PRELIMINARY RESULTS OF RECENT LANDSLIDE SUSCEPTIBILITY MAPPING IN ALBEMARLE AND NELSON COUNTIES, VIRGINIA

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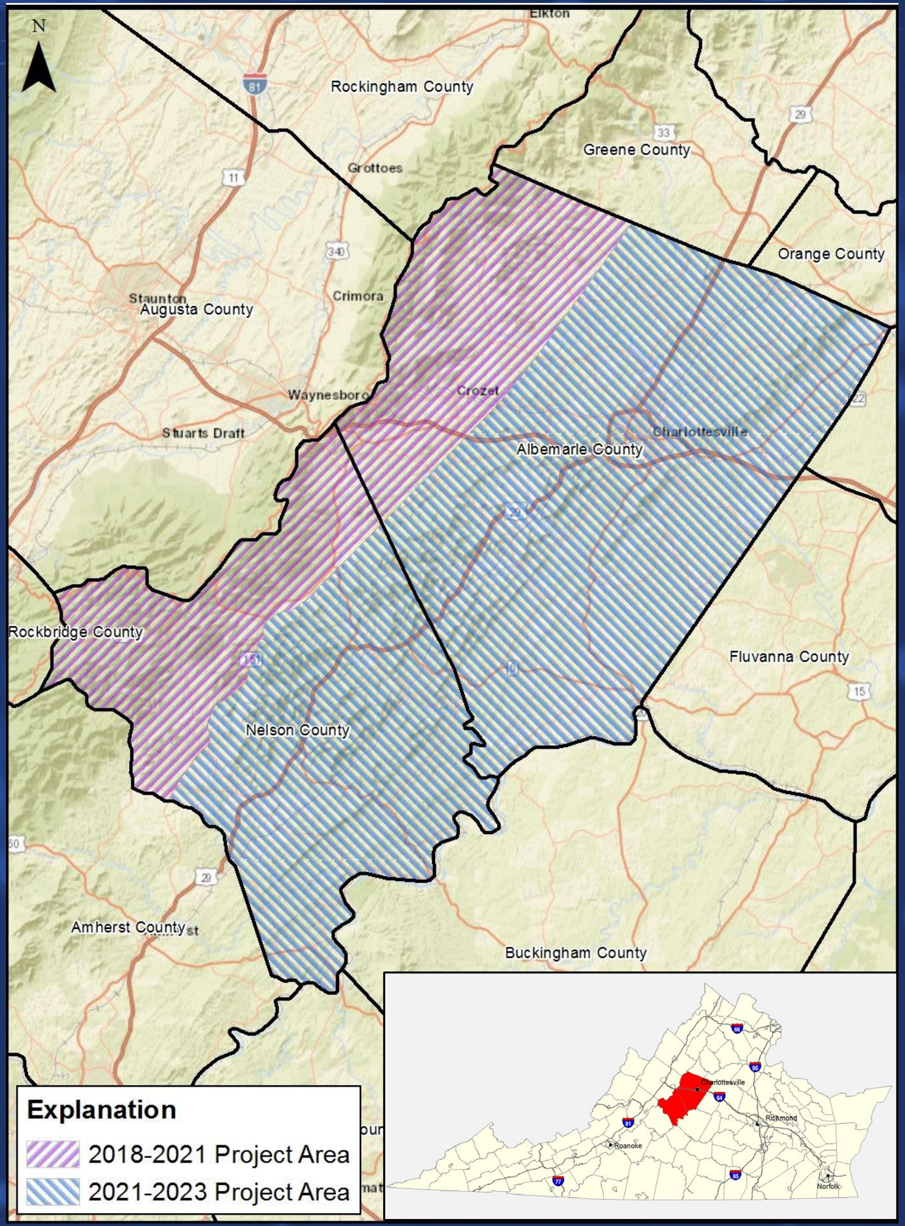
Virginia Energy

VDEM-FEMA PRE-DISASTER MITIGATION GRANT PROJECTS IN NELSON & ALBEMARLE COUNTIES:

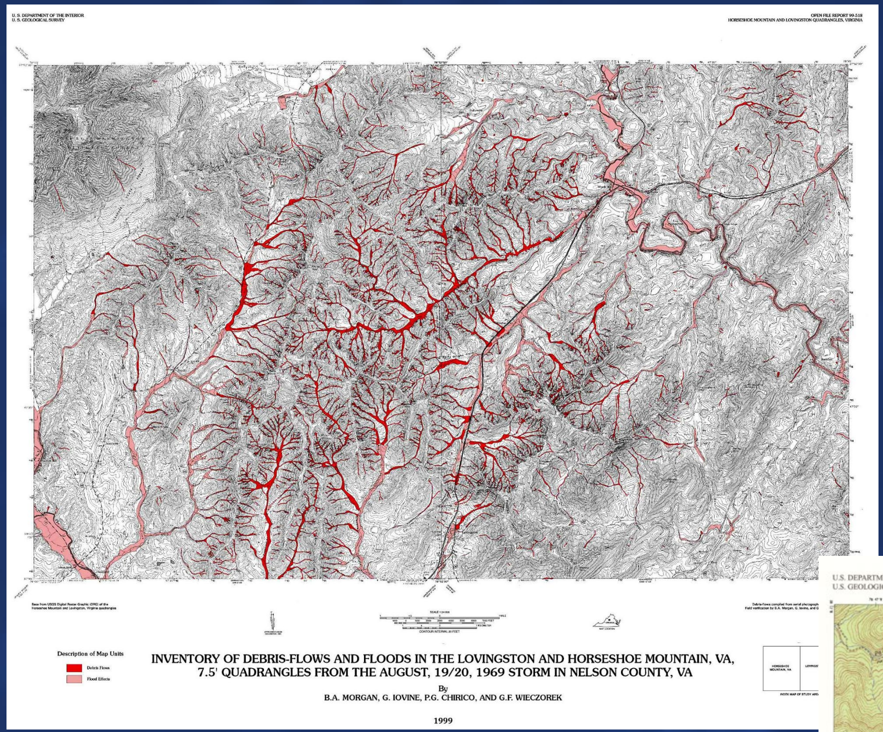
Western Landslide Risk Assessment (2018-2022)
Eastern Landslide Risk Assessment (2021-2023)

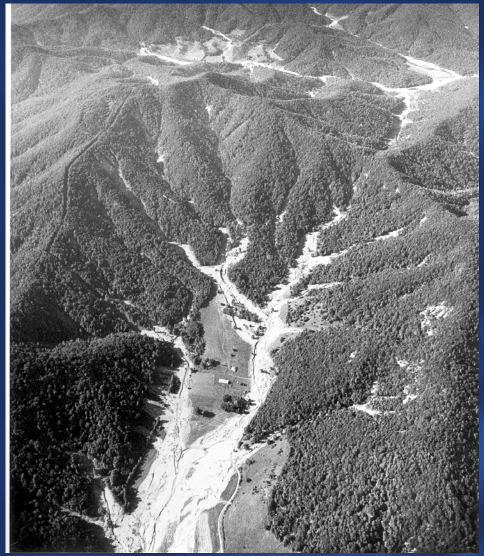
- Received funding to support 1 full-time grant funded geologist for 3 years
- Goal: Complete a landslide hazard map for Nelson and Albemarle Counties to identify at-risk properties and infrastructure
- First in Commonwealth to use high-resolution LIDAR
- Western Study area delivered March 2022
- Final Maps will be delivered Sept 2024

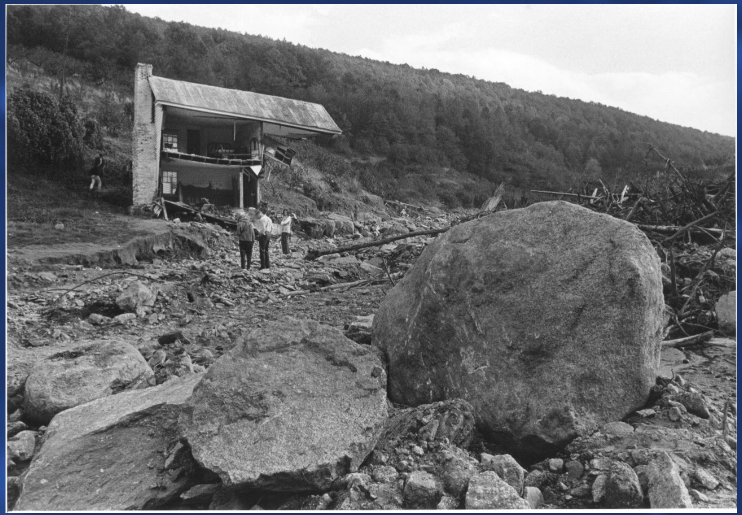


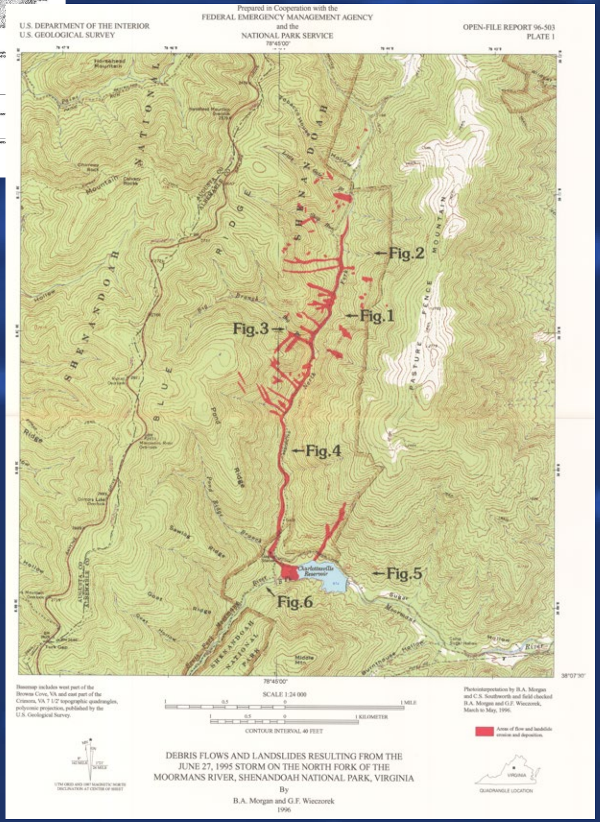
BACKGROUND

- Study area was affected by two major rainfall events which generated 100s to 1000s of landslides
  - Hurricane Camille (1969) – Nelson County
  - Severe Thunderstorm (1995) – Western Albemarle County
- USGS produced inventory maps of part of the study area (1996, 1999)









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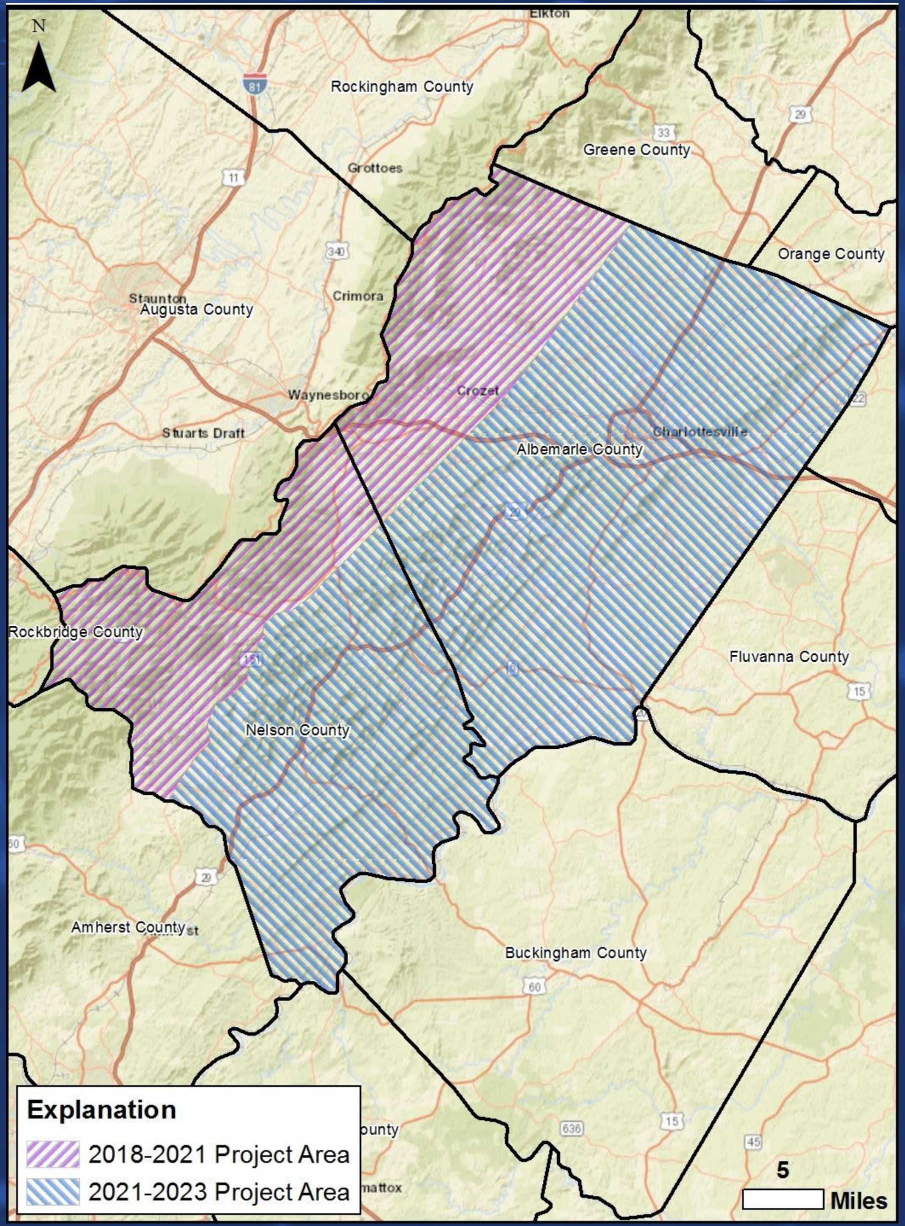
VDEM-FEMA PRE-DISASTER MITIGATION GRANT PROJECTS IN NELSON & ALBEMARLE COUNTIES:

Western Landslide Risk Assessment (2018-2022)
Eastern Landslide Risk Assessment (2021-2023)

This project will be completed in four phases:

1. Remote sensing of modern and prehistoric landslides in the study area using LIDAR
2. Geologic field mapping of landslide prone areas
3. Landslide susceptibility mapping and modeling
4. Presentation of data products and results to the planning community and the public.



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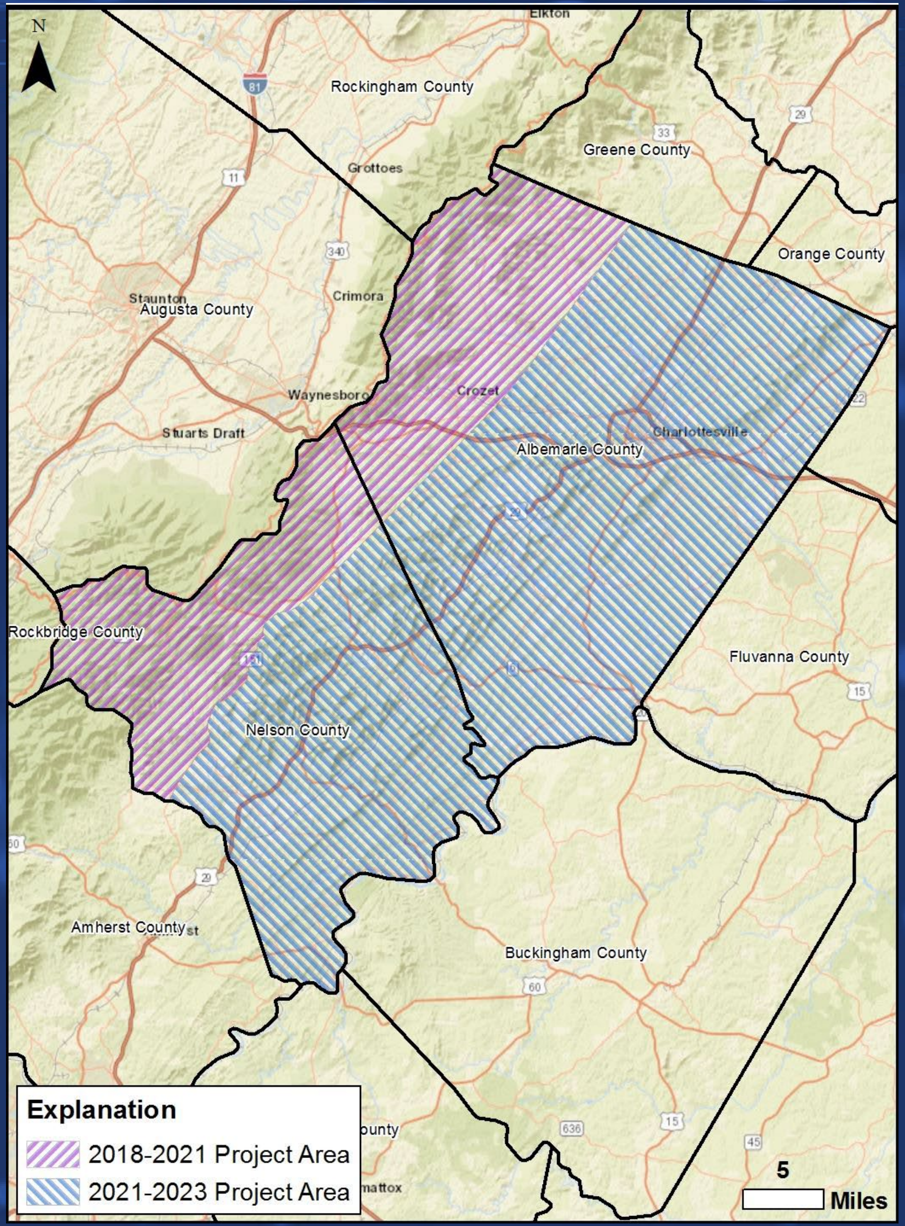
VDEM-FEMA PRE-DISASTER MITIGATION GRANT PROJECTS IN NELSON & ALBEMARLE COUNTIES:

Western Landslide Risk Assessment (2018-2022)

Eastern Landslide Risk Assessment (2021-2023)

This project will be completed in four phases:

1. ~~Remote sensing of modern and prehistoric landslides in the study area using LIDAR~~
2. ~~Geologic field mapping of landslide prone areas~~
3. Landslide susceptibility mapping and modeling (complete in western study area)
4. Presentation of data products and results to the planning community and the public (ongoing)



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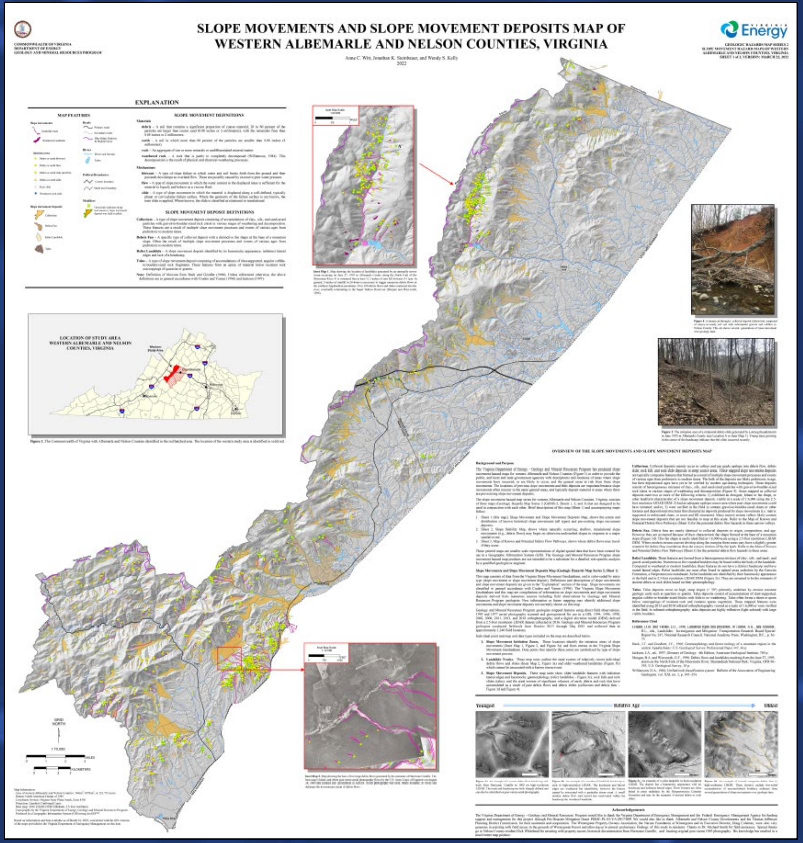
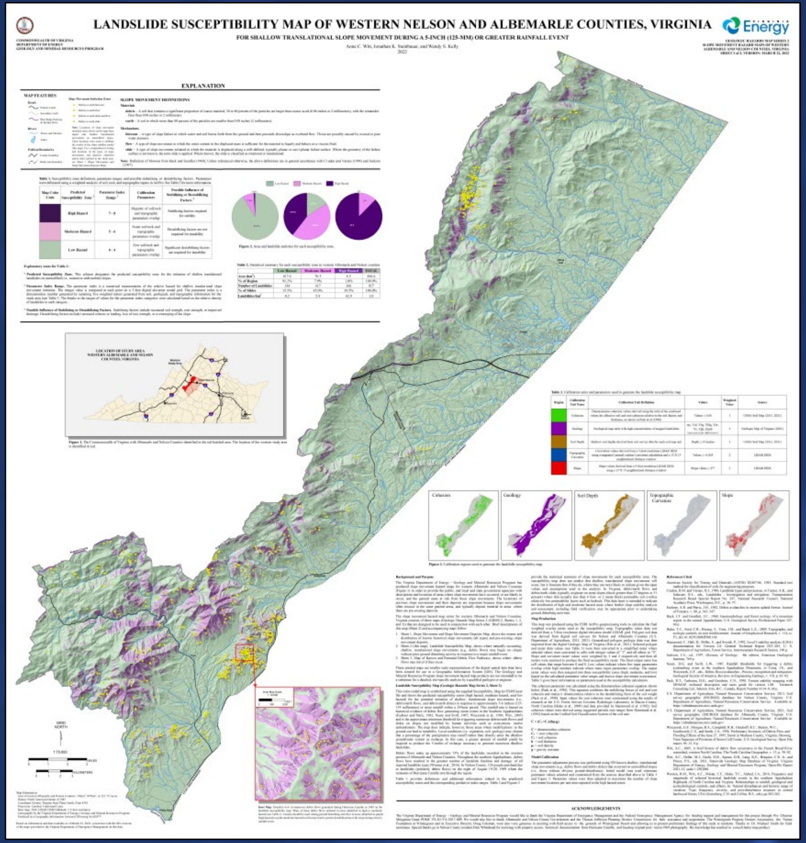
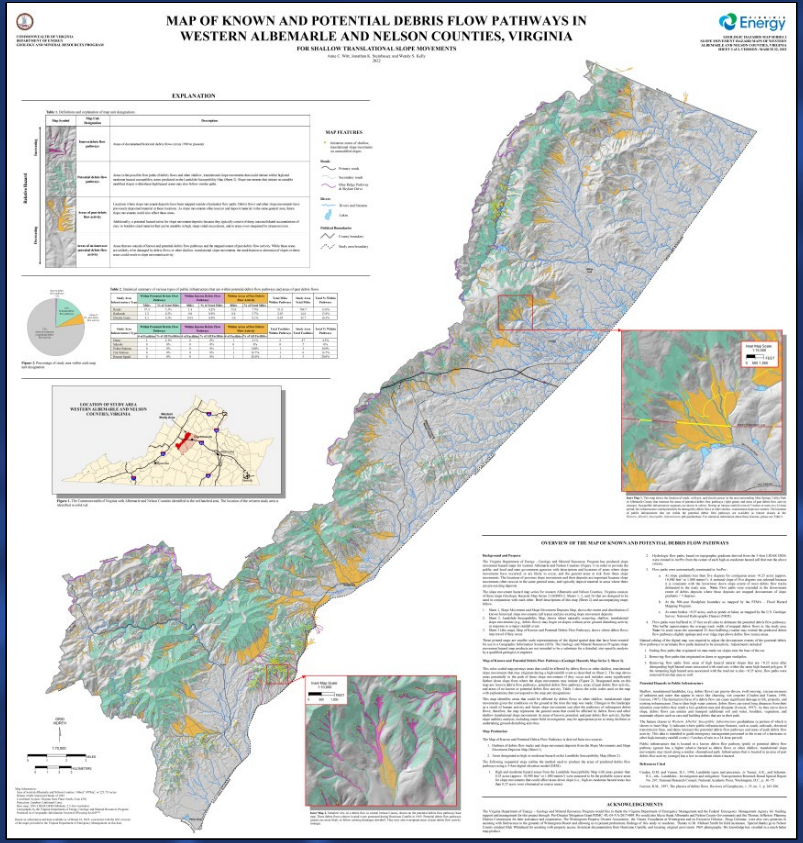
MARCH 2022 FEMA/VDEM DELIVERABLES







1 Landslide Inventory Map

2 Landslide Susceptibility Map

3 Landslide Pathway Map

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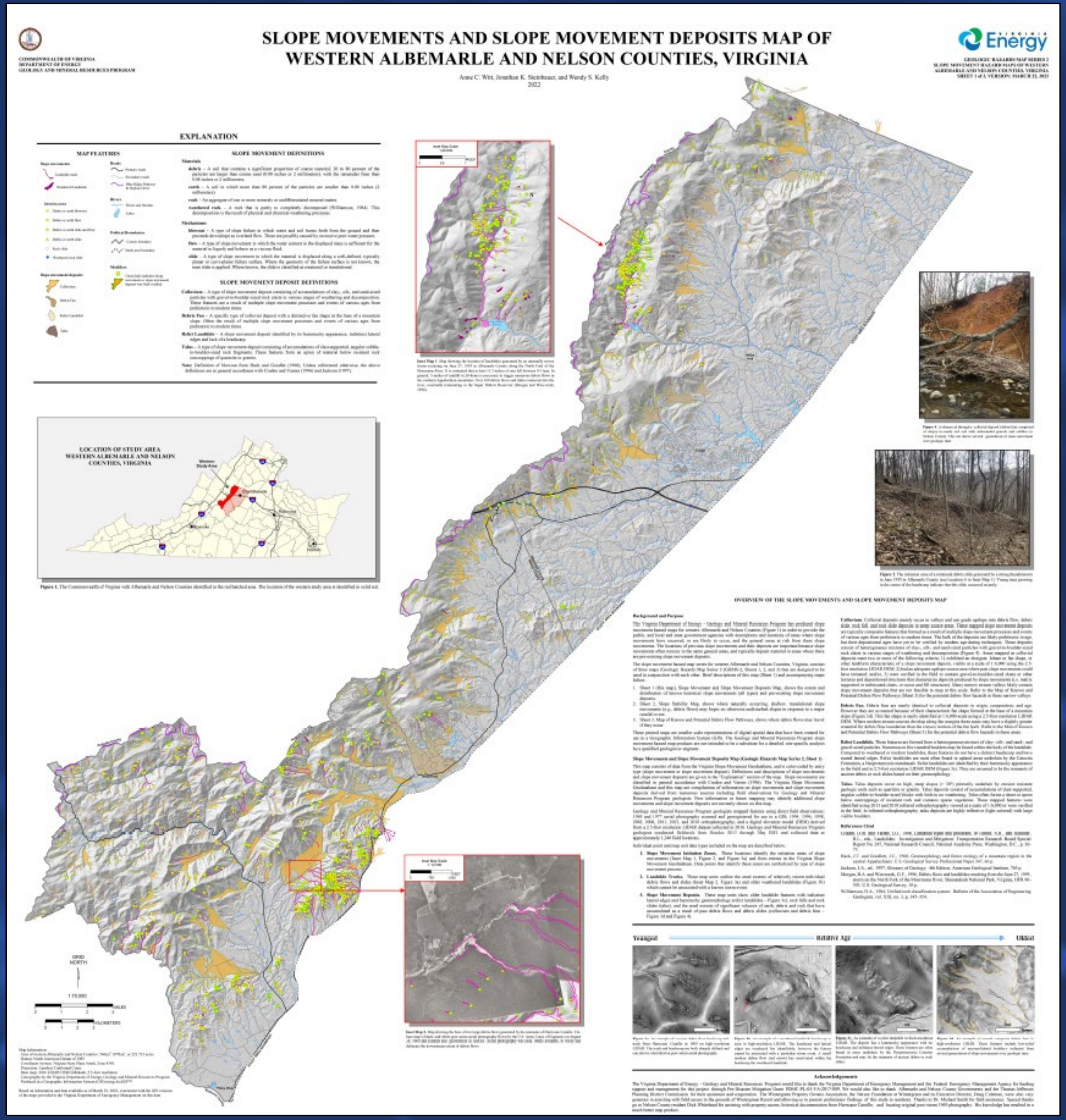
*PDF maps, GIS data and metadata, users guide

VDEM-FEMA PRE-DISASTER MITIGATION GRANT PROJECTS IN NELSON & ALBEMARLE COUNTIES:

First county-scale landslide project in Virginia to use high-resolution 1-meter LIDAR data

- Current study results – 2 county area:
  - Landslides identified (headscarps): 7809
  - Hurricane Camille 1969: 7241 (93%)
  - June 27, 1995 Storm: 189 (2%)
  - Landslides field verified by a Virginia Energy geologist: 415 (5%)
- Landslide outlines (tracks): 1772
  - 73 Weathered & 146 Relict Landslides
- Ancient landslide deposits: 1592

*Updated data as of April 2024



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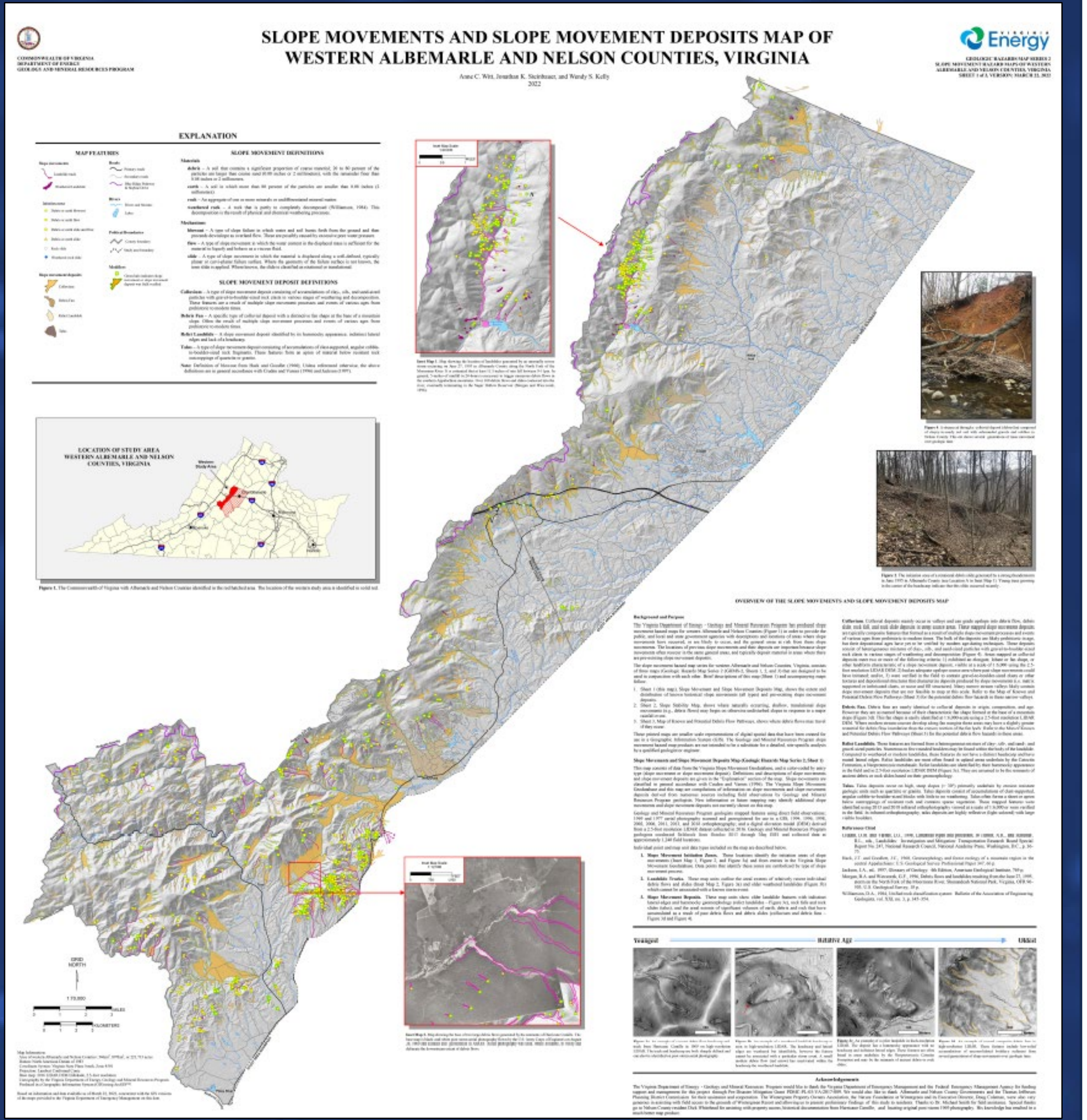

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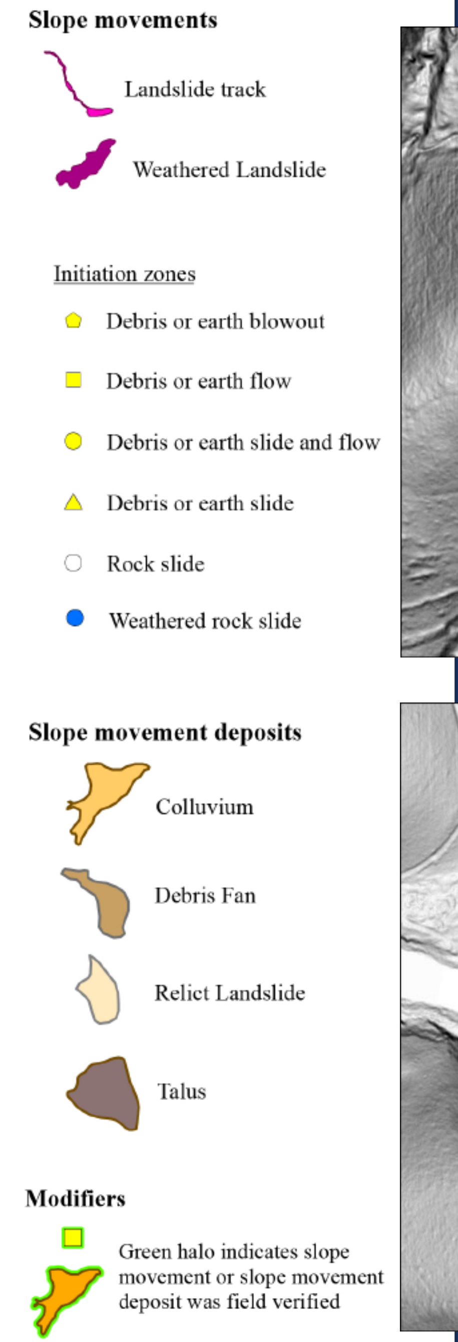
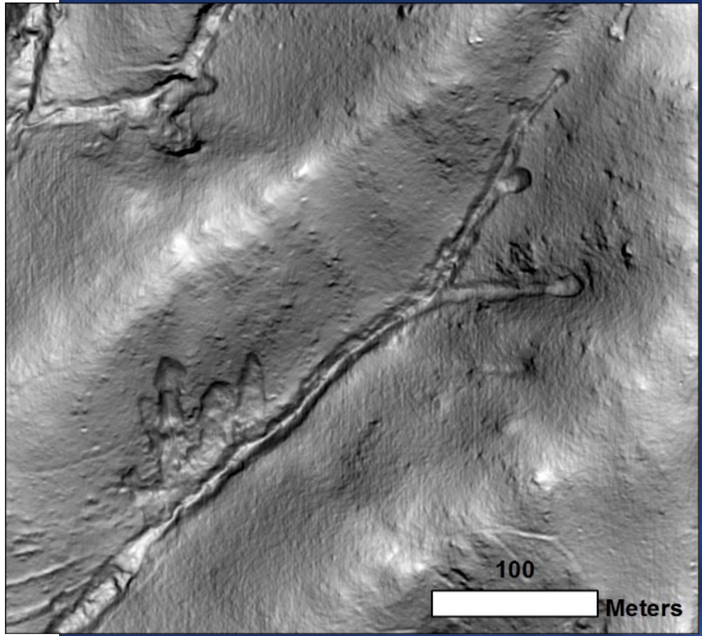
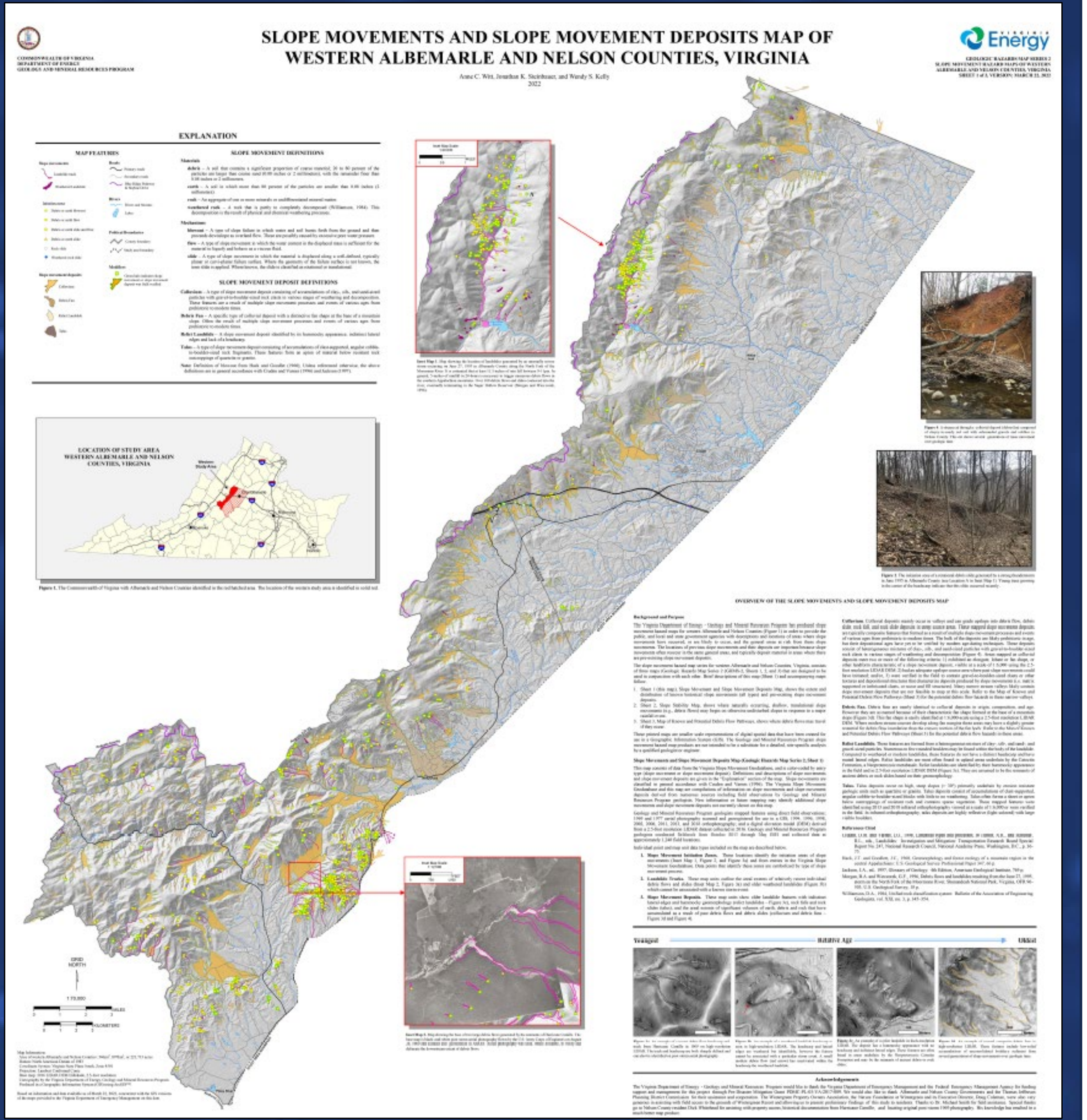




Modern Landslide: track and headscarp sharply defined, can be identified on post-storm aerial photography

Weathered Landslide: headscarp and lateral edges weathered but identifiable; cannot be associated with storm event



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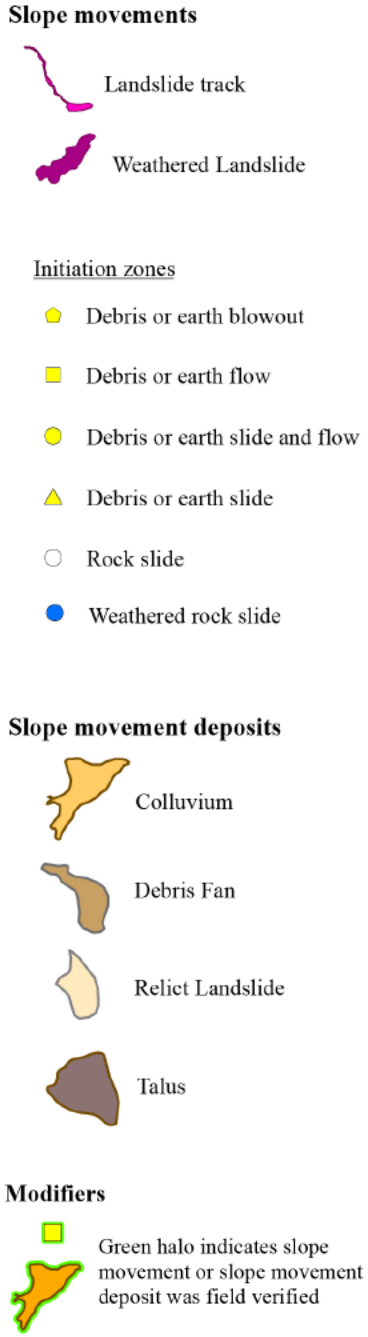
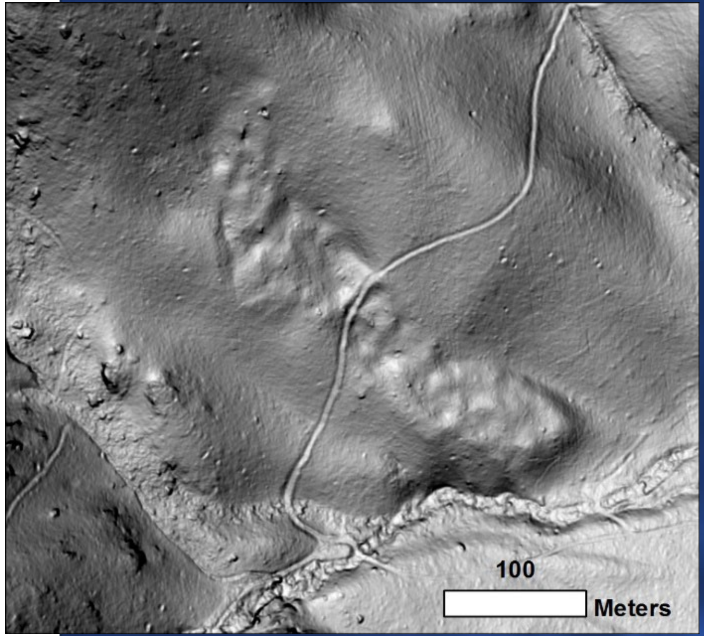
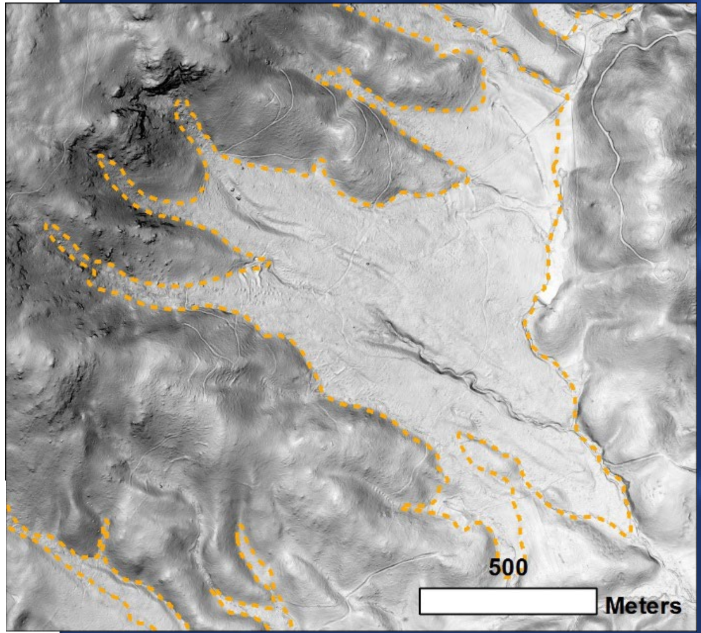




Relict Landslide: hummocky appearance, indistinct lateral edges and no headscarp



Landslide Deposits: low-relief accumulations of unconsolidated bouldery sediment

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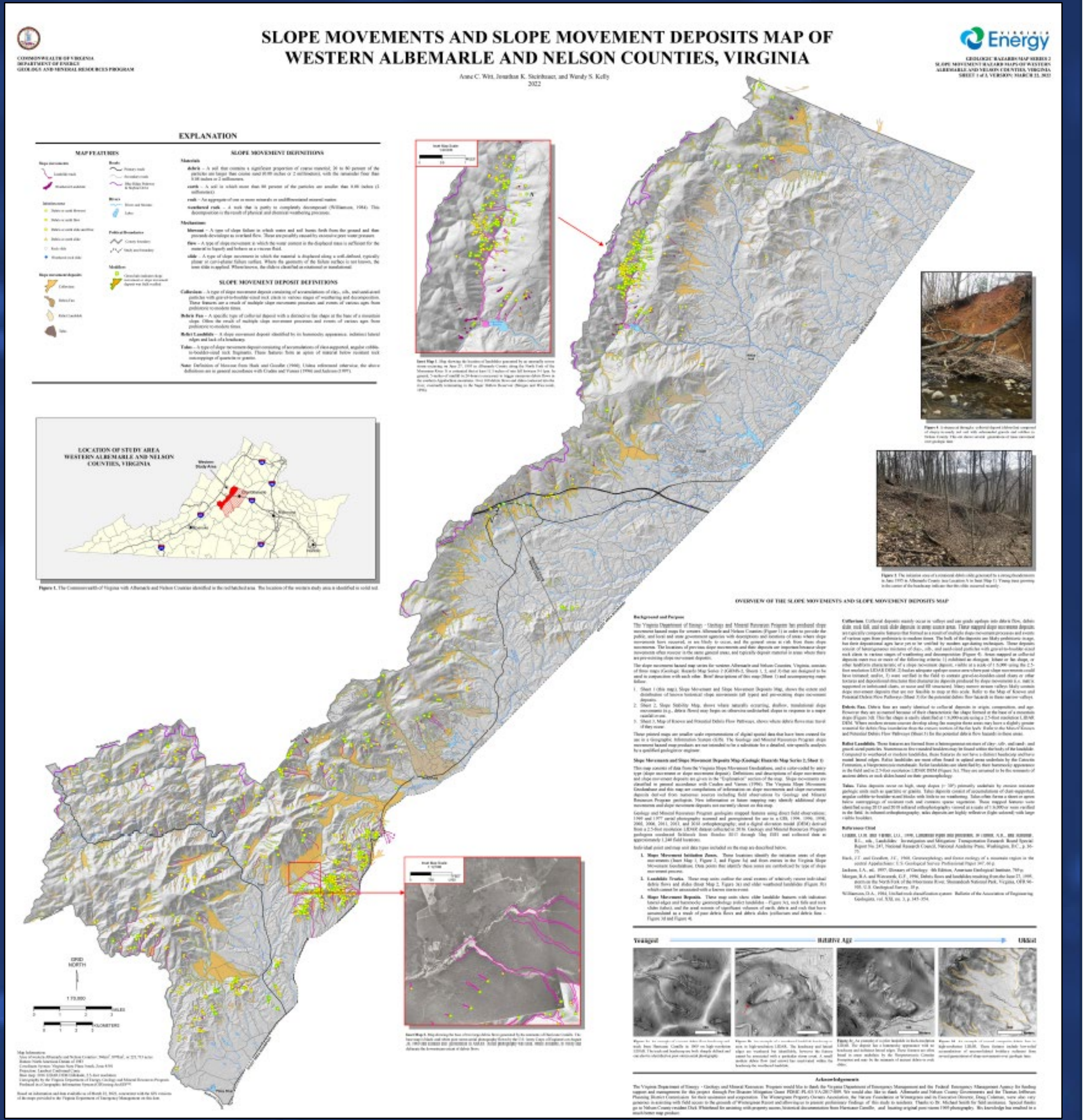


1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

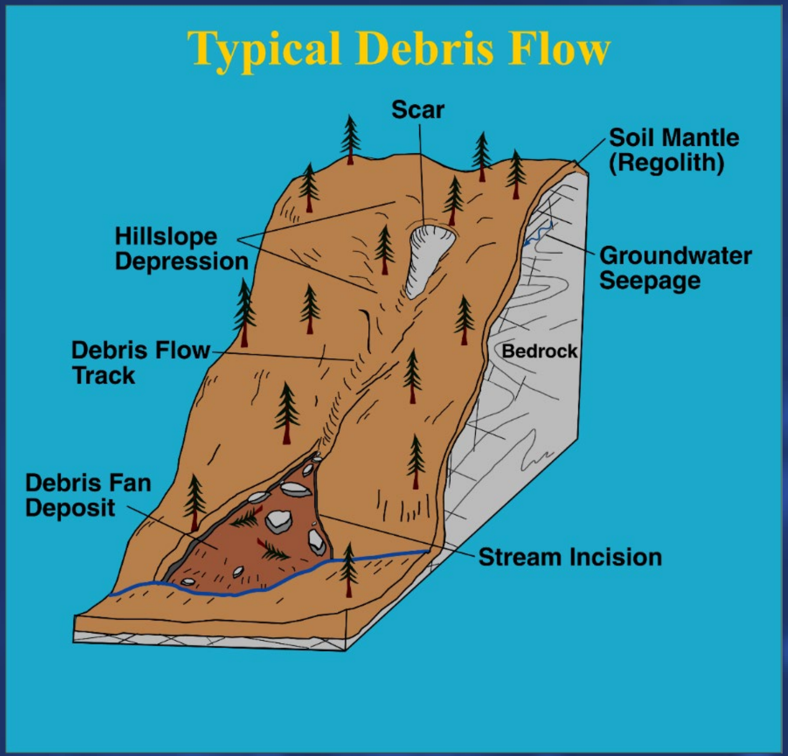
- Debris or earth blowout 7
- Debris or earth flow 6087
- Debris or earth slide and flow 13
- Debris or earth slide 1696
- Rock slide 5
- Weathered rock slide 1

Slope movement deposits

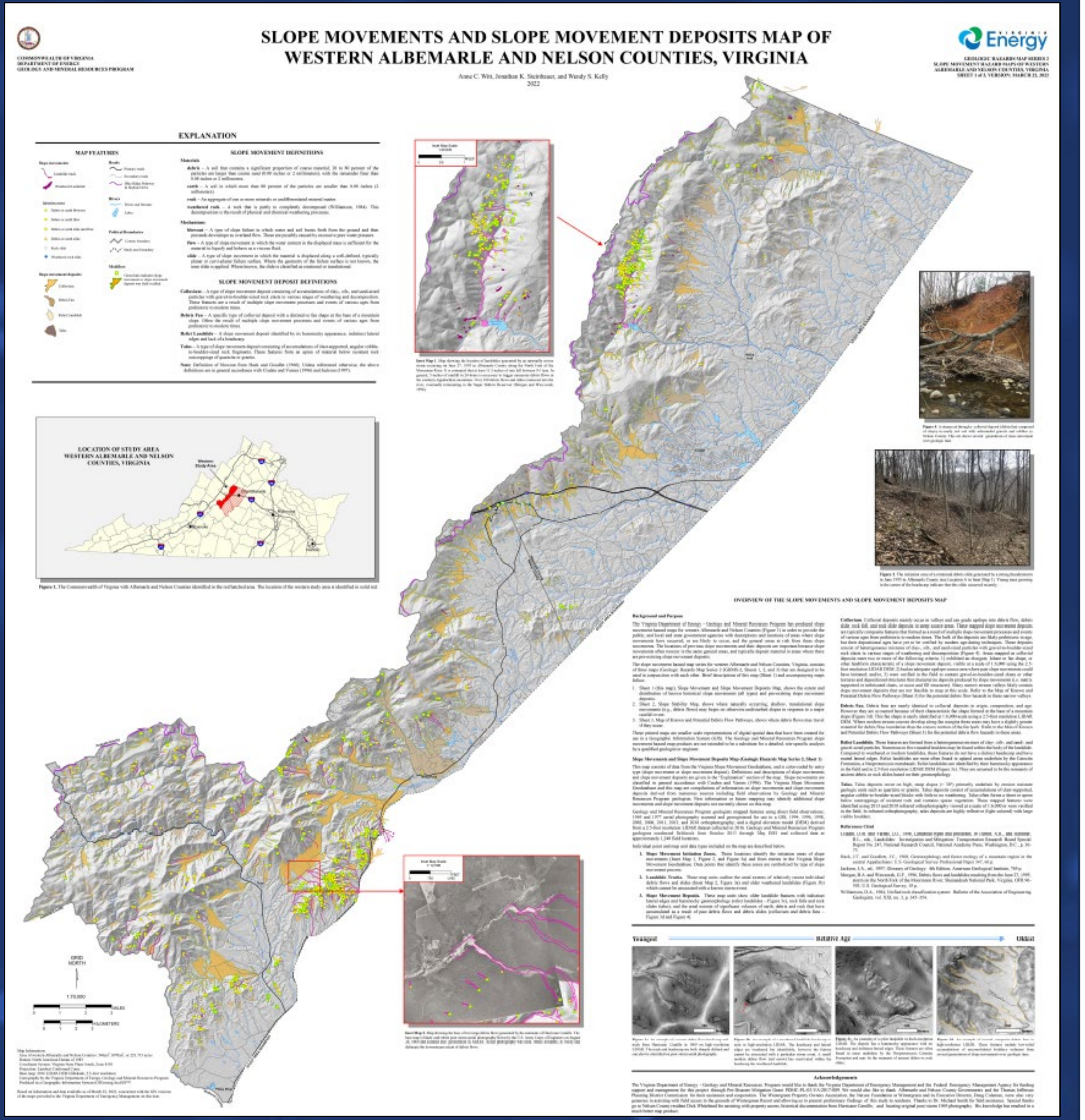
- Colluvium
- Debris Fan
- Relict Landslide
- Talus

Modifiers

Green halo indicates slope movement or slope movement deposit was field verified



	Type of Movement	Slide Translational Rotational	Flow	Topple	Fall	Composite
MATERIAL	Earth (>80% <2mm)					
	Debris (>20% >2mm)		X			
	Weathered Rock (PDS-CDS)					
	Rock (STS-VFS)					



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Slope movements

Landslide track

Weathered Landslide

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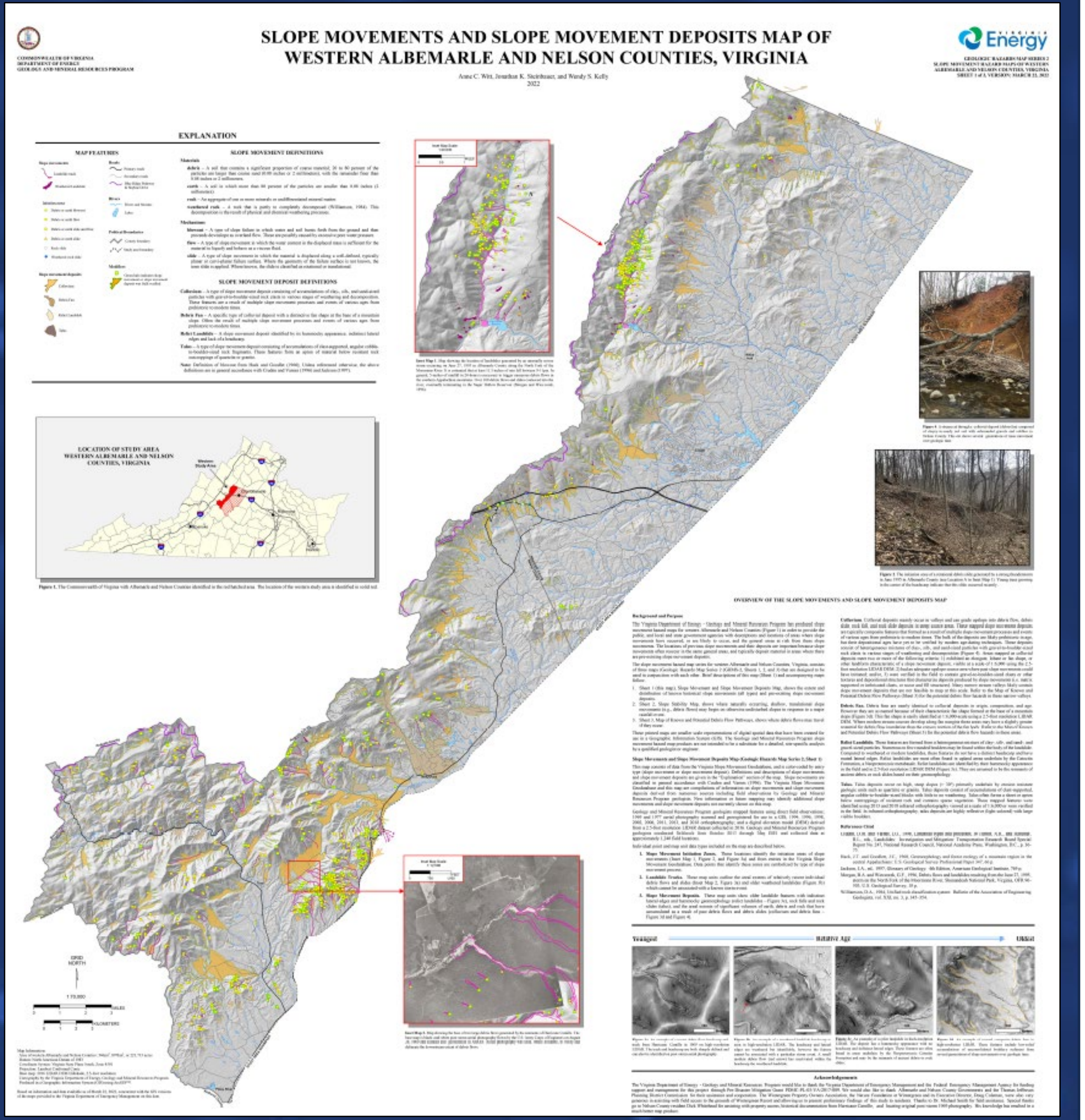
Energy



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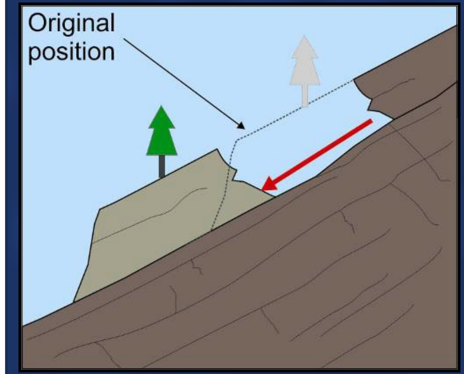
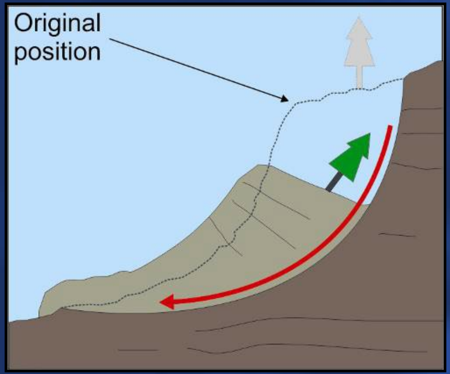


Translational slide



Rotational slide

	Type of Movement	Slide Translational Rotational	Flow	Topple	Fall	Composite
MATERIAL	Earth (>80% <2mm)					
	Debris (>20% >2mm)	X				
	Weathered Rock (PDS-CDS)					
	Rock (STS-VFS)					

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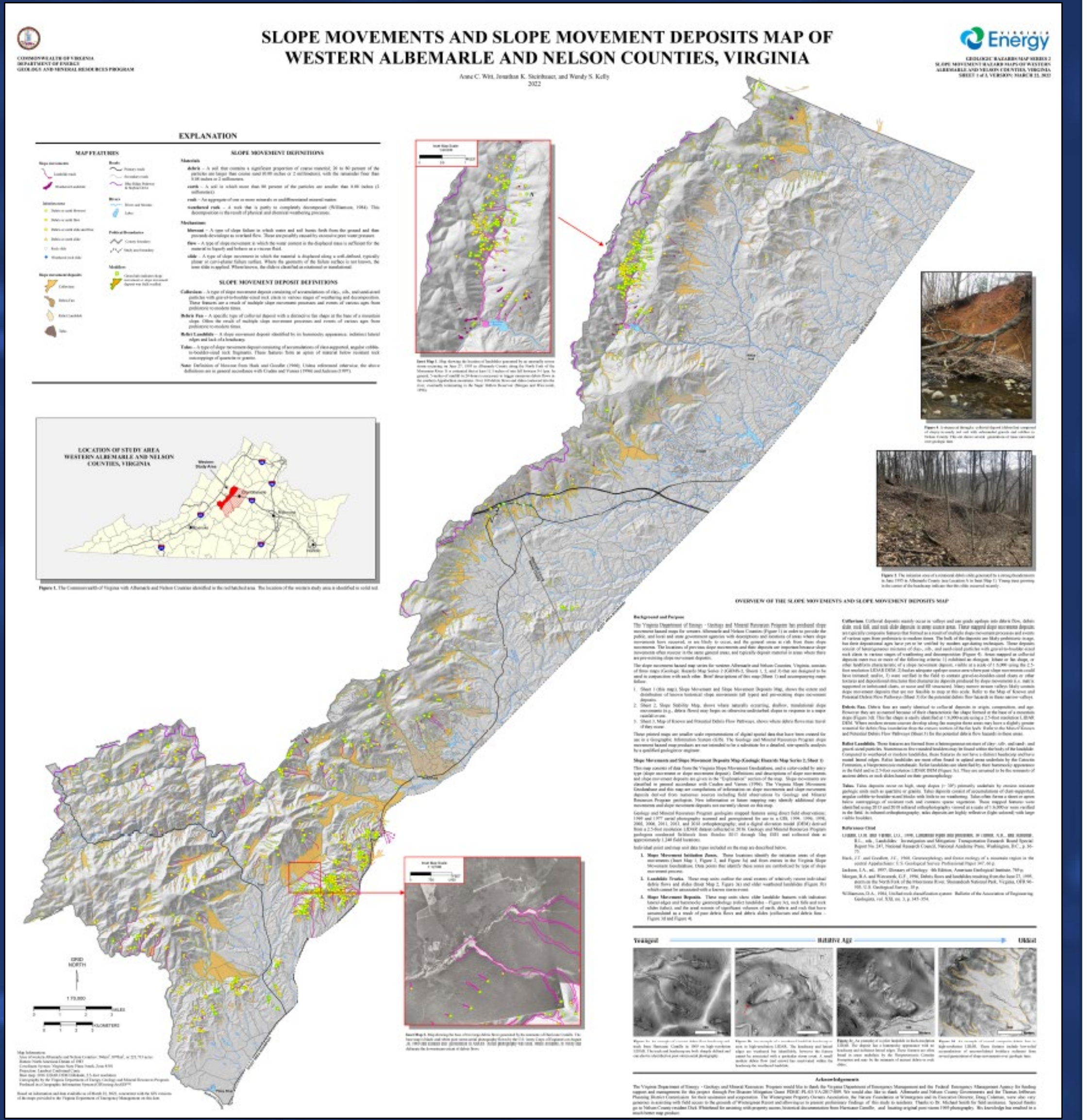

Slope movements

Landslide track

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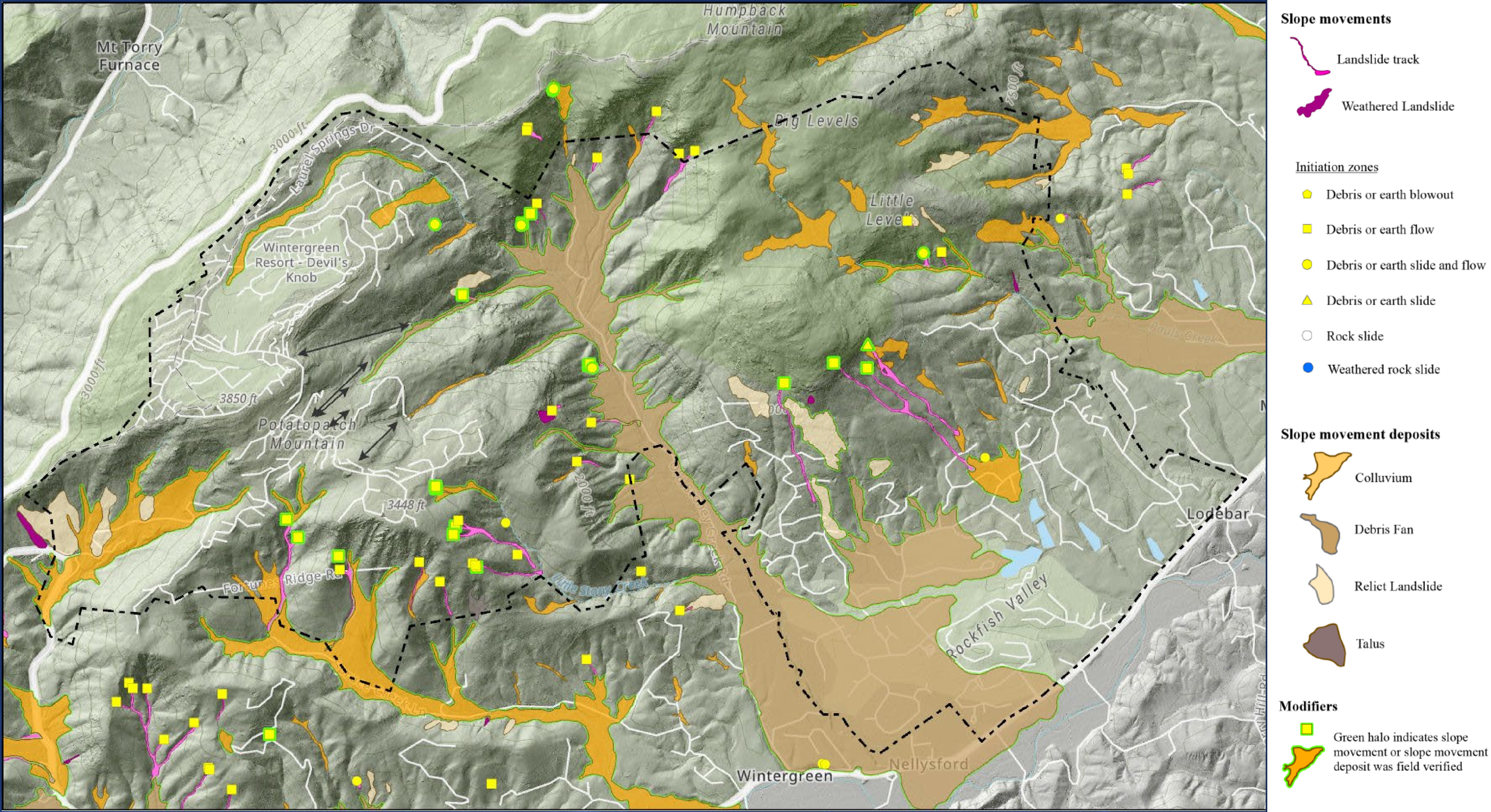
Humpback Mountain
Mt Torry Furnace
Laurel Springs Dr
3000 ft
Big Levels
Little Levels
2500 ft
Wintergreen Resort - Devil's Knob
3850 ft
Potatopatch Mountain
3448 ft
2000 ft
Fortunes Ridge Rd
Little Stony Creek
Rockfish Valley
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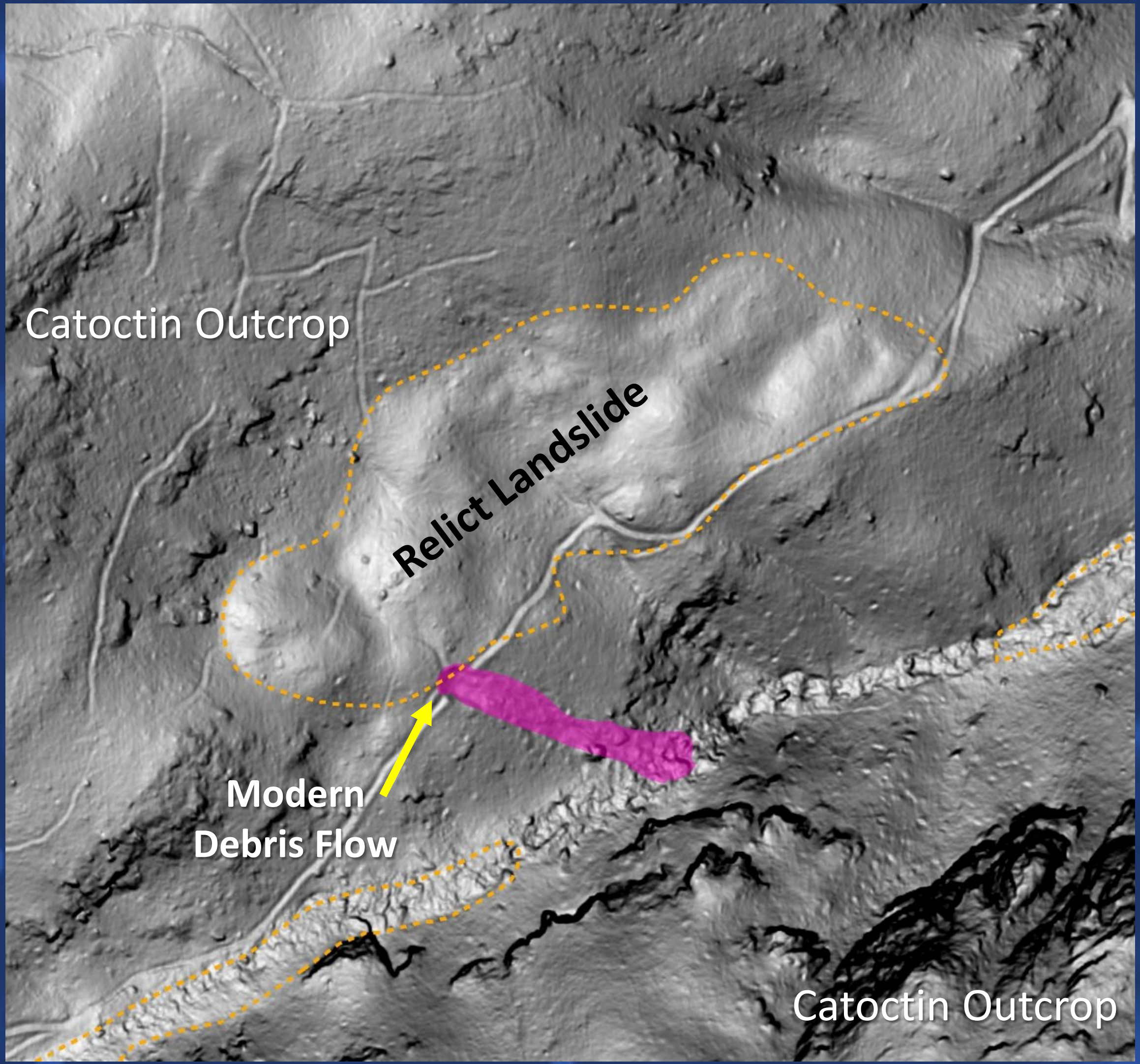
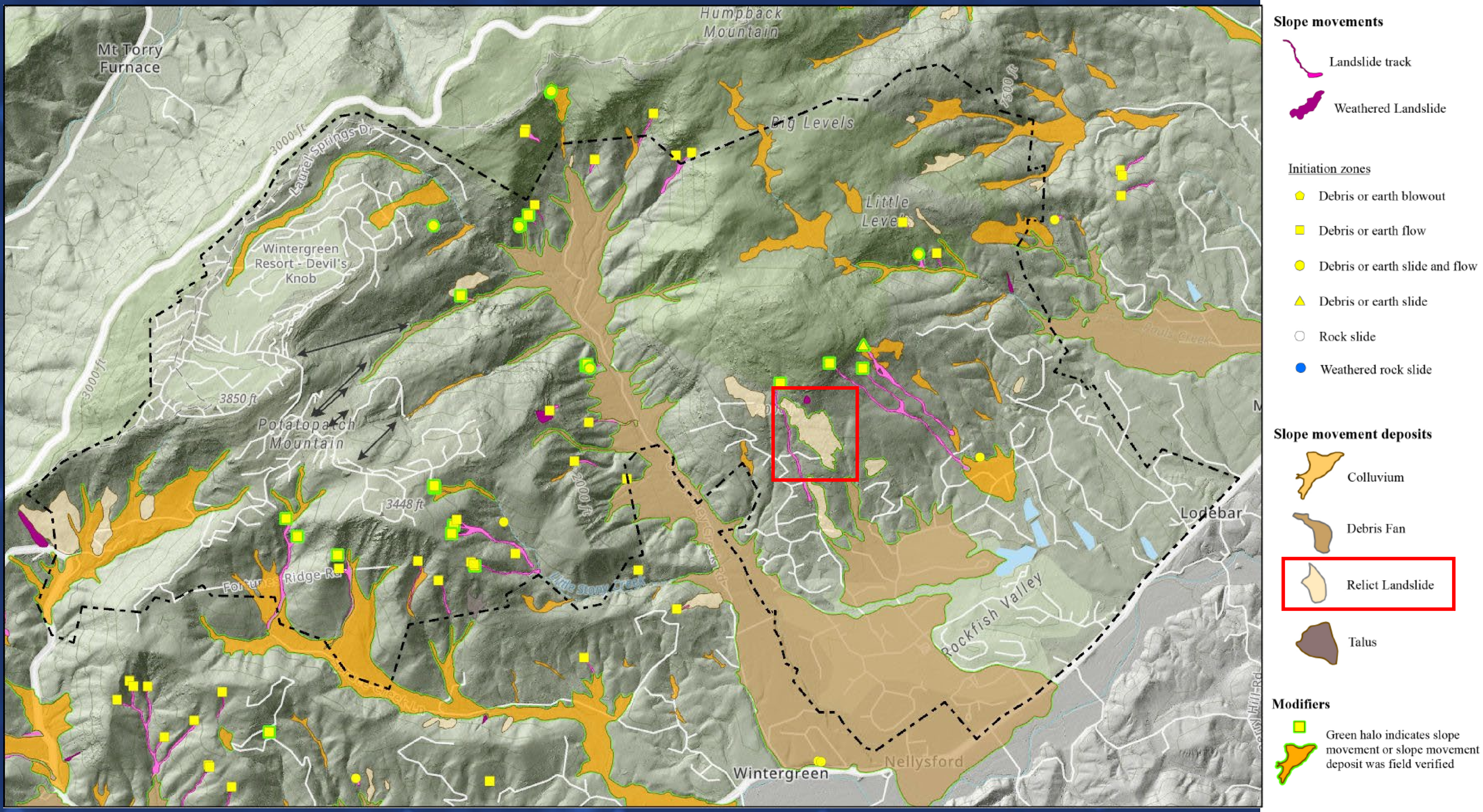


RELICT LANDSLIDES

- Remnants of several generations of downslope movement
- All evidence of scarping and lateral boundaries have been weathered away over geologic time, leaving a hummocky surface exposure
- Sometimes occur below a cliff face or outcrop source
- Primarily found in areas underlain by Catoctin metabasalt
- Primary concern is for construction and initiation of new landslides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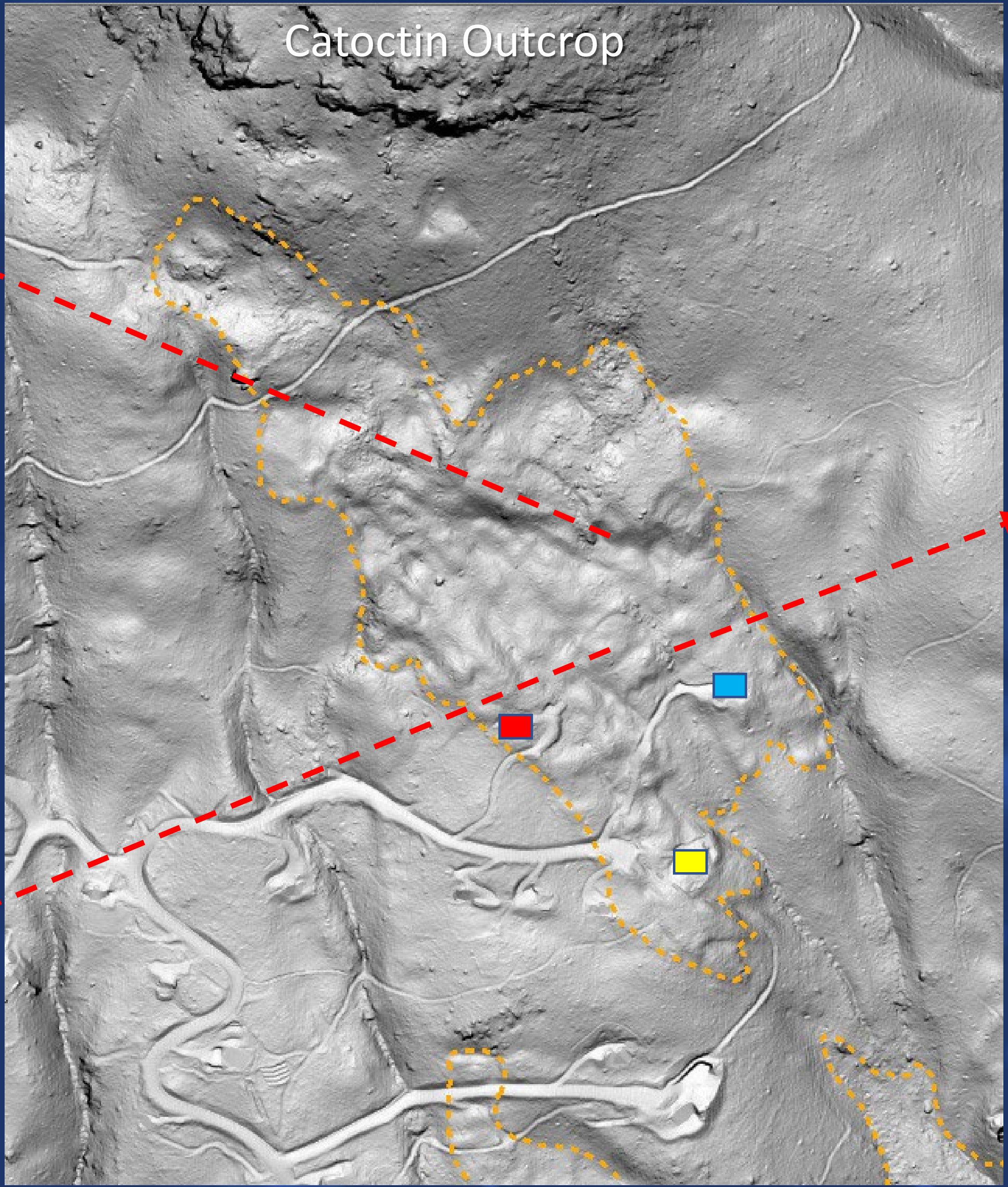
Shelf of exposed bedrock within landslide deposit

Lobe of hummocky, cobble-to-boulder sized debris

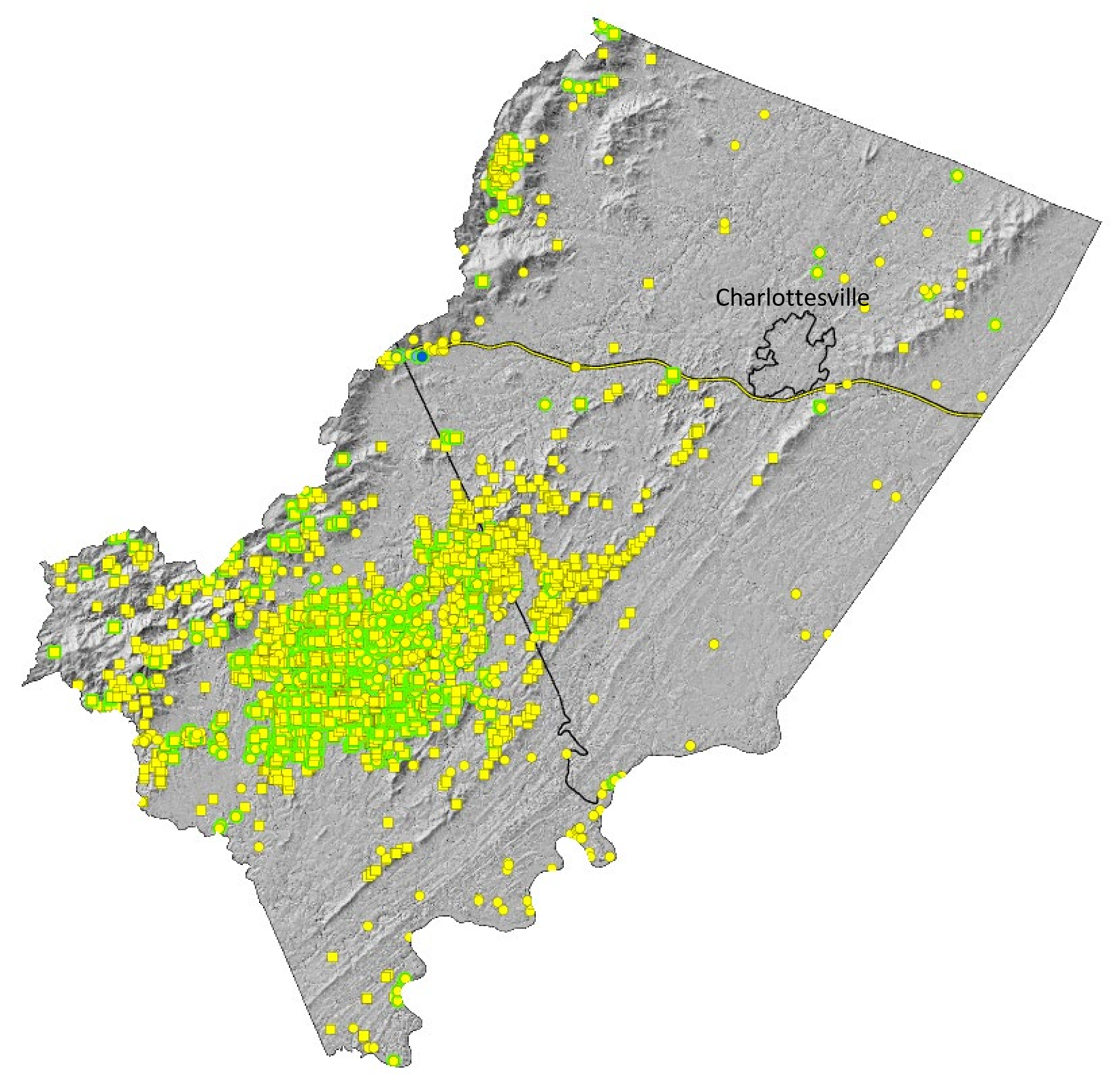


Wintergreen Relict Landslide Deposit

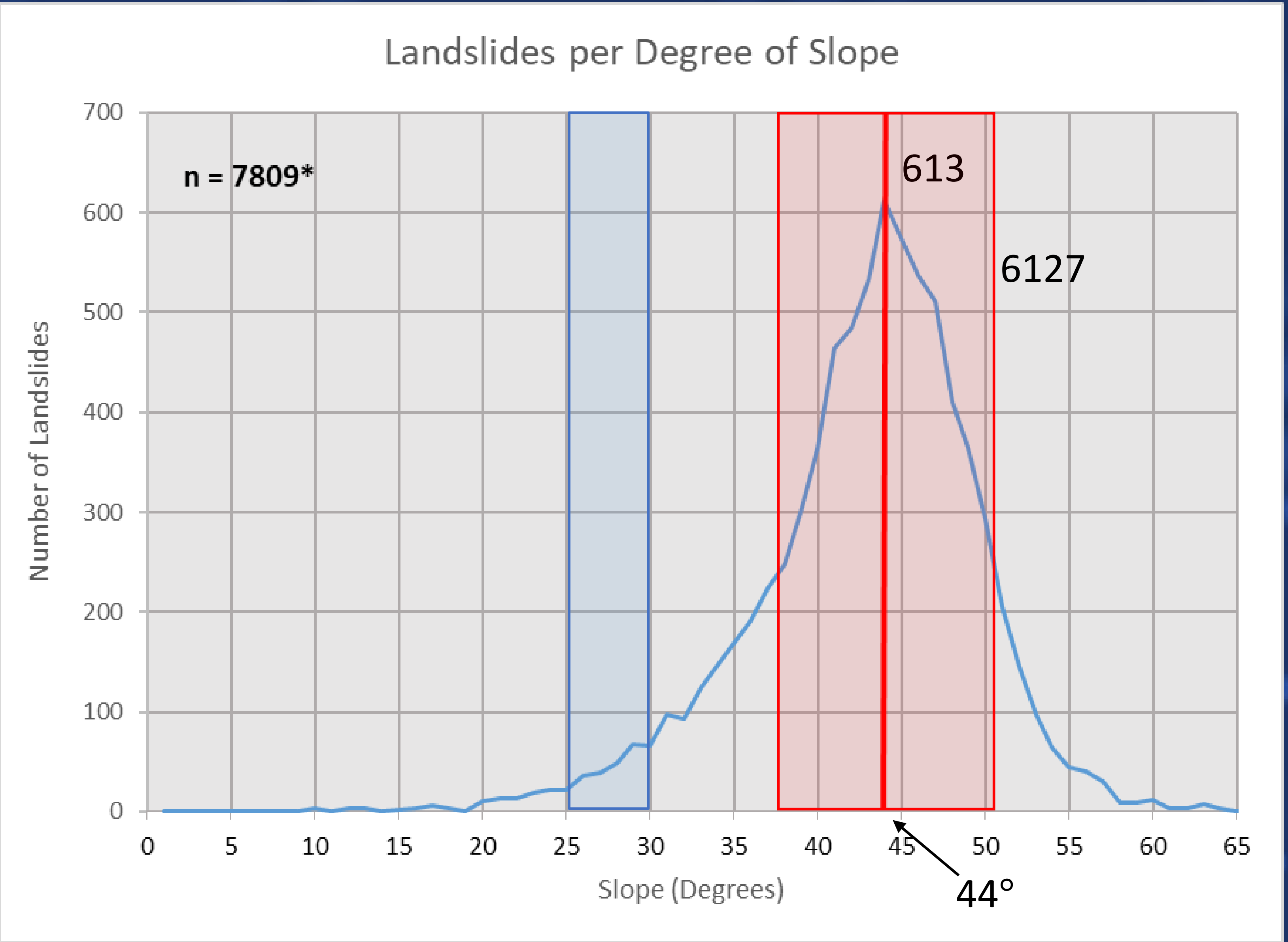
Boulder Stream

INVENTORY UPDATE APRIL 2024

- Robust inventory allows us to perform helpful spatial statistics with pre-existing datasets (slope, aspect, elevation, geology, soil, etc)
- Constrains data used for susceptibility modeling
- Provides useful information to planners and emergency management about past landslide activity in an area



UPDATED LANDSLIDE STATISTICS: SLOPE



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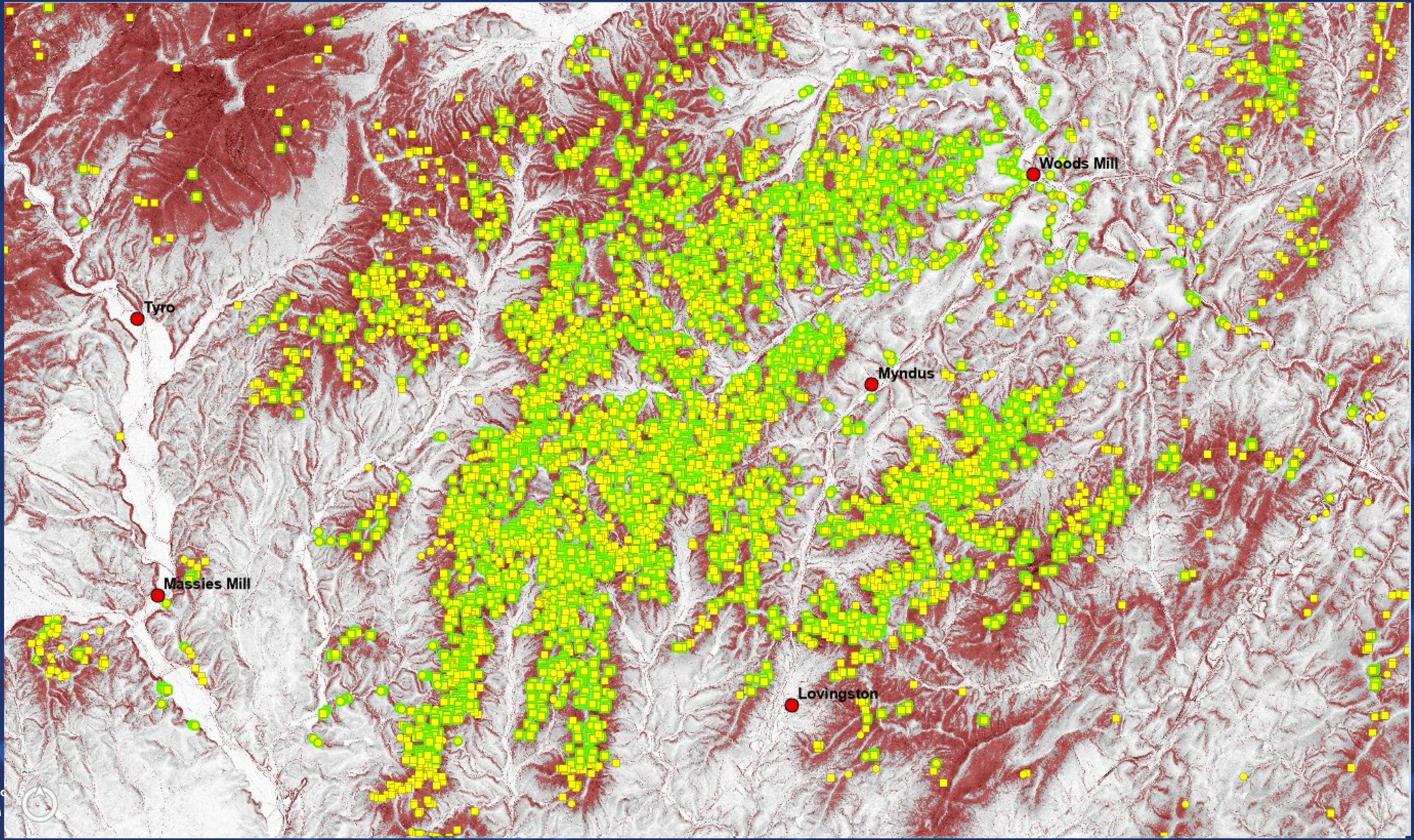
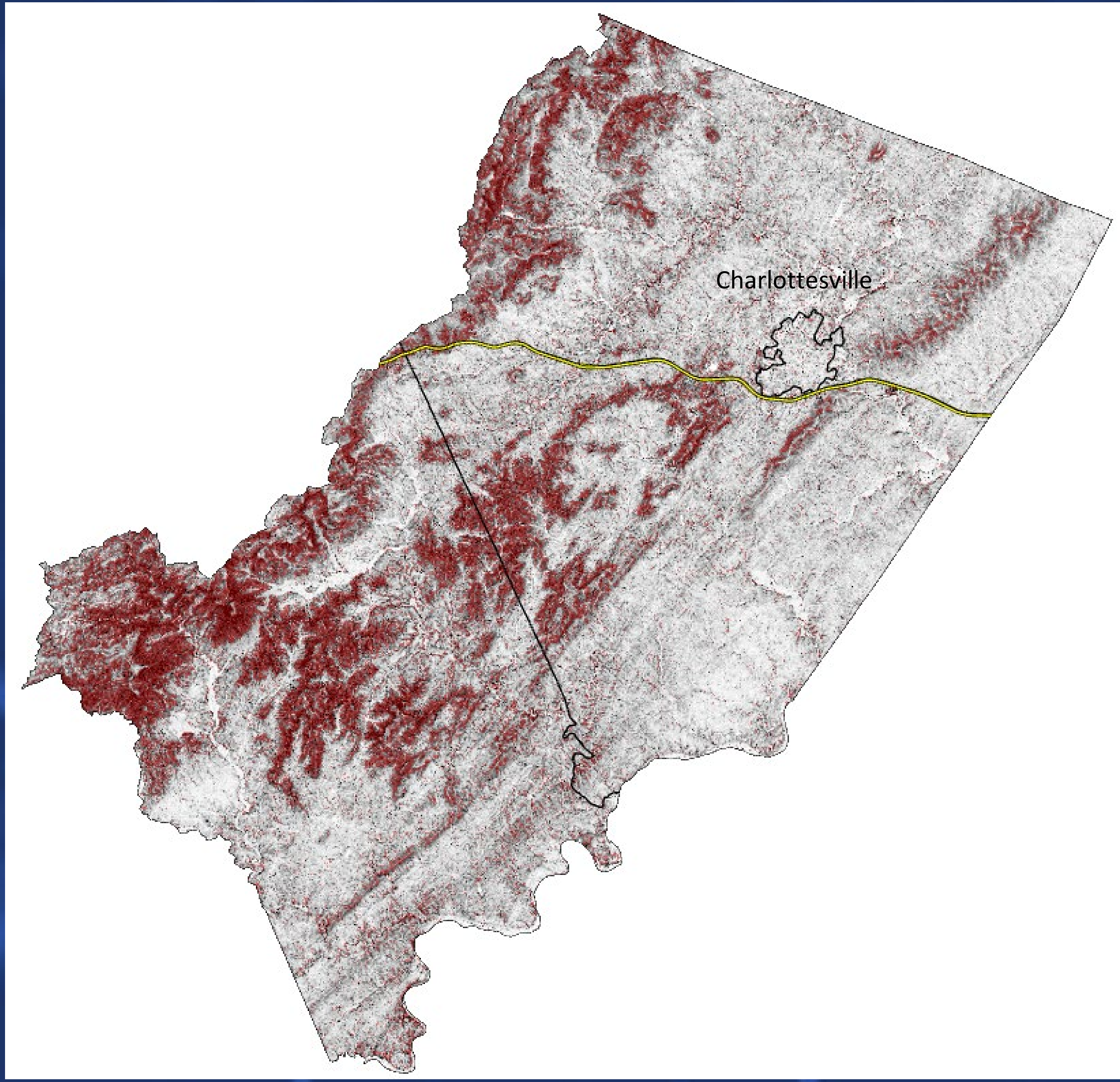


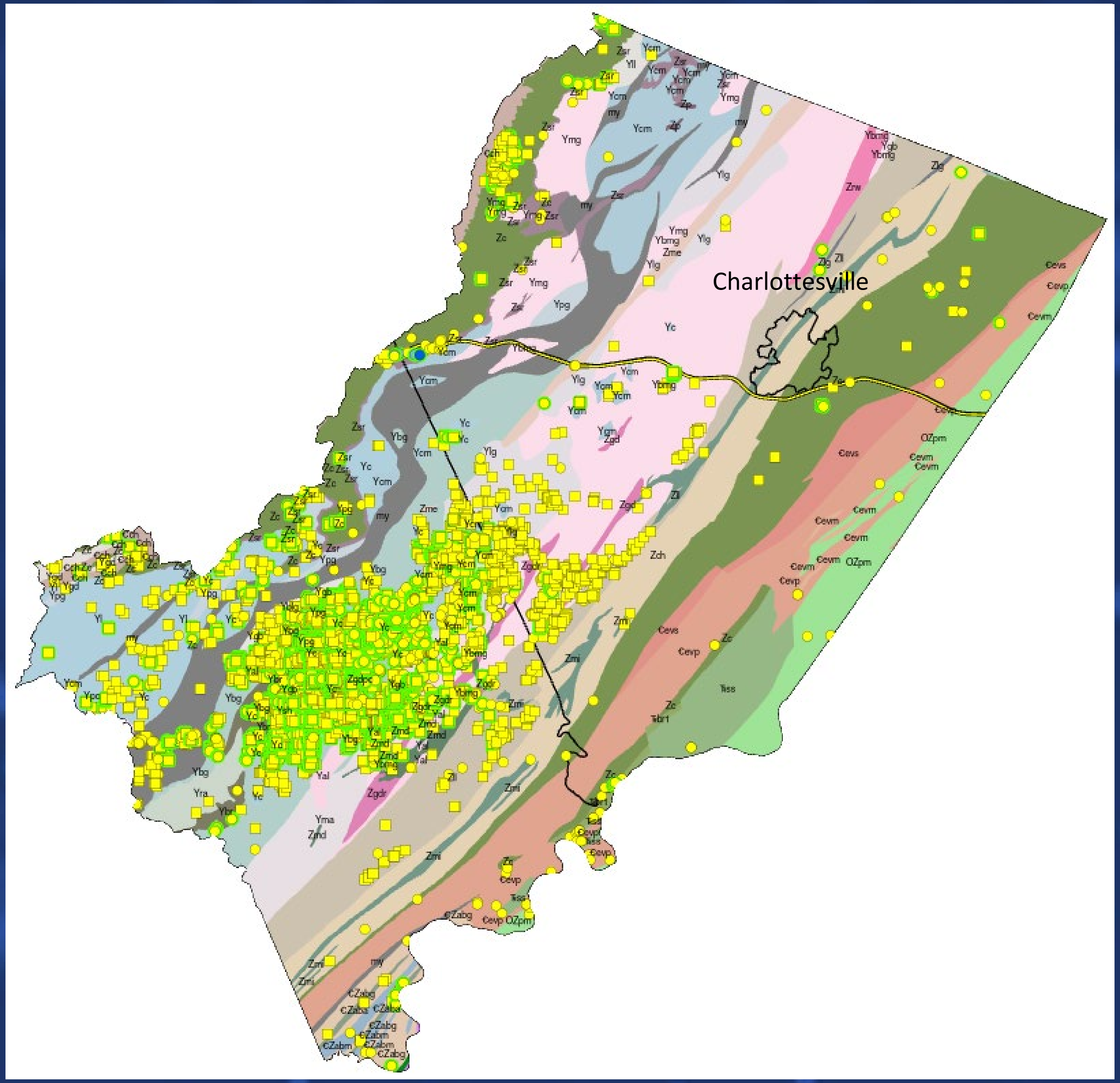
UPDATED LANDSLIDE STATISTICS: SLOPE

- Albemarle & Nelson = 1210 mi^2
- Area of counties that has slopes steeper than 25° = 130 mi^2 or 11% of the study area
- 7676 (98%) of landslides occur on slopes greater than 25° → 59 landslides/mi^2
- For higher degrees of slope, 40-50°, only 0.5% of study area → landslide density increases to 754/mi^2



UPDATED LANDSLIDE STATISTICS: GEOLOGY

- Area is within the central and eastern flank of the Blue Ridge Geologic Province
- 48 different geologic units, based on geology from the Geologic Map of Virginia (2021)
- Nearly all the landslides (83%) occur in middle-to-late Proterozoic basement gneisses, meta-granitoids, and other meta-intrusive rocks



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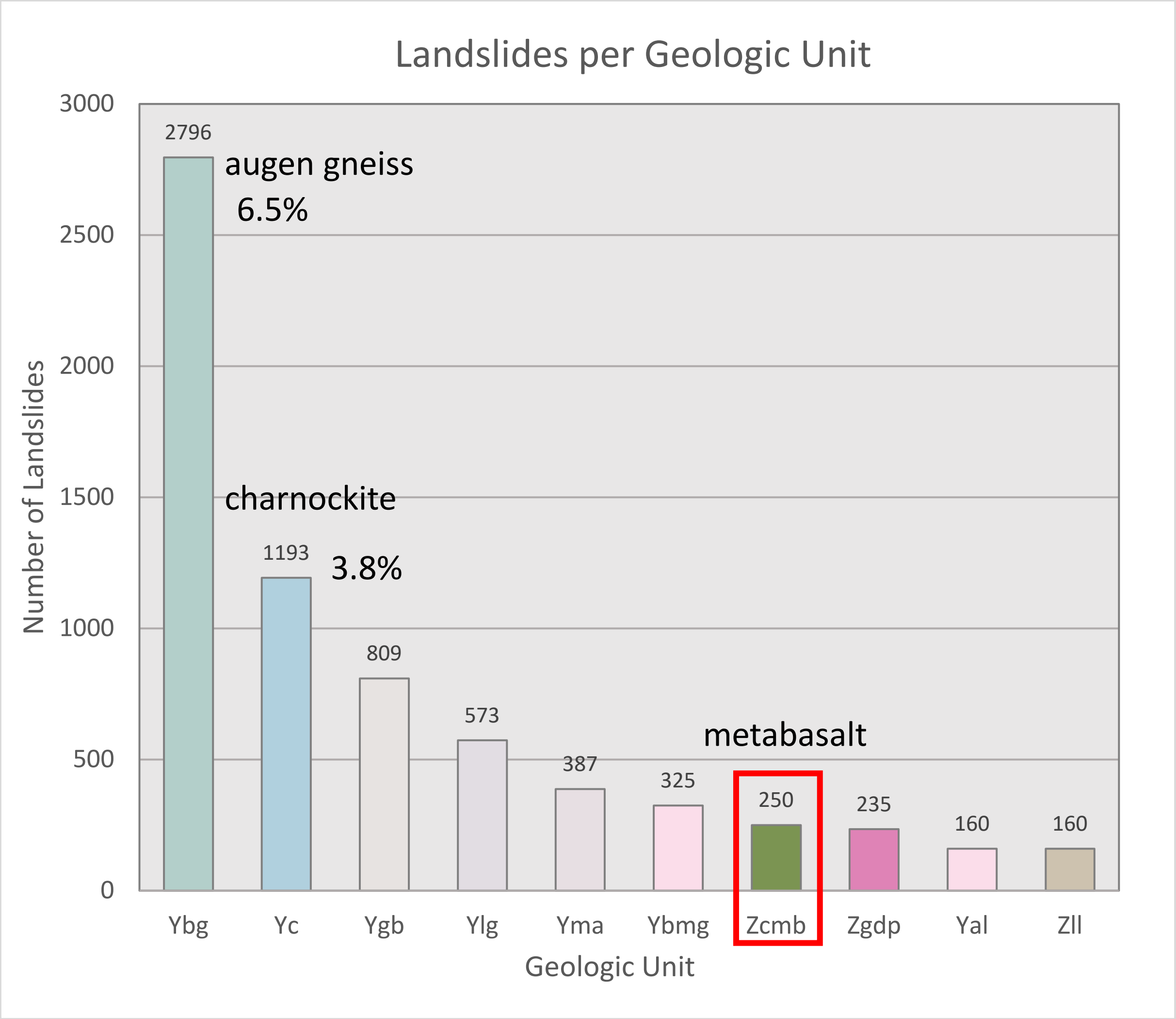
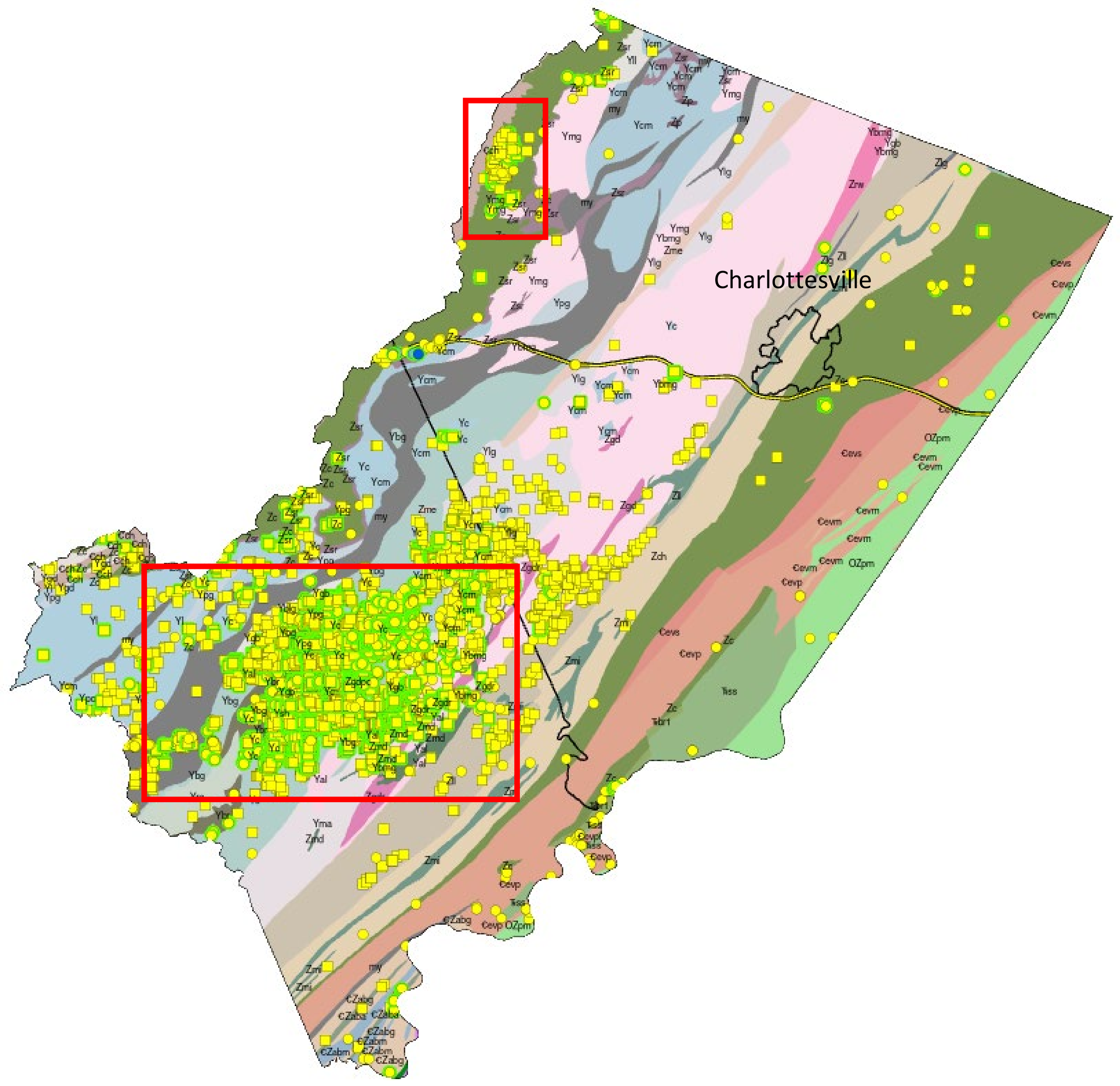
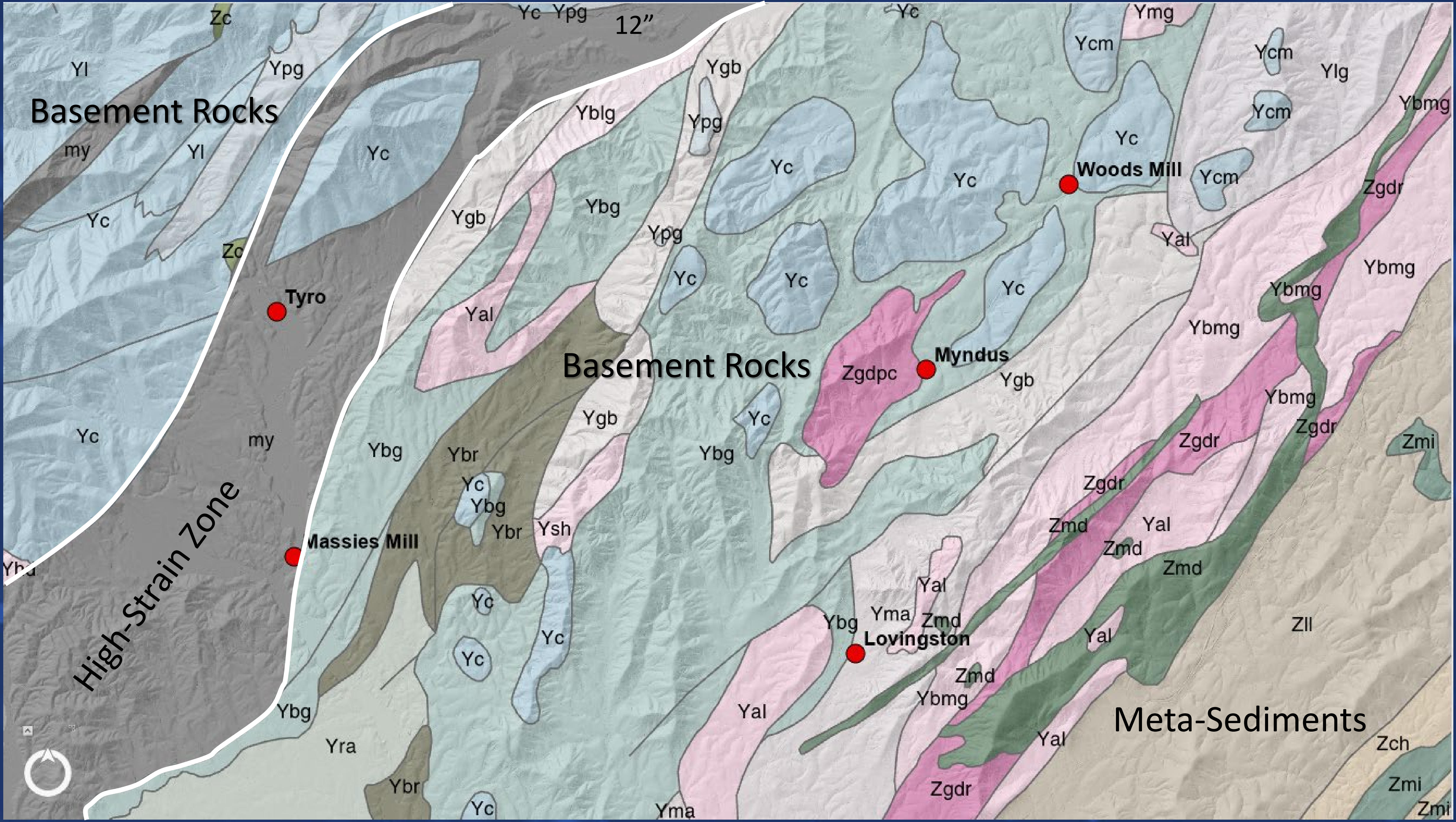
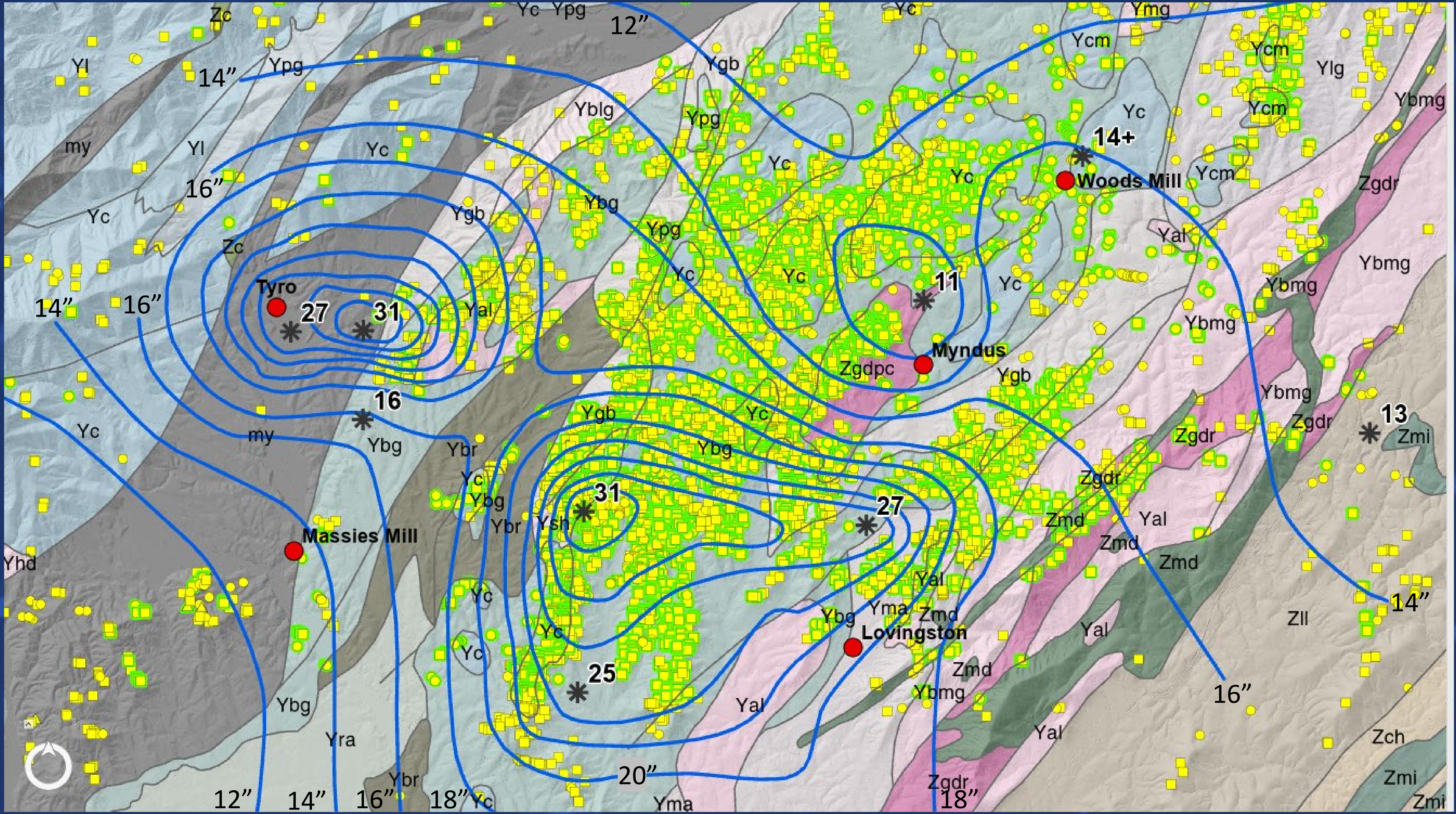






Basement Rocks
Basement Rocks
Meta-Sediments
High-Strain Zone
12”
Tyro
Massies Mill
Myndus
Woods Mill
Lovingston
Zc
Yl
Ypg
Yc
my
Ygb
Yblg
Ybg
Yal
Ybr
Ysh
Ymg
Ycm
Ylg
Ybmg
Zgdr
Zgdpc
Yma
Zmd
Zmi
Zll
Zch
Yra



Tyro
Woods Mill
Myndus
Massies Mill
Lovingston
27
31
16
11
14+
31
27
25
13
12”
14”
16”
20”
18”
Zc
Yc
Ypg
Ymg
Ycm
Ylg
Ybmg
Yl
my
Ygb
Yblg
Ybg
Zgdr
Yal
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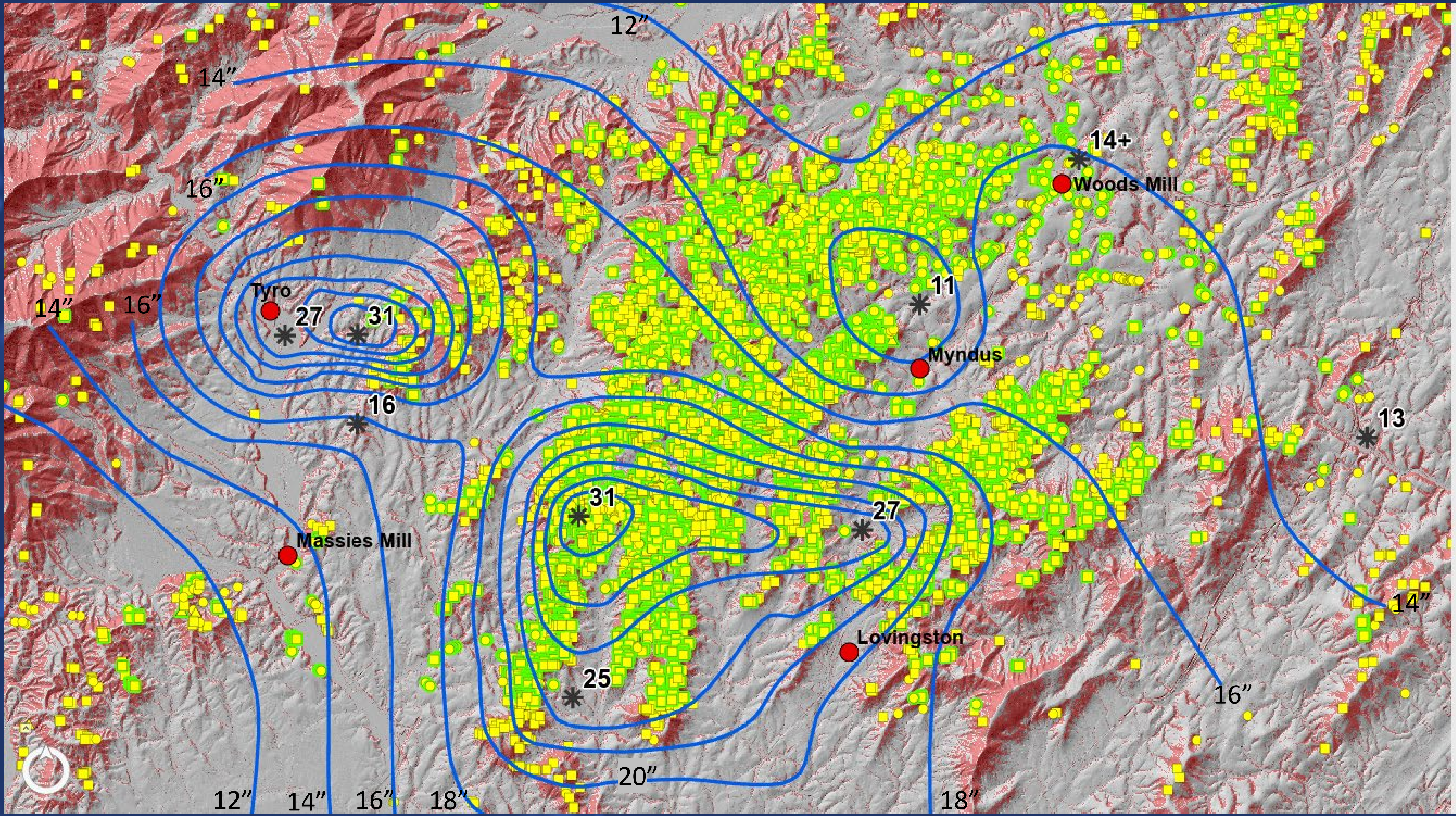
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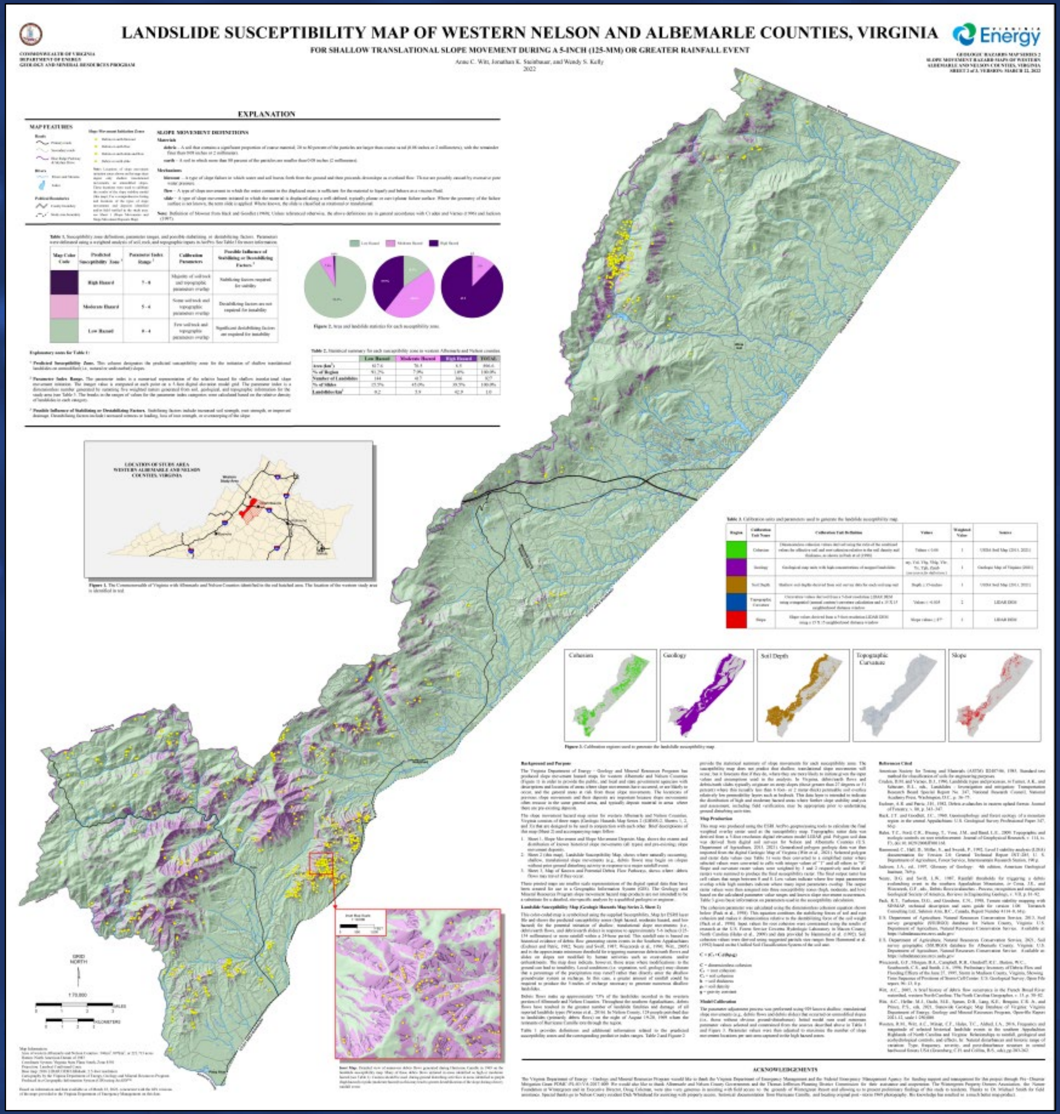
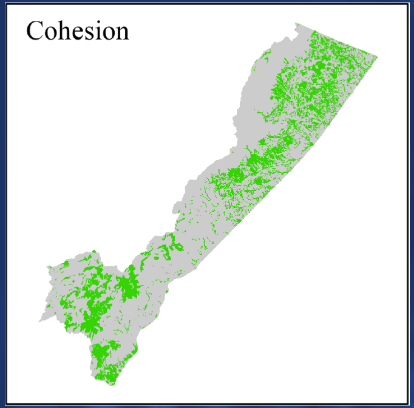
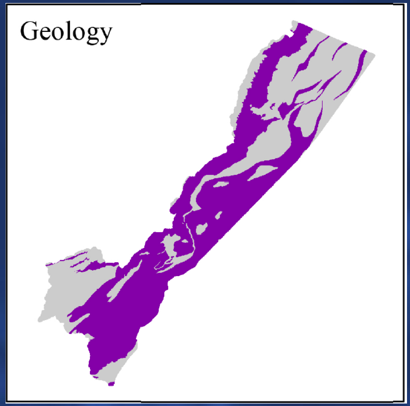
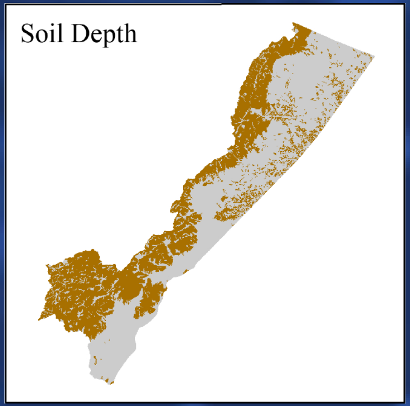
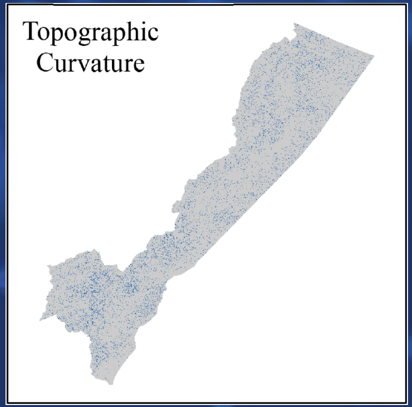


Region	Calibration Unit Name	Calibration Unit Definition	Values	Weighted Value	Source
(green)	Cohesion	Dimensionless cohesion values derived using the ratio of the combined values for effective soil and root cohesion relative to the soil density and thickness, as shown in Pack et al (1998)	Values ≤ 0.06	1	USDA Soil Map (2013, 2021)
(purple)	Geology	Geological map units with high concentrations of mapped landslides	my, Yal, Ybg, Yblg, Ybr, Yc, Ygb, Zcmb (*see source for definitions*)	1	Geologic Map of Virginia (2021)
(brown)	Soil Depth	Shallow soil depths derived from soil survey data for each soil map unit	Depth ≤ 35-inches	1	USDA Soil Map (2013, 2021)
(blue)	Topographic Curvature	Curavature values derived from a 5-foot resolution LIDAR DEM using a tangential (normal contour) curvature calculation and a 15 X 15 neighborhood distance window	Values ≤ -0.005	2	LIDAR DEM
(red)	Slope	Slope values derived from a 5-foot resolution LIDAR DEM using a 15 X 15 neighborhood distance window	Slope values ≥ 27°	3	LIDAR DEM









2 Landslide Susceptibility Map

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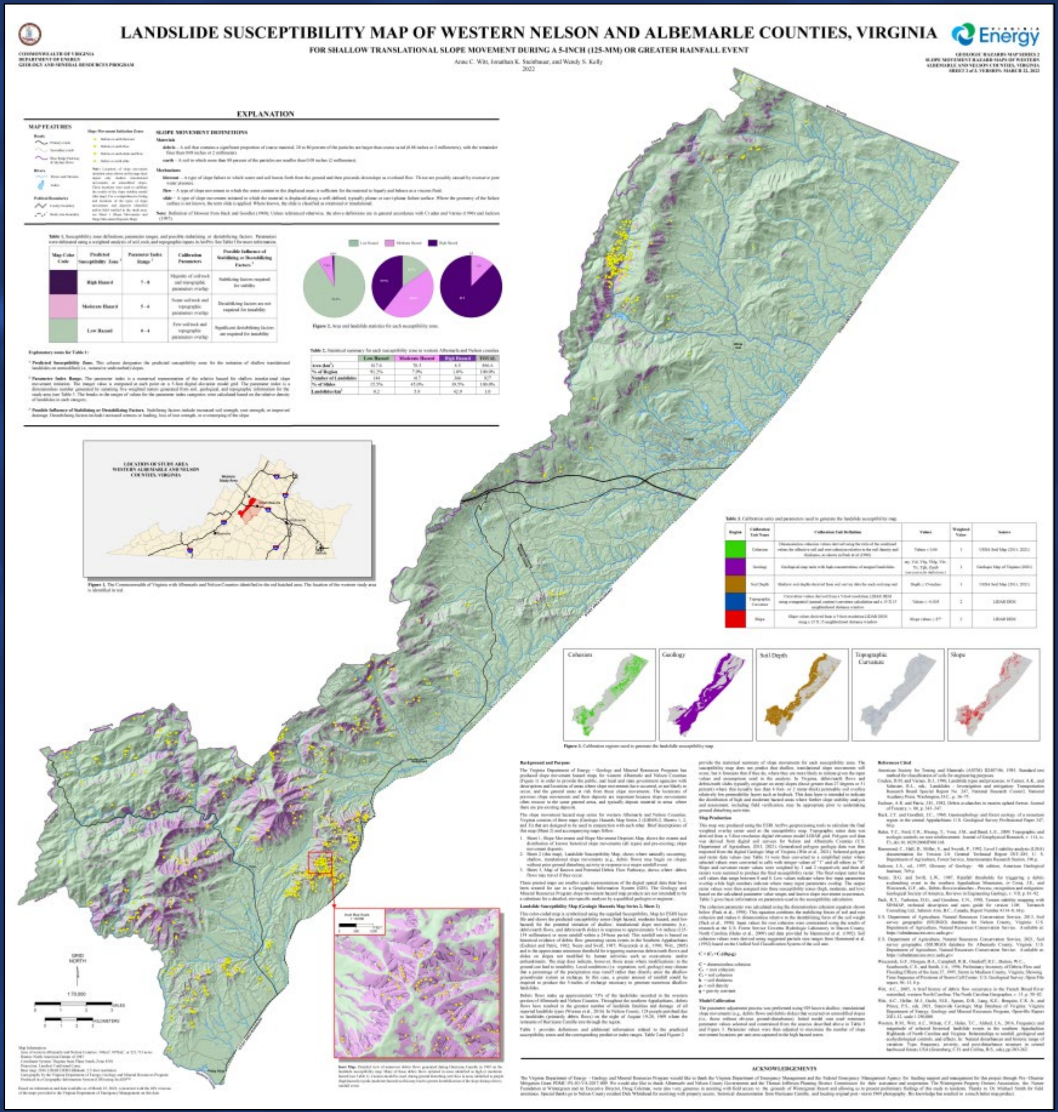
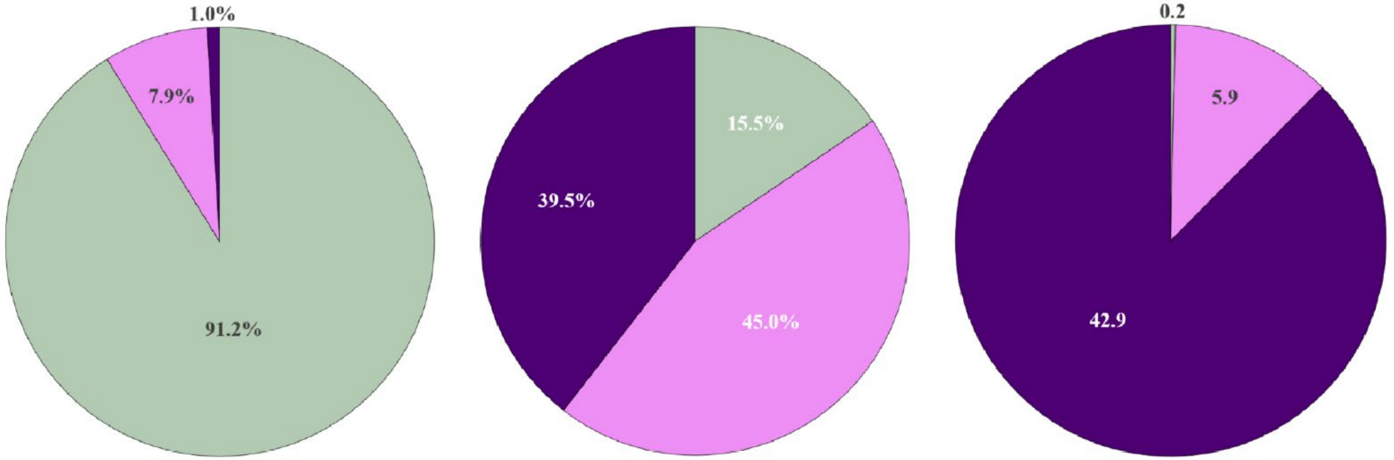


2 Landslide Susceptibility Map

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



% of Region

% of Landslides

Landslides/km^2

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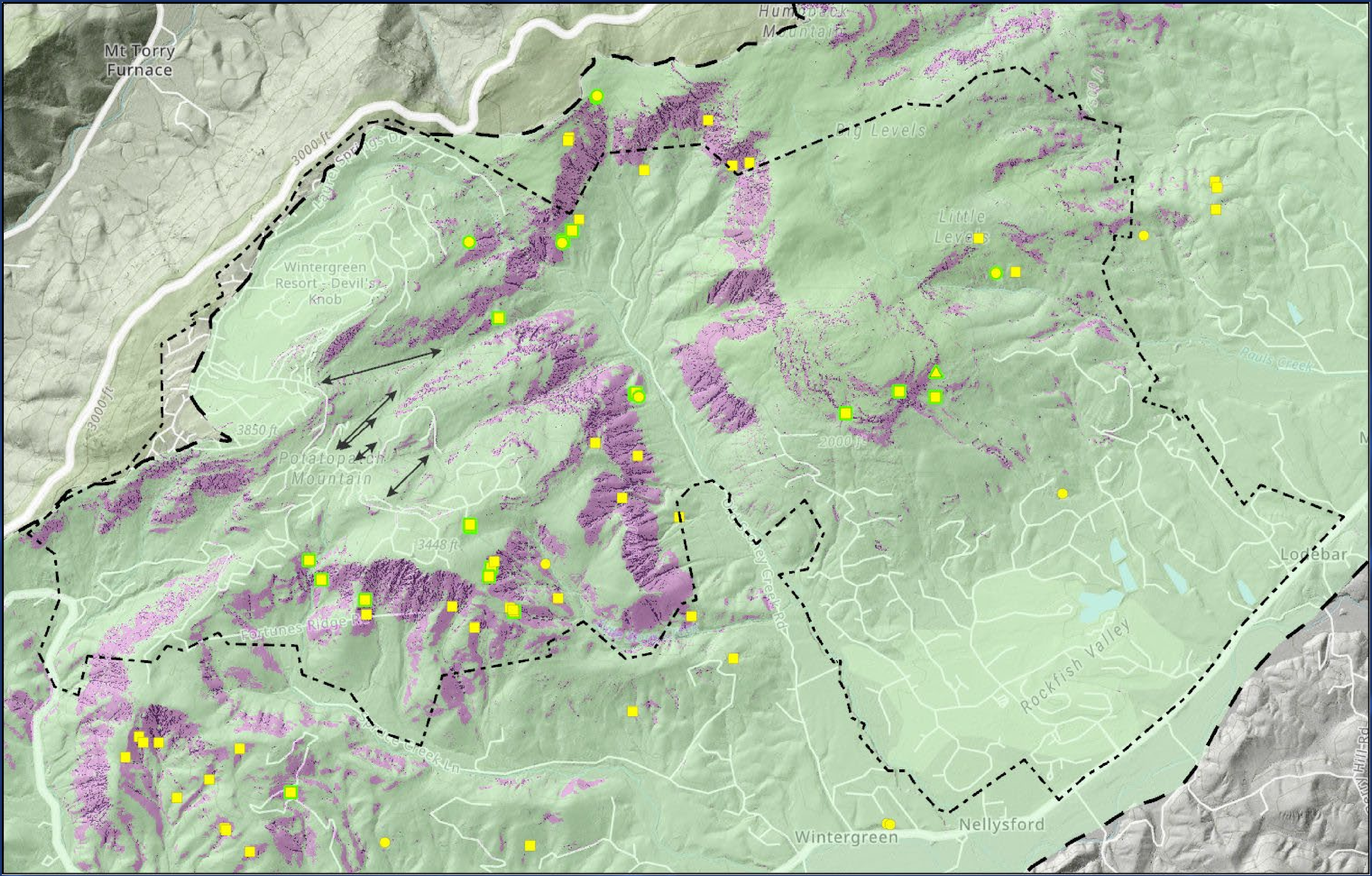


Low Hazard

Moderate Hazard

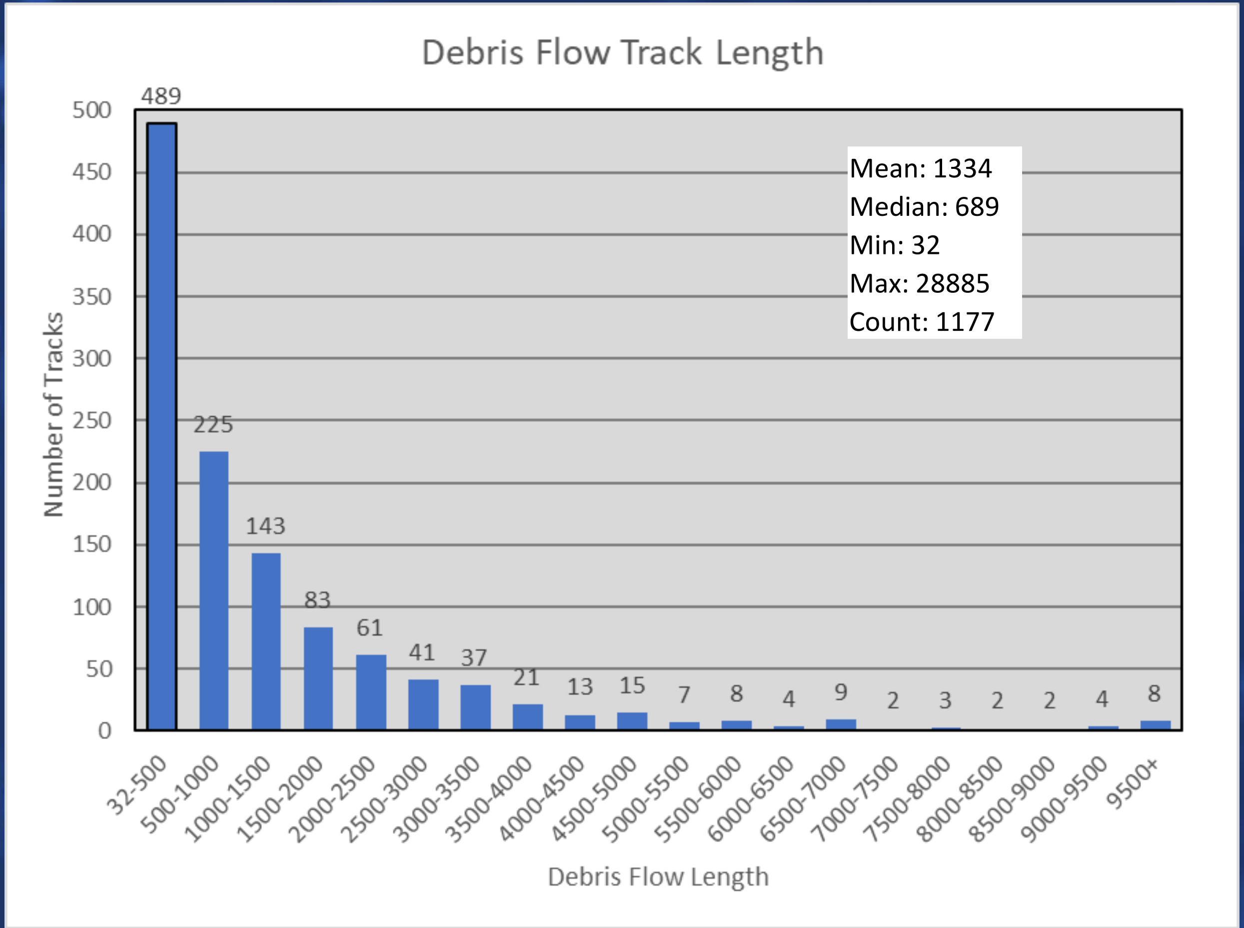
High Hazard

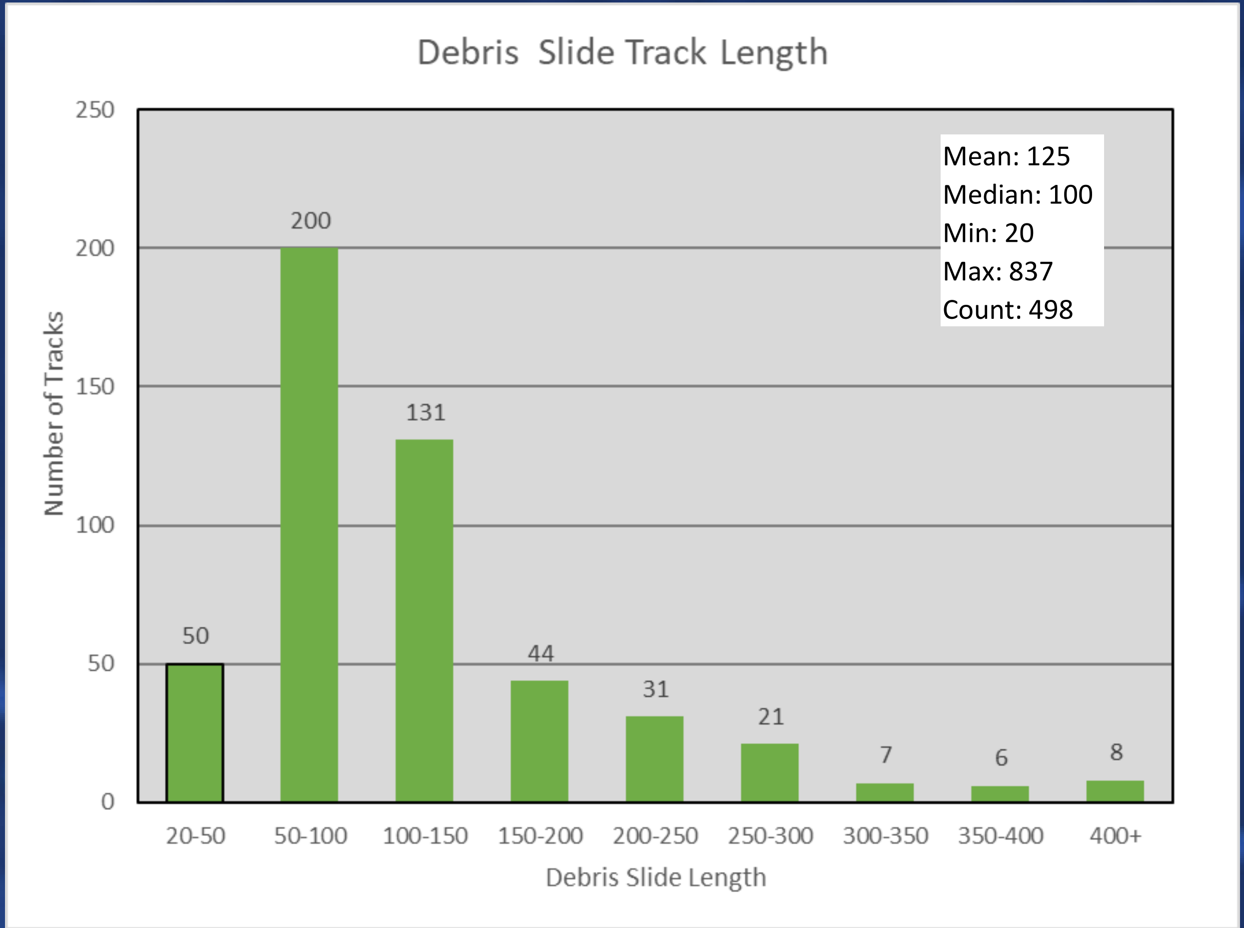
UPDATED LANDSLIDE STATISTICS: LANDSLIDE TRACK LENGTH

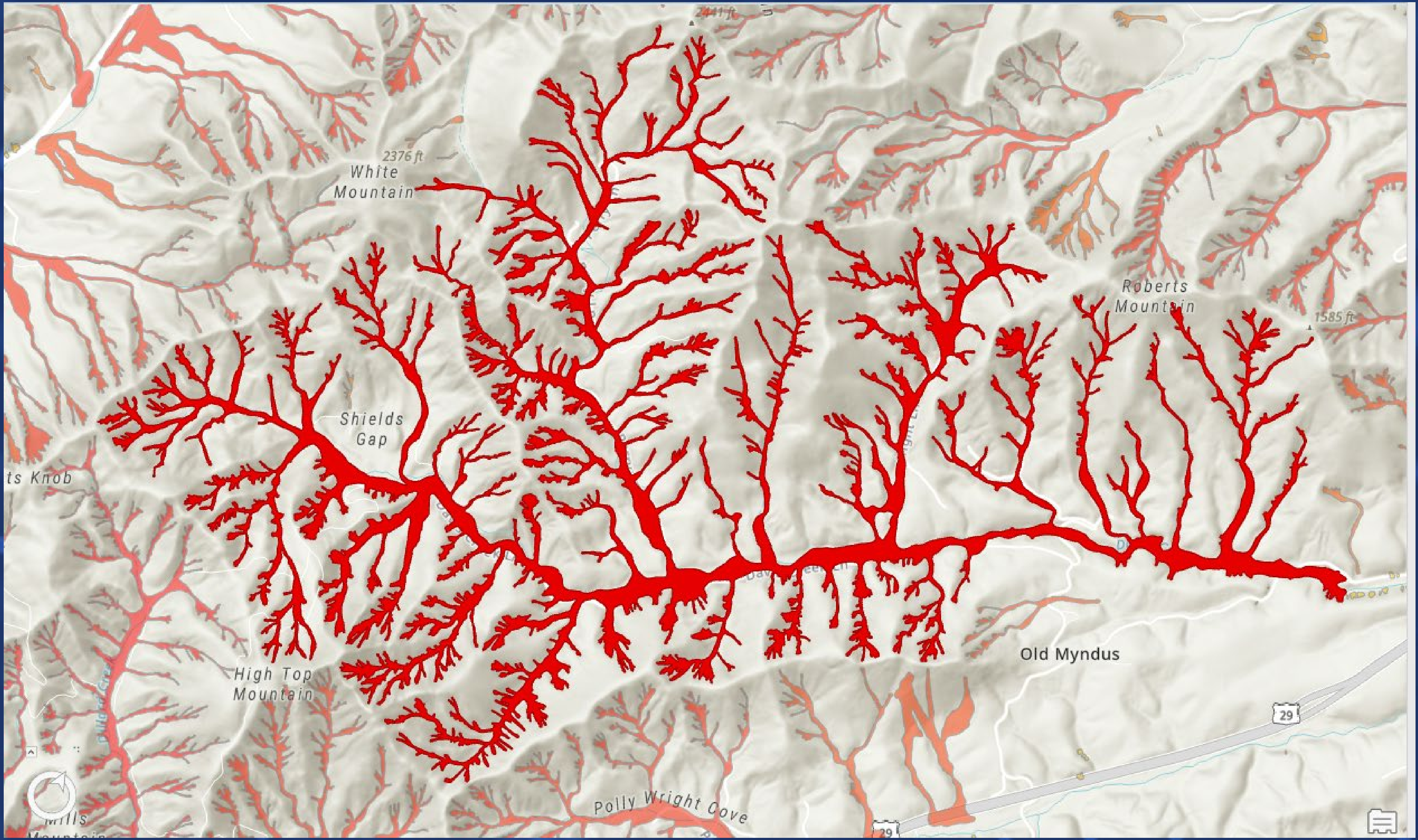
- Not only concerned about where landslides may start, but also where they go and what areas they may inundate.
- Path of destruction from a debris flow can be narrow.
- Use known debris flow tracks to estimate potential track length and width as part of "debris flow pathways" map.

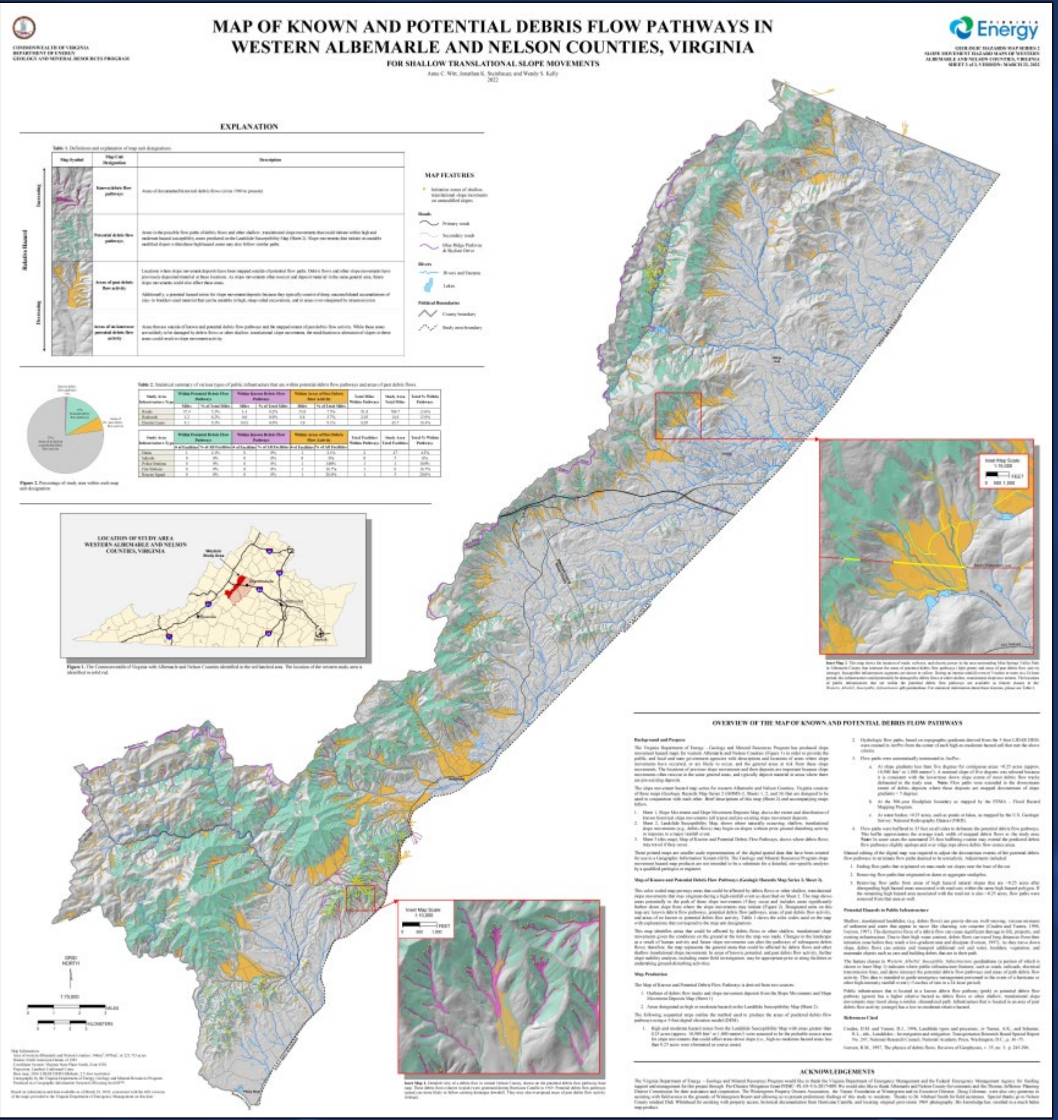
Davis Creek area of Nelson County, where 52 lives were lost, after Hurricane Camille in 1969. Nearly every first and second order stream in this area was inundated, generating a massive debris flow 5.3 miles long.

UPDATED LANDSLIDE STATISTICS: LANDSLIDE TRACK LENGTH



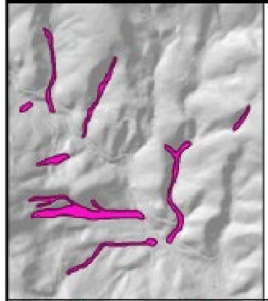
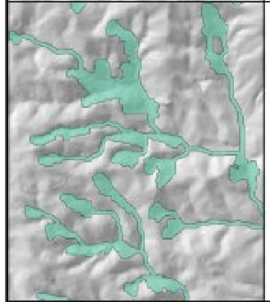
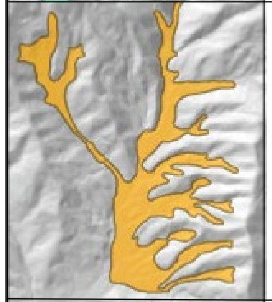



2441 ft
2376 ft
White Mountain
Shields Gap
ts Knob
High Top Mountain
Roberts Mountain
1585 ft
Old Myndus
29
Polly Wright Cove
Mills Mountain



3 Landslide Pathway Map

Relative Hazard (Increasing ↑ / Decreasing ↓)

Map Symbol	Map Unit Designation	Description
	Known debris flow pathways	Debris flow tracks (1969 to present)
	Potential debris flow pathways	Possible flow paths that initiate within high/moderate hazard susceptibility zones
	Areas of past debris flow activity	Mapped ancient landslide deposits
	Areas of no known or potential debris flow activity	Areas unlikely to be damaged by debris flows

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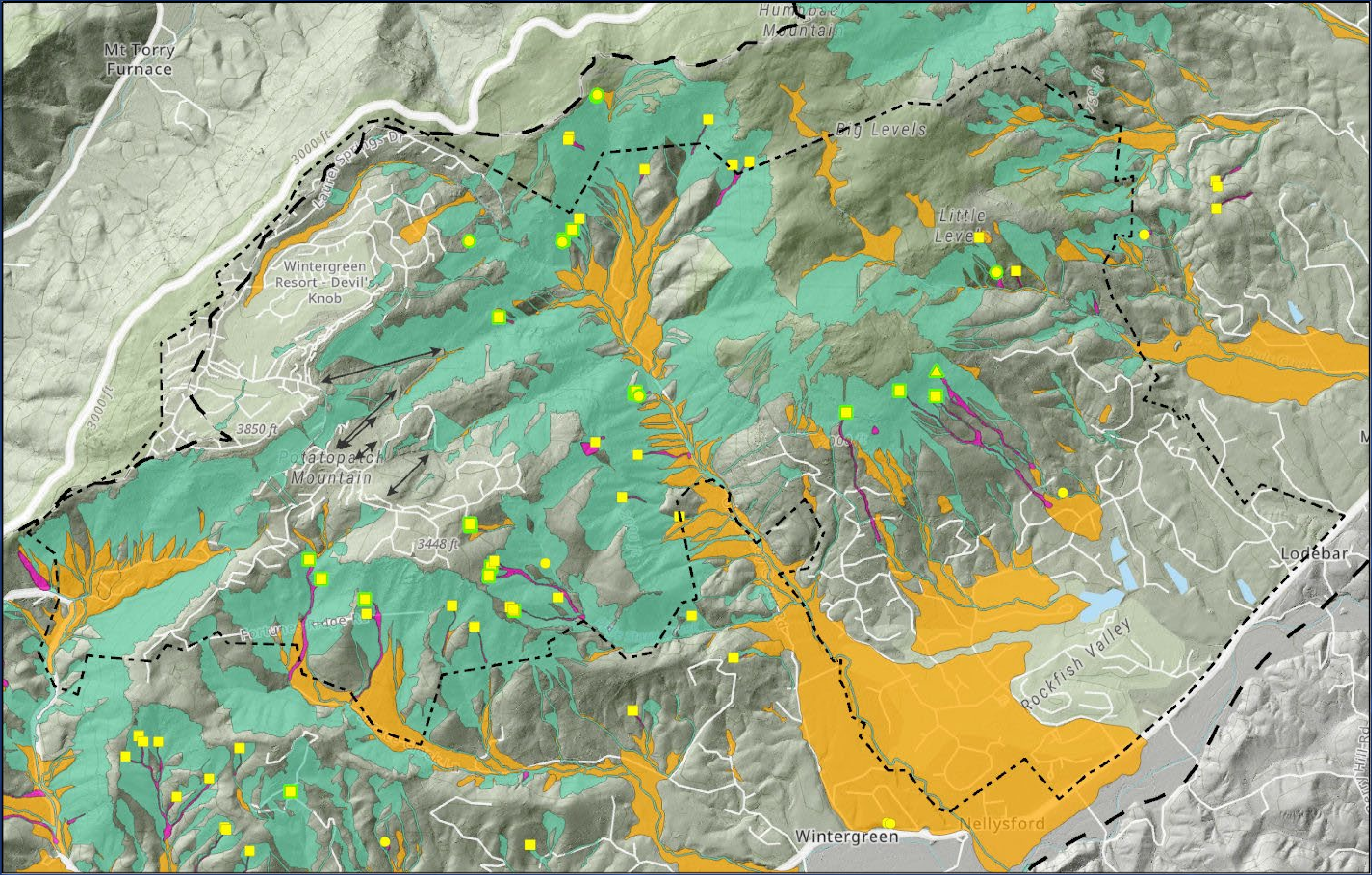
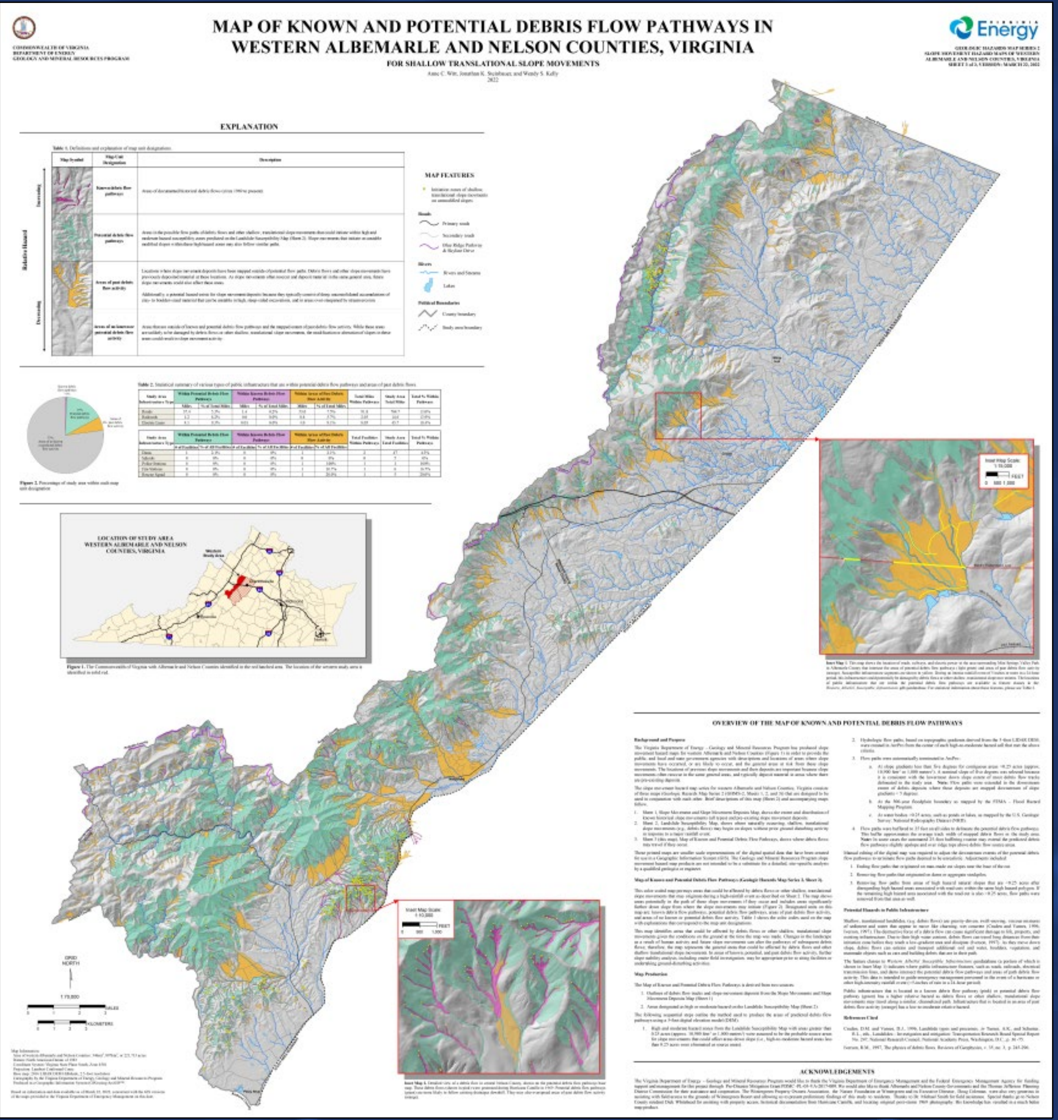


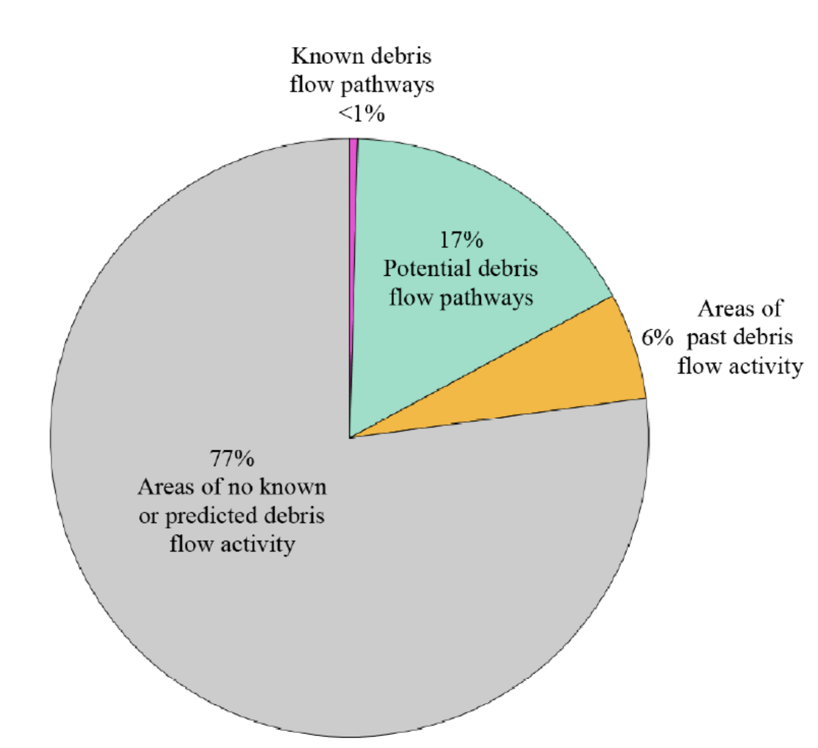
Known Debris Flow Pathways

Potential Debris Flow Pathways

Areas of past DF activity

No known or potential hazard





Study Area Infrastructure Type	Within Potential Debris Flow Pathways		Within Known Debris Flow Pathways		Within Areas of Past Debris Flow Activity		Total Miles Within Pathways	Study Area Total Miles	Total % Within Pathways
	Miles	% of Total Miles	Miles	% of Total Miles	Miles	% of Total Miles			
Roads	37.4	5.3%	1.4	0.2%	53.0	7.5%	91.8	704.7	13.0%
Railroads	1.2	8.2%	0.0	0.0%	0.8	5.7%	2.03	14.6	13.9%
Electric Lines	4.1	9.3%	0.01	0.0%	4.0	9.1%	8.05	43.7	18.4%

Study Area Infrastructure Type	Within Potential Debris Flow Pathways		Within Known Debris Flow Pathways		Within Areas of Past Debris Flow Activity		Total Facilities Within Pathways	Study Area Total Facilities	Total % Within Pathways
	# of Facilities	% of All Facilities	# of Facilities	% of All Facilities	# of Facilities	% of All Facilities			
Dams	1	2.1%	0	0%	1	2.1%	2	47	4.3%
Schools	0	0%	0	0%	0	0%	0	5	0%
Police Stations	0	0%	0	0%	1	100%	1	1	100%
Fire Stations	0	0%	0	0%	1	16.7%	1	6	16.7%
Rescue Squad	0	0%	0	0%	1	20.0%	1	5	20.0%

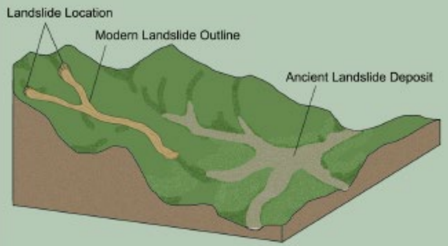
3 Landslide Pathway Map

VIRGINIA Energy

How to Use Landslide Hazard Maps

① Landslide Inventory Map → *WHERE HAVE LANDSLIDES OCCURRED?*

This map (also called the *Slope Movements and Slope Movement Deposits* map) identifies landslide features within the study area including:

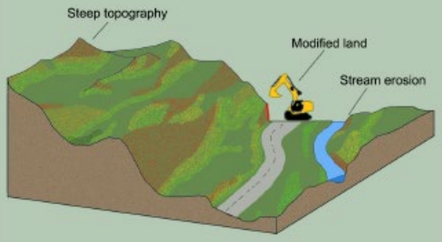


LANDSLIDE LOCATIONS are places where modern landslides start before sliding or flowing downhill.

LANDSLIDE OUTLINES are the boundaries of recent landslides. There are many different types of landslides, but most of these landslide outlines will identify *debris flows*.

LANDSLIDE DEPOSITS are large volumes of clay, silt, sand, and rocks that have accumulated over time as a result of multiple ancient landslide events.

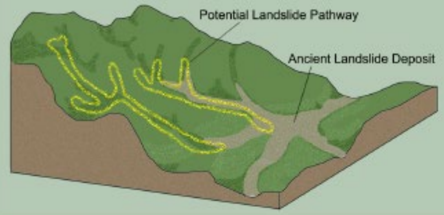
② Landslide Susceptibility Map → *WHERE COULD LANDSLIDES START?*



These maps identify areas that may be at greater risk of failure during an extreme rainfall event (such as a hurricane). Susceptibility maps typically highlight areas of steepest topography, in addition to other factors that influence where a landslide may initiate. Soil thickness and type, geology, degree of fracturing, aspect, and vegetation can all be significant.

Slopes are more susceptible to failure in areas affected by clearcutting, burning, stream erosion, or site development. Such activities may cause reduction of soil cohesion or the oversteepening of slopes resulting in a greater risk of failure.

③ Landslide Pathway Map → *WHERE COULD LANDSLIDES GO?*



These maps identify the potential pathways a landslide could take if one were to occur during an extreme rainfall event. Landslides typically follow a path of least resistance downhill, such as a valley or drainage. Once a landslide encounters shallow topography, such as a flood plain, the material can spread outward covering a broader area.

What Should a Property Owner Do?

step 1 *Begin with the* **Landslide Inventory Map** (*Slope Movements and Slope Movement Deposits Map*)

Is there a Landslide Feature on your property?

NO → There are no *known* landslides in your area, however, new landslides could occur. Go to step 2 (page 3) to view the LANDSLIDE SUSCEPTIBILITY MAP.

YES → What kind of feature is it?

LANDSLIDE DEPOSIT → Landslide Deposits are in your area of interest. These are large volumes of clay, silt, sand, and rocks that have accumulated over time as a result of multiple ancient landslides.

Be cautious when building in deposits, as they are composed of material that can become unstable when disturbed. Refer to step 2 (page 3) and the LANDSLIDE SUSCEPTIBILITY MAP to see if there is modern landslide potential in this area.

LANDSLIDE LOCATION → A Landslide Location is in your area of interest. This is the initiation zone where a documented modern landslide began before sliding or flowing downhill.

If you plan to build in this area, it is a good idea to ***contact a qualified geotechnical engineer*** or geologist. Refer to step 2 (page 3) and the LANDSLIDE SUSCEPTIBILITY MAP to see if there is potential for future landslides to occur in this area.

LANDSLIDE OUTLINE → A Landslide Outline has been identified in your area of interest. These are the tracks of documented modern landslides (composed of debris, earth, or weathered rock) that have flowed, slid, or fallen downhill.

If you plan to build in this area, it is a good idea to ***contact a qualified geotechnical engineer*** or geologist. Refer to step 2 (page 3) and the LANDSLIDE SUSCEPTIBILITY MAP to see if there is potential for future landslides to occur in this area.

*Guide modeled after the Geologic Stability Maps Quick Reference developed by Appalachian Landslide Consultants, PLLC

What Should a Property Owner Do?

step 2 — Look at the Landslide Susceptibility Map

Is your area of interest in a stability zone ranked as ***Moderate Hazard*** or ***High Hazard***?

YES

This area has been given a ***Moderate*** to ***High*** **landslide hazard ranking.** This ranking delineates where natural landslides (not due to construction) are ***most likely*** to occur during an extreme rainfall event. Several factors contribute to calculating a ranking system for determining moderate to high hazard zones: topographic slope, topographic curvature, soil depth and cohesion, and bedrock geology.

NO

Your area of interest is in a relatively stable zone. However, even though landslides are not likely to *begin* in your area during a storm event, landslides could move across this area if they fail uphill from this location. Even in a relatively stable zone, a landslide may be triggered if construction or stream erosion cause ***oversteepening*** of an otherwise gentle slope.

Next refer to step 3 (page 4) and view the LANDSLIDE PATHWAY MAP for more information.

MODERATE HAZARD ZONE

Your area of interest is within a ***moderate landslide hazard zone***. Such areas have a moderate ranking with several contributing factors that could result in failure.

Use caution when building in these zones. Pay attention to any previously built cut or fill slopes for signs of instability such as tension cracks and slumping. Ensure stormwater runoff is effectively contained and appropriately directed. ***Contact a qualified geotechnical engineer*** for a ***site assessment*** if you have concerns. Refer to step 3 (page 4) and the LANDSLIDE PATHWAY MAP for more information.

HIGH HAZARD ZONE

Your area of interest is within a ***high landslide hazard zone***. Such areas have high ranking with multiple contributing factors that increase the probability of instability during an extreme storm event.

Use caution when building in these zones. It may be a good idea to ***contact a qualified geotechnical engineer*** or geologist for a ***site assessment***. If your property is within one of these zones, monitor for evidence of instability such as cracks in soil, tilted trees, sagging or taut power lines, or leaking or broken pipes. Ensure stormwater runoff is effectively contained and appropriately directed. Refer to step 3 (page 4) and the LANDSLIDE PATHWAY MAP for more information.

What Should a Property Owner Do?

step 3 — Look at the Landslide Pathway Map

Is your area of interest in or near:

AREAS OF PAST DEBRIS FLOW ACTIVITY

Landslides accumulated in this area during ancient times (thousands to millions of years ago). Landslides often occur in the same areas and old material from previous landslides may become reactivated if a severe storm event were to occur or if such material is disturbed by building processes.

If you plan to build here, it is a good idea to contact a ***qualified geotechnical engineer*** or geologist for an evaluation if the area is deemed to be at risk and follow safe building guidelines in order to avoid creating unsafe oversteepened slopes.

NO KNOWN DEBRIS FLOW ACTIVITY

Landslides have not been recorded in this area. It is unlikely that damage could occur here due to landslides, ***however*** oversteepening of otherwise stable slopes due to excavation during construction could lead to slope failure.

If you plan to build here, be sure to follow safe building guidelines in order to avoid creating unsafe oversteepened slopes.

KNOWN DEBRIS FLOW PATHWAYS

These are documented landslides that occurred during historic time. Landslides often occur in the same areas and old material from previous landslides may become reactivated if severe storms occur or if such material is disturbed by construction.

If you plan to build here, it is a good idea to contact a ***qualified geotechnical engineer*** or geologist and follow safe building guidelines in order to avoid creating unsafe oversteepened slopes.

POTENTIAL DEBRIS FLOW PATHWAYS

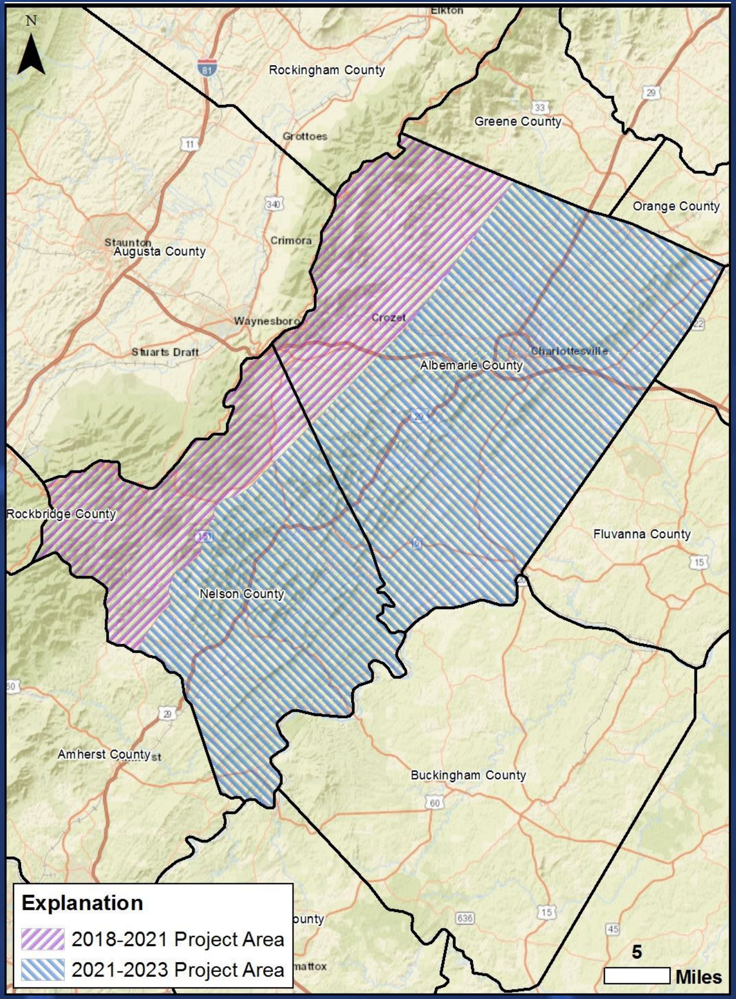
These are estimated landslide pathways that could develop if an extreme storm event were to occur in this area. The exact width and length of an actual landslide here could vary from the map estimates.

Contact a qualified geotechnical engineer or geologist if you intend to build and follow safe building guidelines in order to avoid creating unsafe oversteepened slopes. If you live near a potential landslide pathway, be mindful of weather conditions and be prepared to leave for safer ground if a severe storm event occurs in your area.

Acknowledgements: This guide is modeled after the Geologic Stability Maps Quick Reference developed by Appalachian Landslide Consultants, PLLC

*Guide modeled after the Geologic Stability Maps Quick Reference developed by Appalachian Landslide Consultants, PLLC

WE STILL HAVE A LOT OF WORK TO DO…



Complete the VDEM/FEMA grant in 2024

- Finish the final phase of the landslide susceptibility mapping
- Presentation of data products and results to the planning community and the public

NEW as of MARCH 2024: Virginia Energy received a BRIC 2022 grant from VDEM/FEMA to complete a statewide landslide inventory by 2027

https://www.energy.virginia.gov/geology/FEMA_landslide.shtml

VIRGINIA Energy

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Jonathan Steinbauer: Contract Geologist
https://energy.virginia.gov/geology/FEMA_landslide.shtml