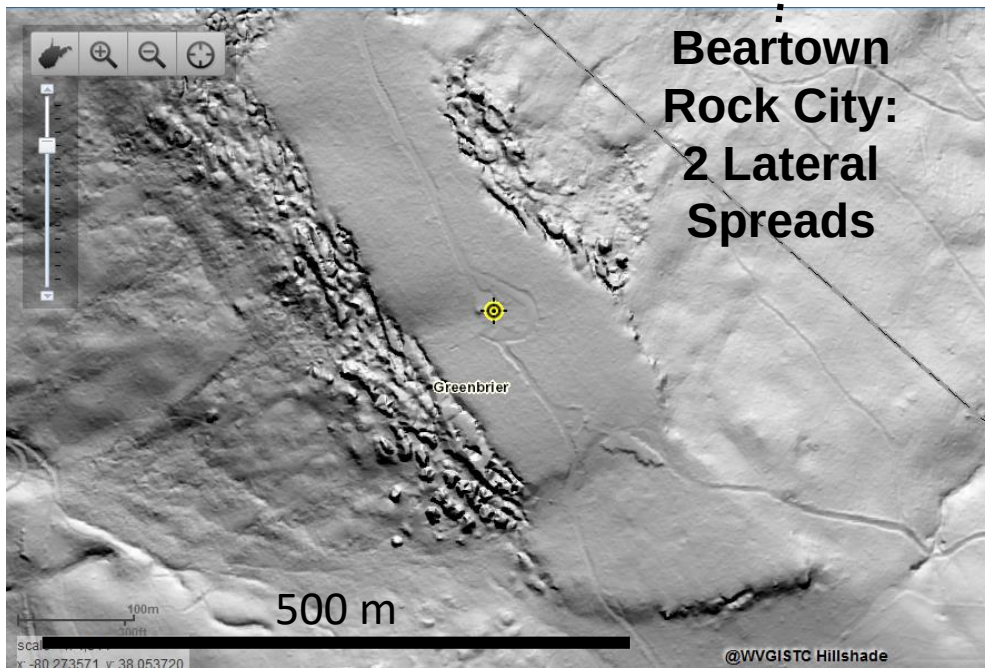
3 WV Hillshades & 1 SlopeShade

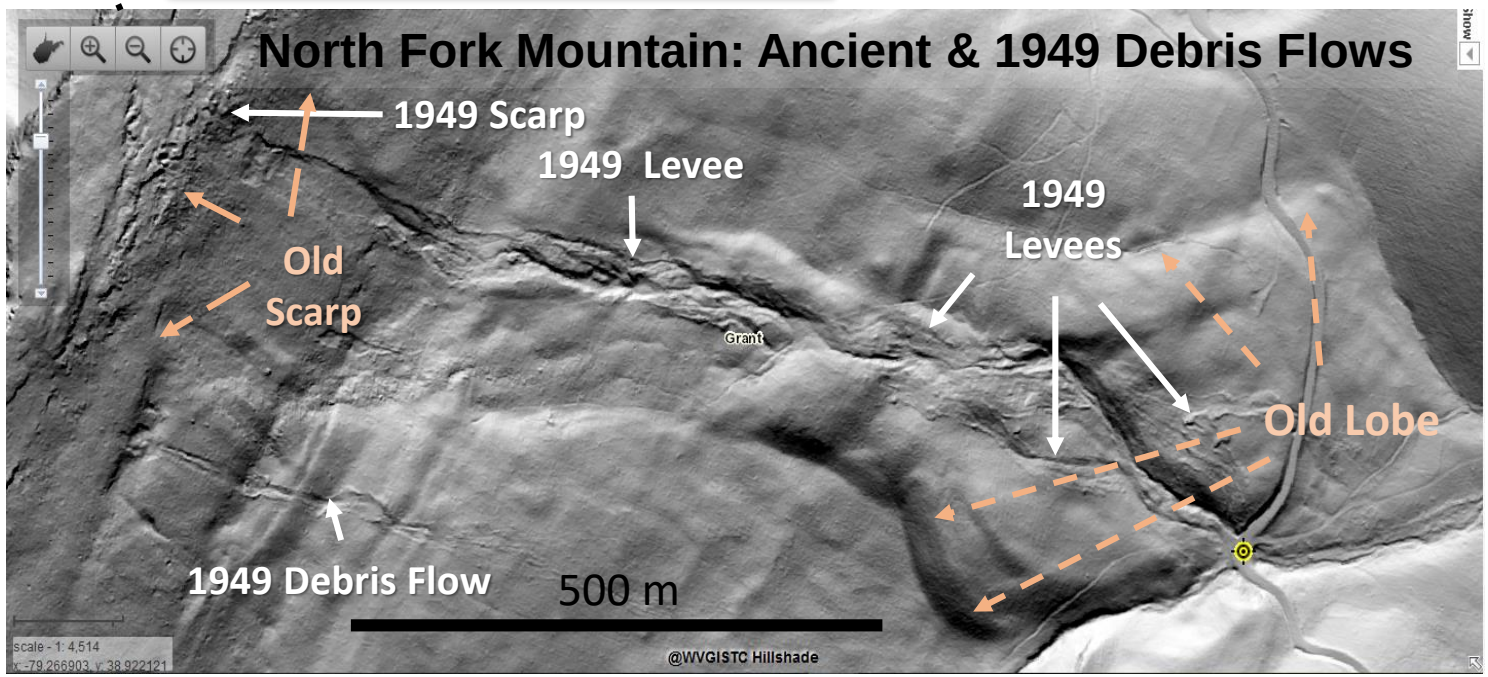


Hillshade **Lost River Rock Slide** **Slope Shade**









WV GIS TC Landslide Mapping

March-September 2019

WV GIS TC Mapping on LiDAR-Based DEMs

8,991 Failures *(≥10 m wide)*

Most from 1 m DEMs

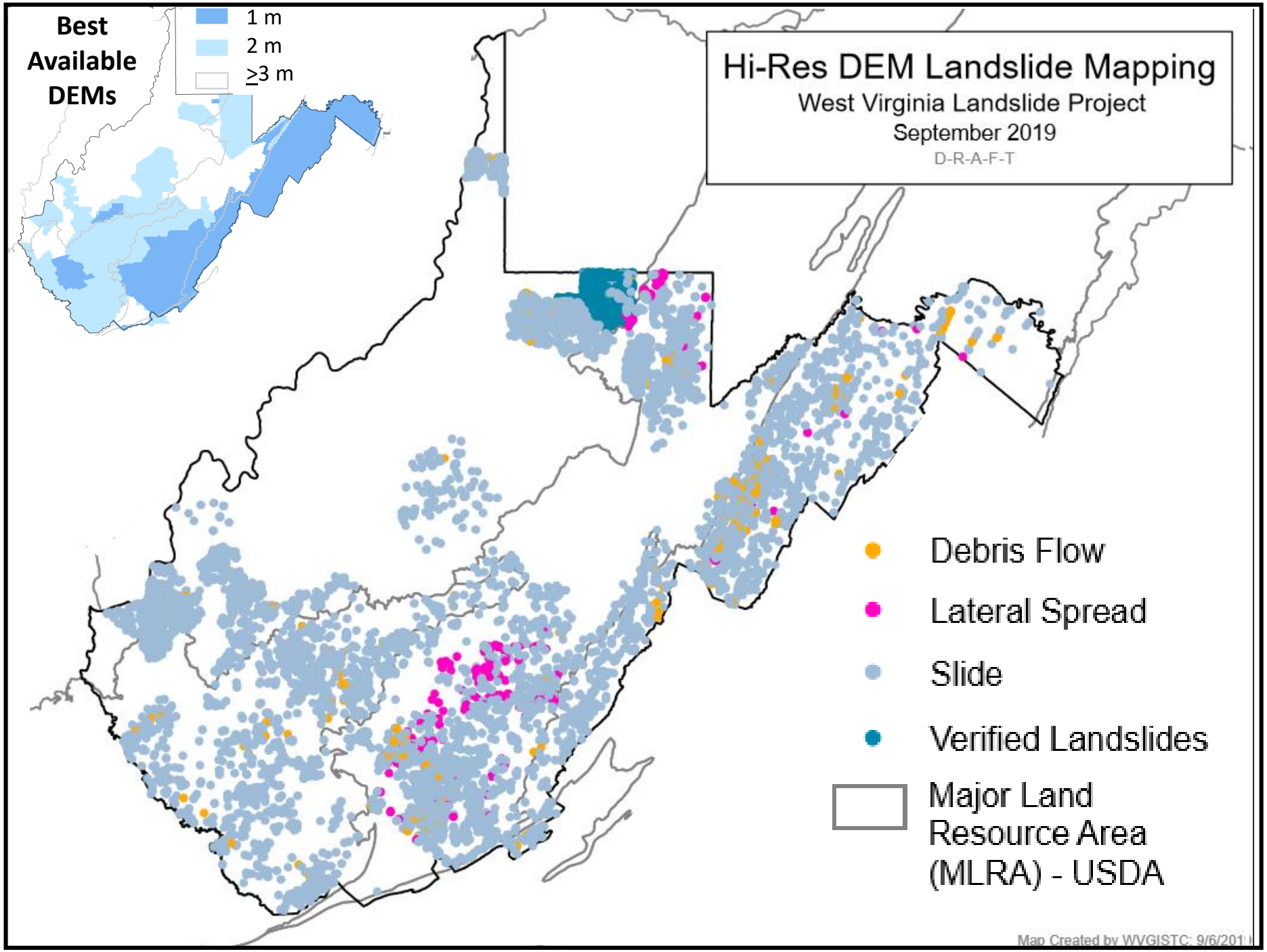
- **334 Debris Flows**
- **241 Lateral Spreads**
- **8,416 Other Failures**

  >97 % "Slides" (or *Slumps*)

Few Rock Falls Identified

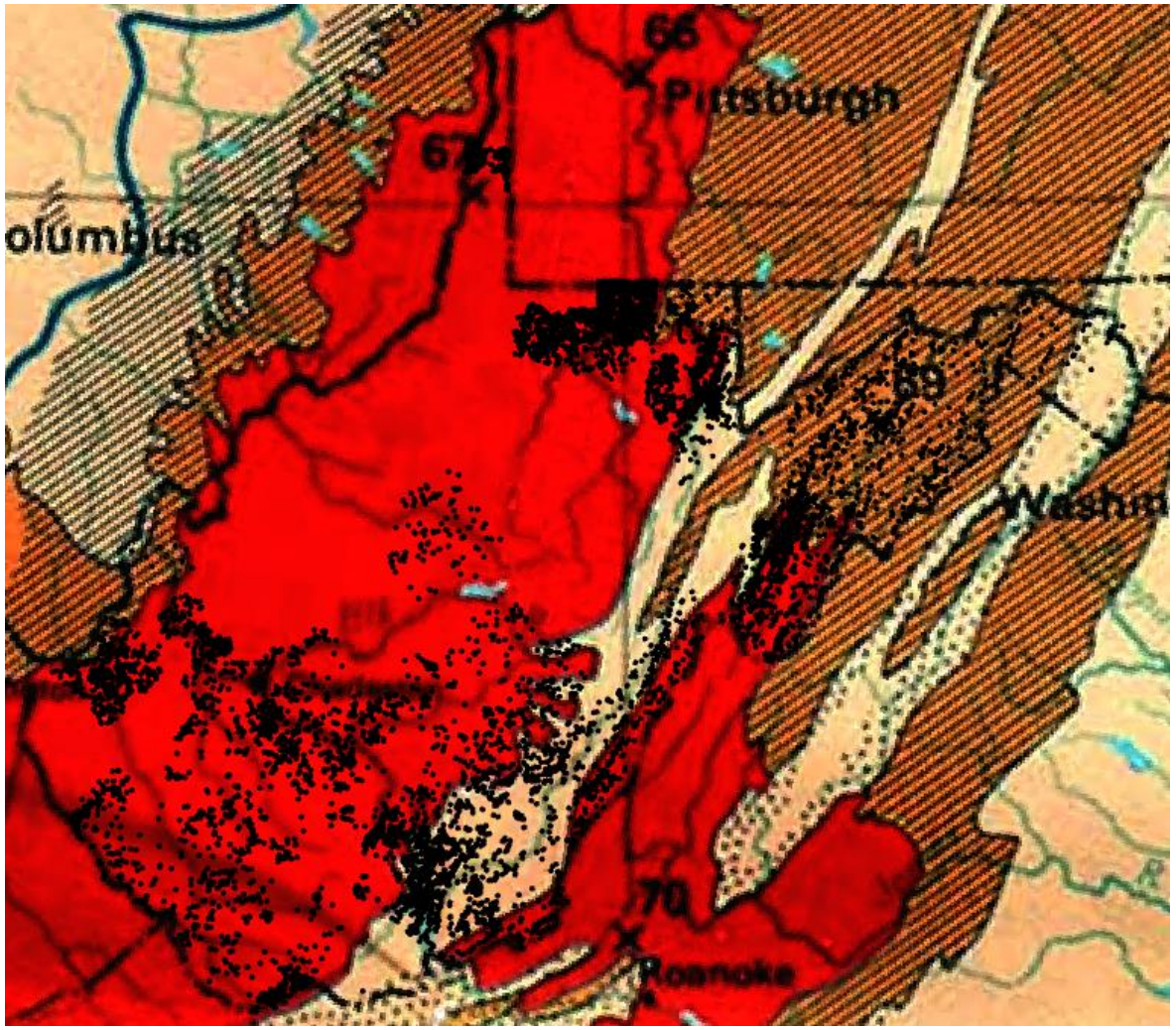
Mapped Landslides Verified on 2 m DEMs

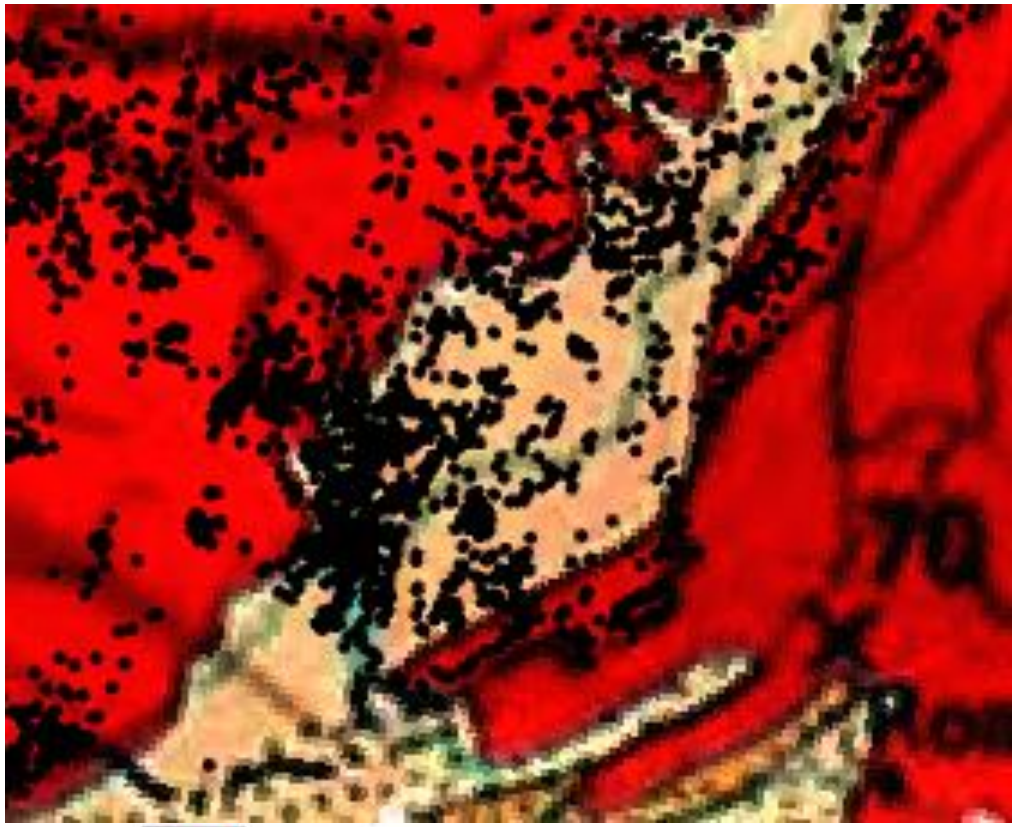
- **1,082 WVGES (1976-80) Monongalia Co. Slides**

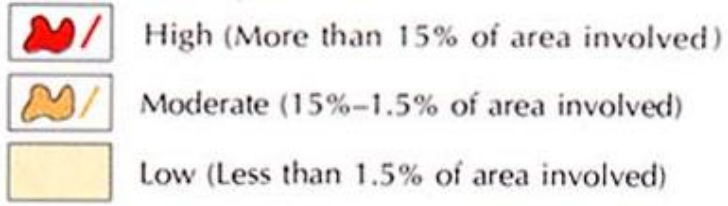


WV GIS TC West Virginia Landslide Mapping

- Newly Mapped Landslides on LiDAR-Based DEMs
  Plotted vs. USGS PP 1183 Landslide Overview Map







~ 75% of WV = "High Landslide Incidence"

Why We Map Landslides!