INVESTIGATING LANDSLIDES IN VIRGINIA

INDENTIFICATION, MAPPING AND EMERGENCY RESPONSE

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WHAT ARE WE GOING TO TALK ABOUT TODAY?

The Geohazards Program at GMR

Common landside types in Virginia

Mapping landslides in the office and the field

Recent examples from across the Commonwealth

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AS A GEOHAZARDS GEOLOGIST WITH VIRGINIA ENERGY I...

- Share data to help improve regional and state-wide hazard mitigation plans
- Prepare geologic reports and maps
- Respond to public inquires regarding geohazards
- Maintain GIS databases of geologic hazards
- Respond to emergency requests for assistance
- Identify areas at greater risk for geologic hazards through grant-funded studies

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https://energy.virginia.gov/geology/Hazards.shtml

Earthquakes

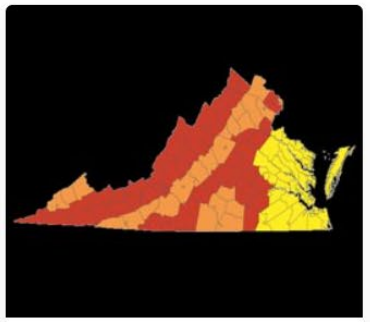
Volcanoes

Tsunamis

Sinkholes and Karst

Acidic Soil

Expansive Soil



Radon

Asbestos

Abandoned Mines

Shoreline Erosion and Coastal Innundation

Landslides

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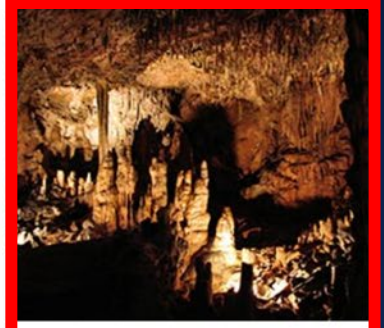

Sinkholes and Karst

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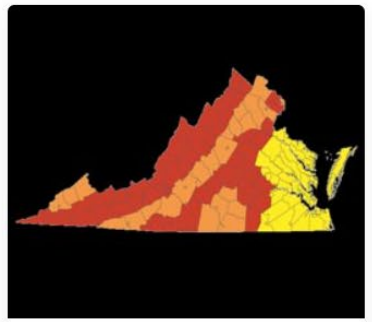
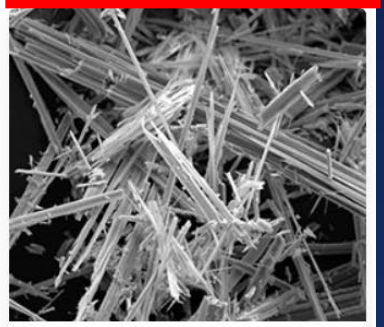


Radon



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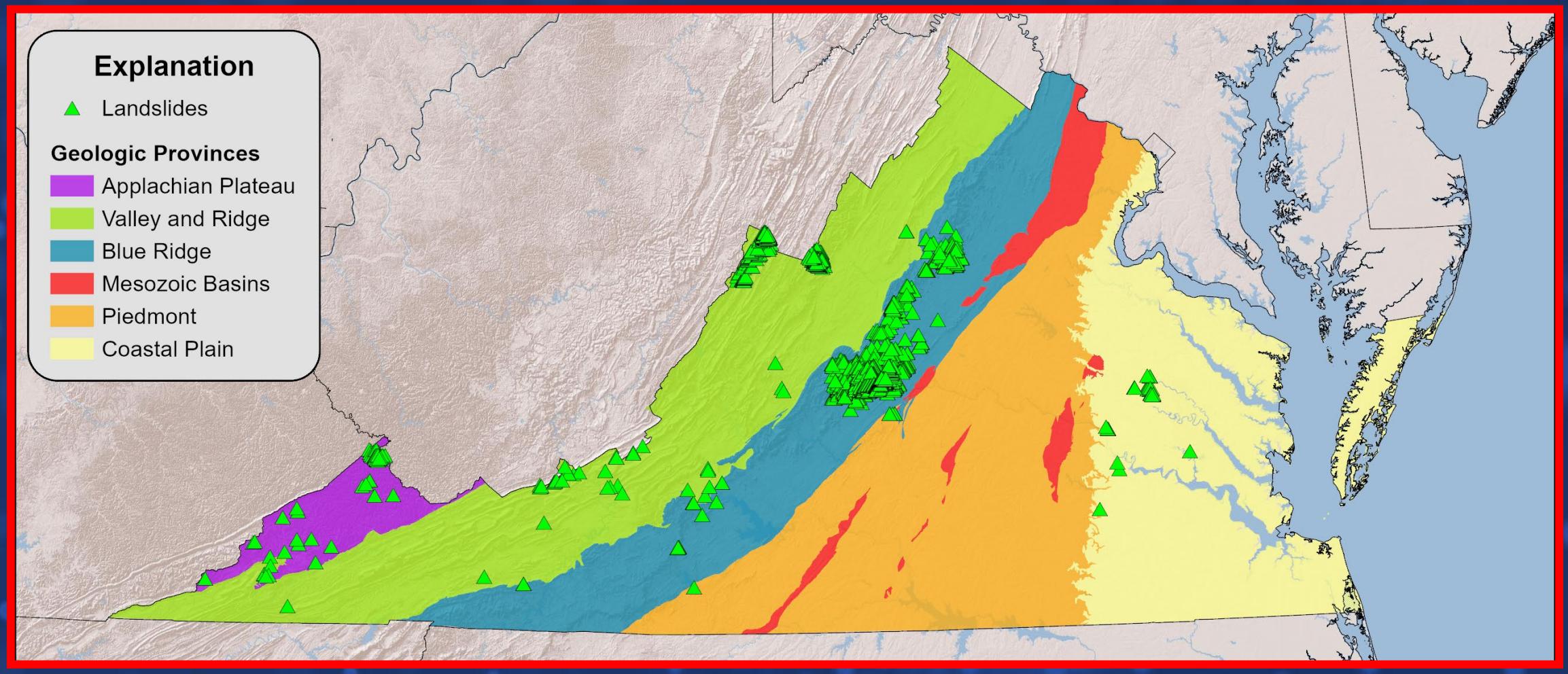
Landslides



The GMR landslide geodatabase contains 8,800+ landslide locations, primarily associated with Hurricane Camille in 1969 (6000+)

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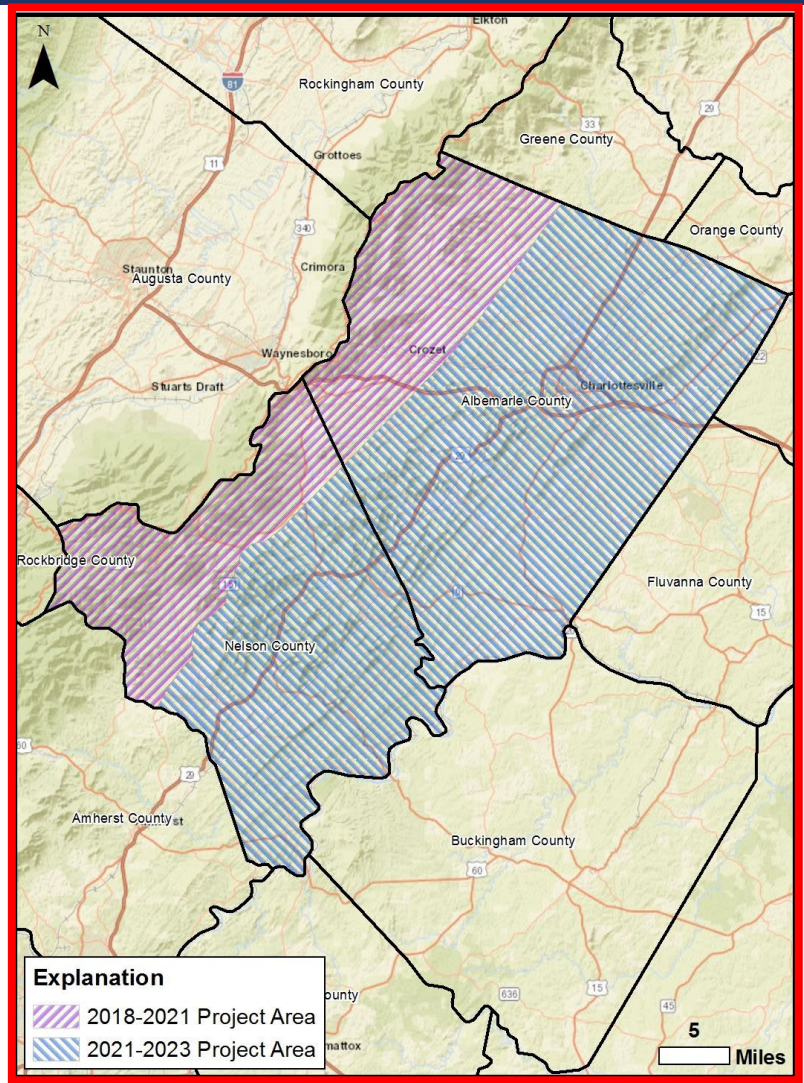
https://energy.virginia.gov/geology/Landslides.shtml

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

Western Landslide Risk Assessment (2018-2022)

Eastern Landslide Risk Assessment (2021-2023)

- Virginia Energy received grant funding from FEMA-VDEM in August 2018
- $85,500 FEMA grant funds, Virginia Energy provides $28,500 in matching funds = TOTAL: $114,000
- Goal: Complete a landslide hazard map for western Nelson and Albemarle Counties to identify at-risk properties and infrastructure by March 2021
- Grant deadline was extended to March 2022 due to COVID
- Geologic field work completed between Fall 2019-Spring 2020



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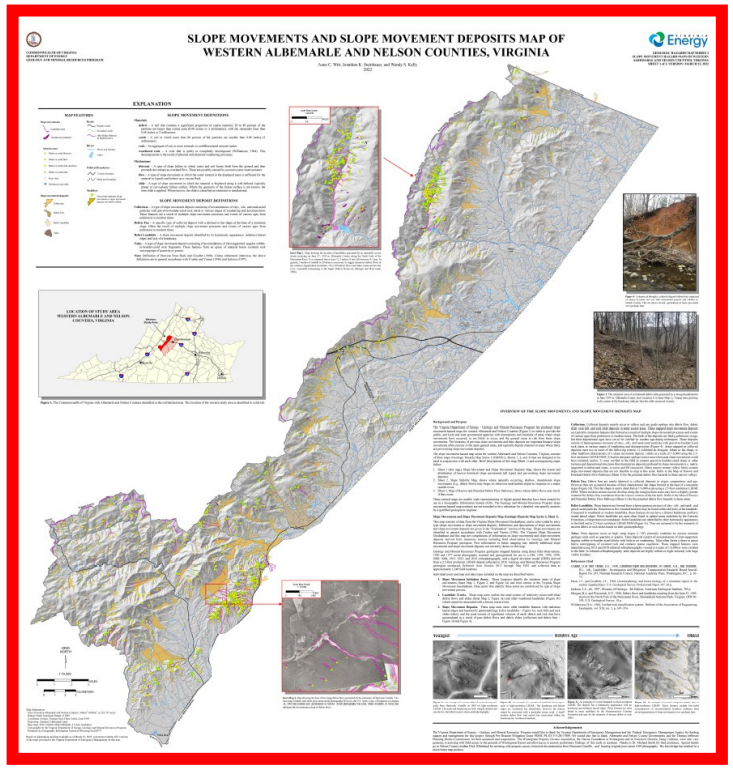
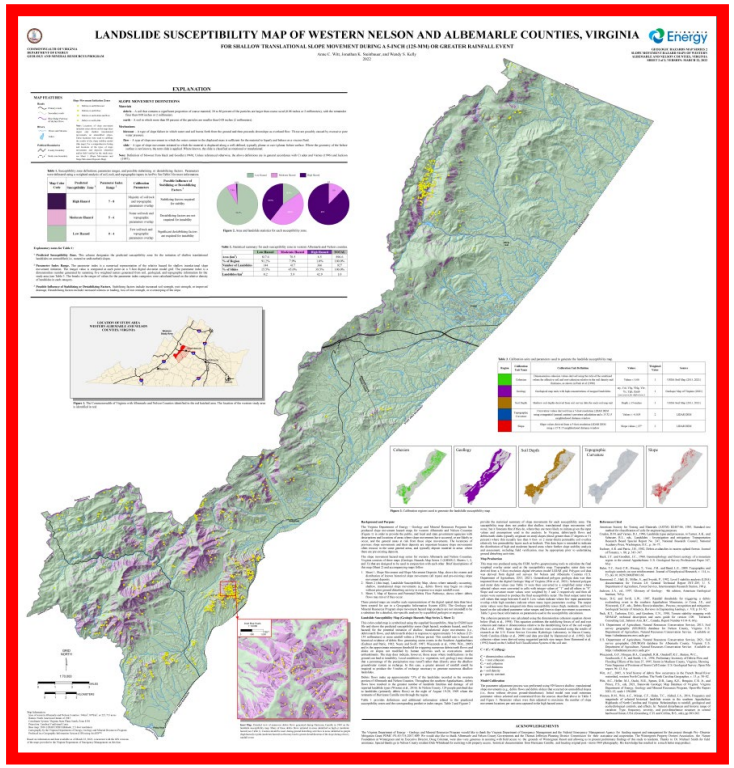
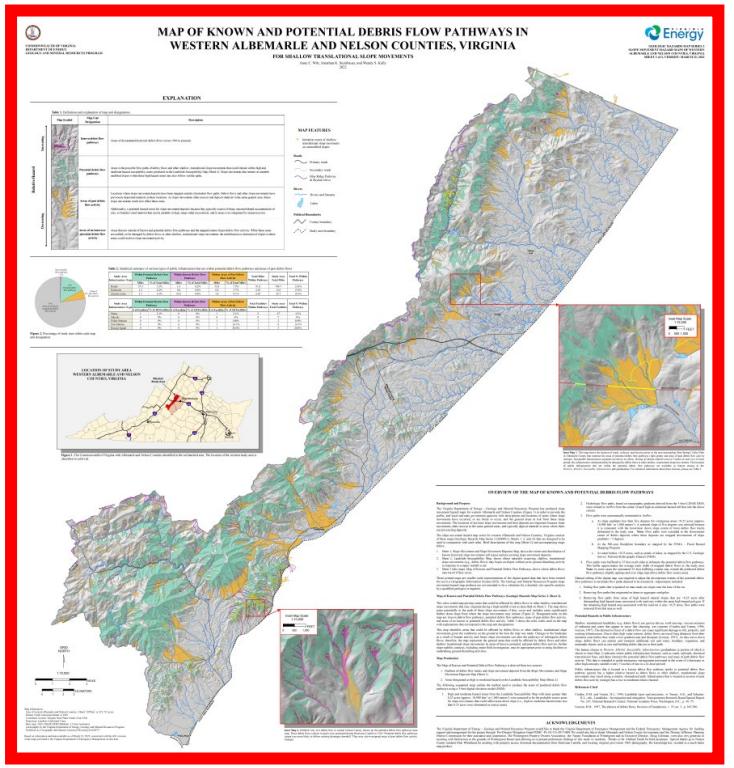
MARCH 2022 FEMA/VDEM DELIVERABLES



Landslide Inventory Map



Landslide Susceptibility Map



Landslide Pathway Map

*Pdf maps, GIS data and metadata, users guide

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HOW DOES A GEOLOGIST INDENTIFY A LANDSLIDE?

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WHAT IS A LANDSLIDE (TO A GEOLOGIST)?

- "Landslide" is a broad term encompassing several varieties downslope movements of earth materials.
- Movement can be slow or fast.
- Landslides are classified by the type of material they are composed of and the type of movement downslope.

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

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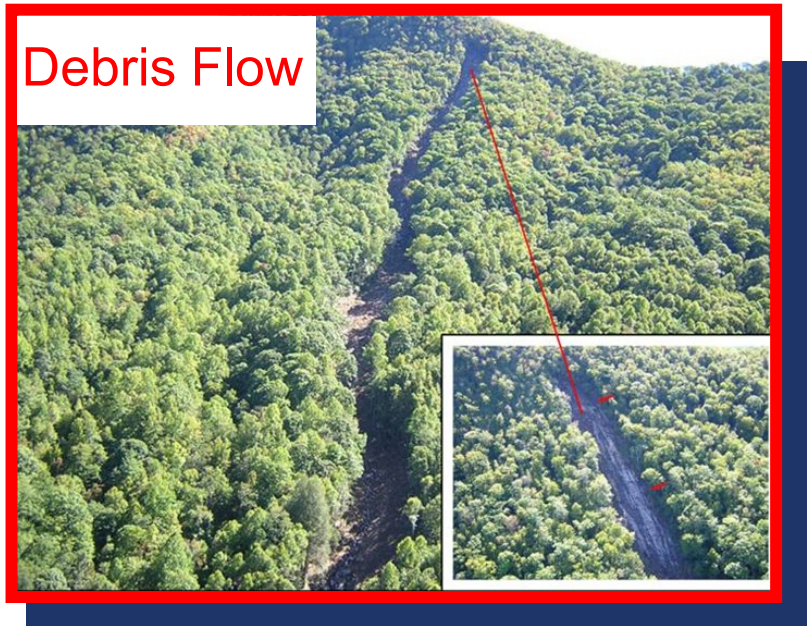
COMMON TYPES OF LANDSLIDES IN THE SOUTHERN APPALACIANS



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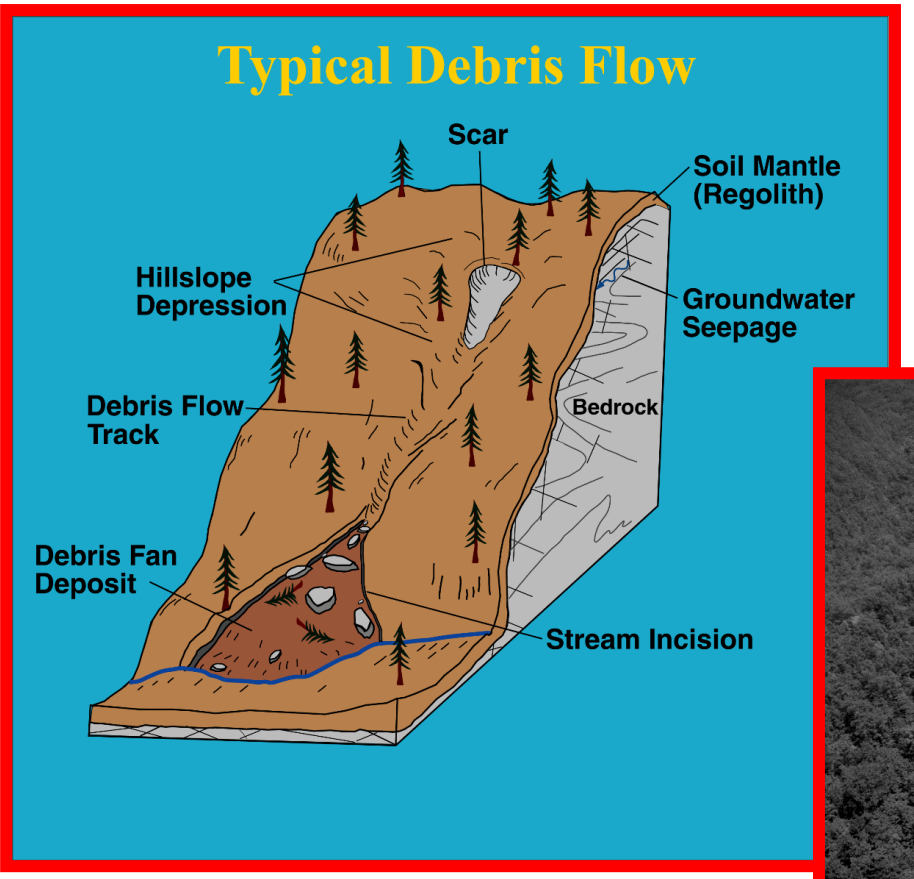
“A FLOOD ON STEROIDS…”



	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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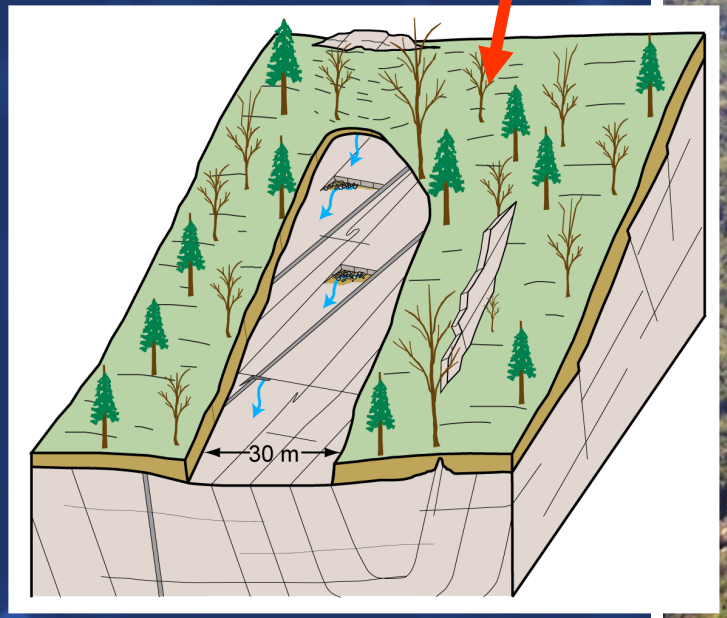
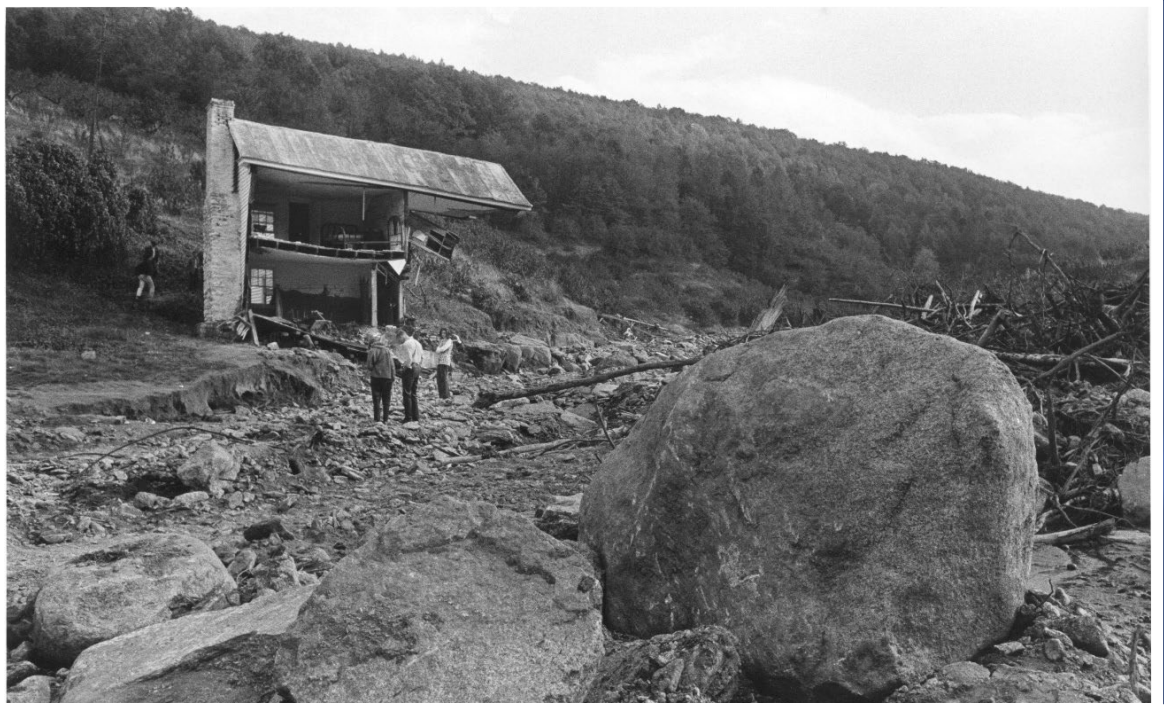


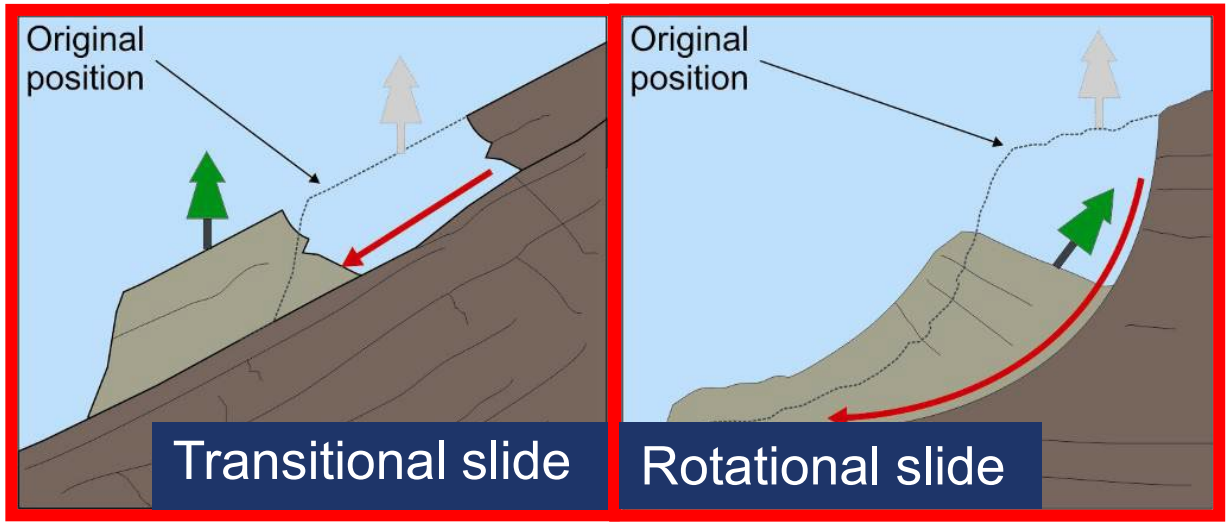
PEEKS CREEK DEBRIS FLOW MACON COUNTY, NC SEPTEMBER 16, 2004 HURRICANE IVAN

Photo from Macon County News & Shopping Guide



NELSON COUNTY, VA
HURRICANE CAMILLE DEBRIS FLOWS
DAVIS CREEK
AUGUST 1969

DEBRIS SLIDE



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DEBRIS SLIDE

Headscarp

King William County, VA
June 2018

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ELKINS BRANCH
BUCHANAN COUNTY, VA
ROTATIONAL DEBRIS SLIDE-FLOW

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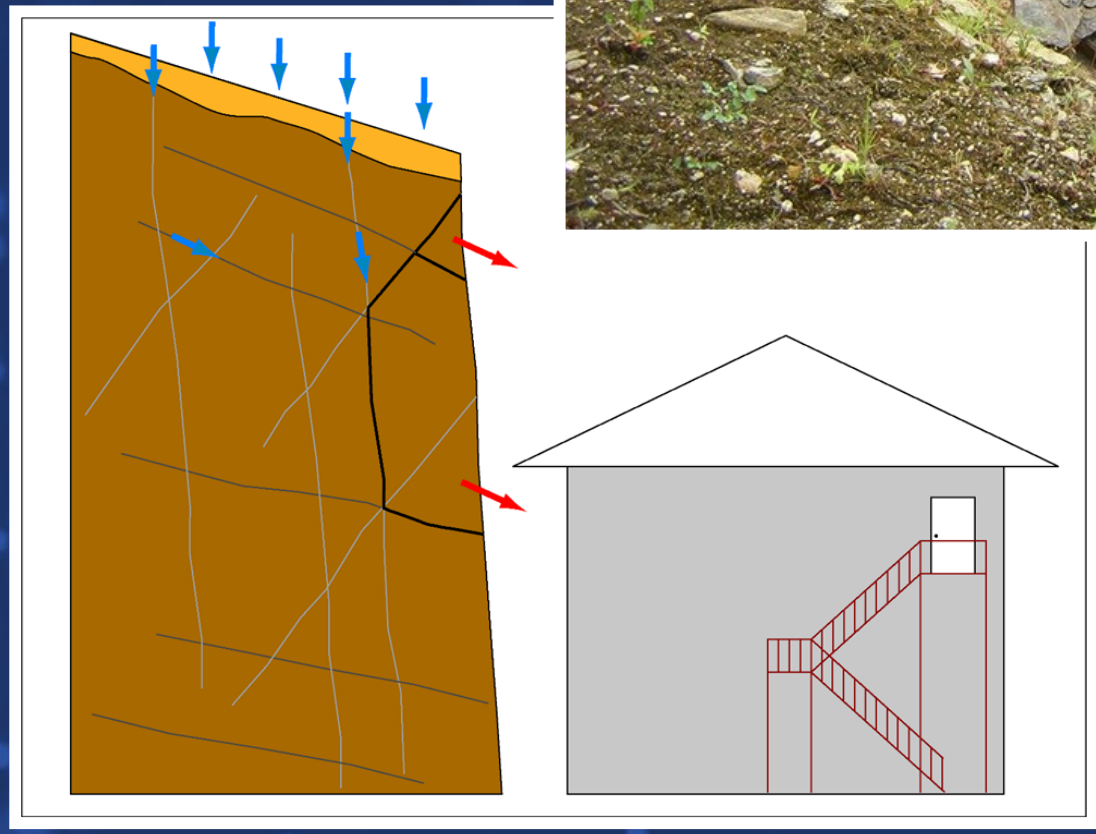
	Type of Movement	Slide (Translational Rotational)	Flow	Topple	Fall	Composite
MATERIAL	Earth (>80% <2mm)					
	Debris (>20% >2mm)	✓	✓			X
	Weathered Rock (PDS-CDS)					
	Rock (STS-VFS)					

Back rotated trees below main headscarp

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

ROCK FALL

BROAD ROVER FIRE DEPT
BUNCOMBE COUNTY, NC
TROPICAL STORM CINDY – JULY 6-7, 2005



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ROCK FALL/ SLIDE

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LANDSLIDES ARE CAUSED BY MANY ITERRELATED FACTORS IN THE SOUTHERN APPALACHIANS

1. Precipitation – greater than five-inches in 24-hours or high intensity rainfall (several inches in an hour)
   - Antecedent Moisture
2. Steep Slopes – greater than 22-degrees
3. Underlying Geology and/or Soils
   - Rock Type
   - Fractures or Foliation direction of the rock
   - Hydrology/Permeability of the soil
4. Deforestation or Wildfire?

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LANDSLIDES ARE CAUSED BY MANY ITERRELATED FACTORS IN THE SOUTHERN APPALACHIANS

5. Poor construction practices or maintenance
   - Oversteepening of embankments
   - Construction waste used as fill
   - Poor drainage, blocked ditches
   - Poorly constructed retaining walls
   - Poor mining practices (steep high walls, shoot/shove operations)
   - *On modified slopes, less rain needed to causes movement*

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HOW DOES A GEOLOGIST MAP LANDSLIDES?

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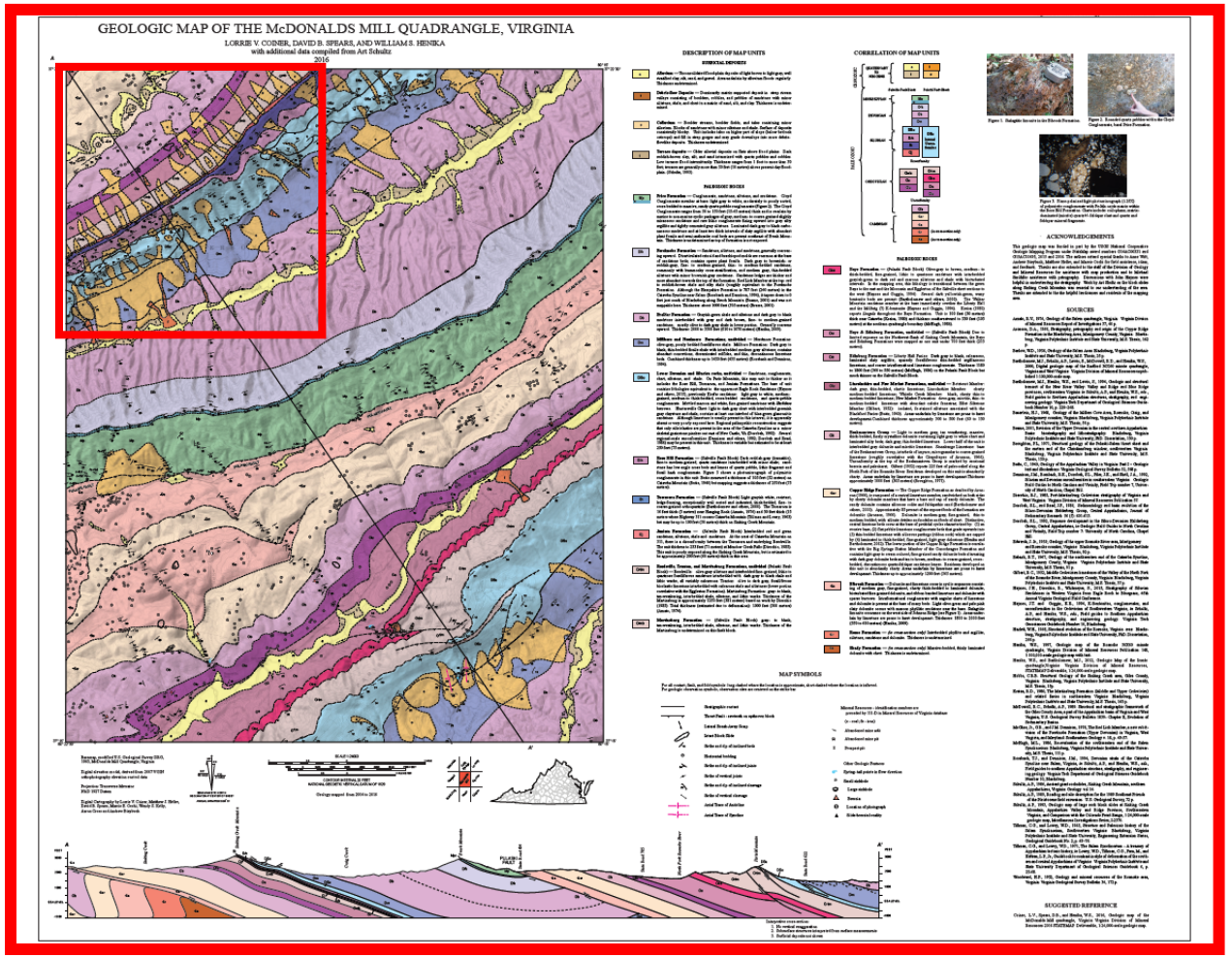
IN THE OFFICE…

Consider the basic conditions that favor landslide development:

- Geology
- Soil
- Topography (slope)
- Vegetation (or lack thereof)
- Surface water and groundwater

https://www.energy.virginia.gov/commerce



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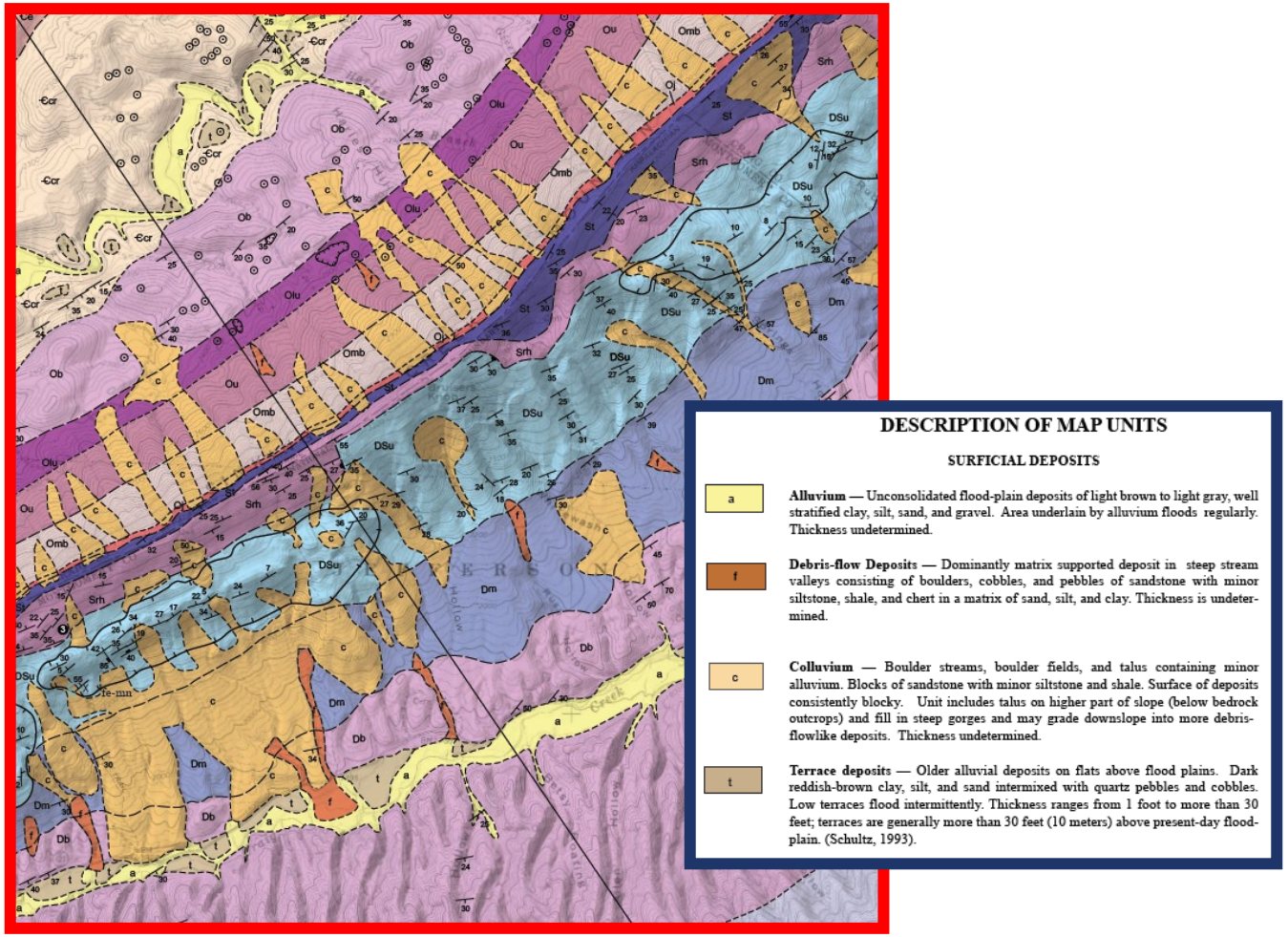

IN THE OFFICE…

Examine several vintages of aerial photography

1997

2017

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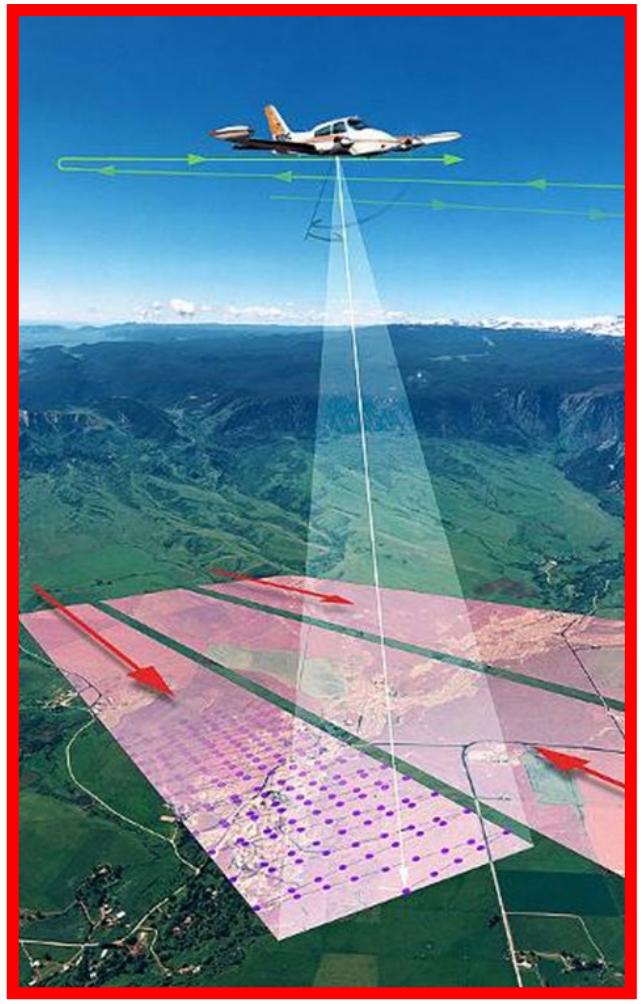
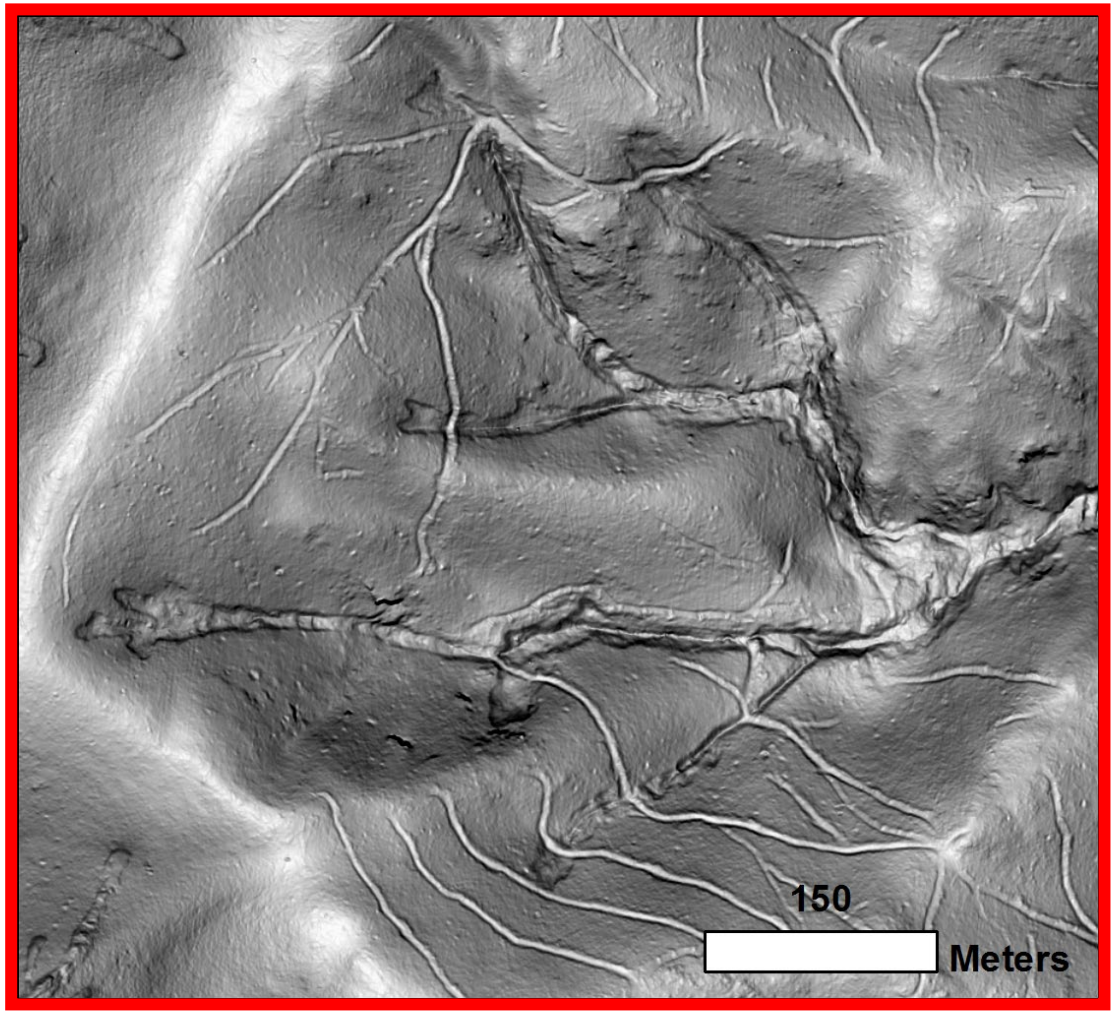
IN THE OFFICE…

Interpret 1-meter resolution LIDAR (Light Detection and Ranging)





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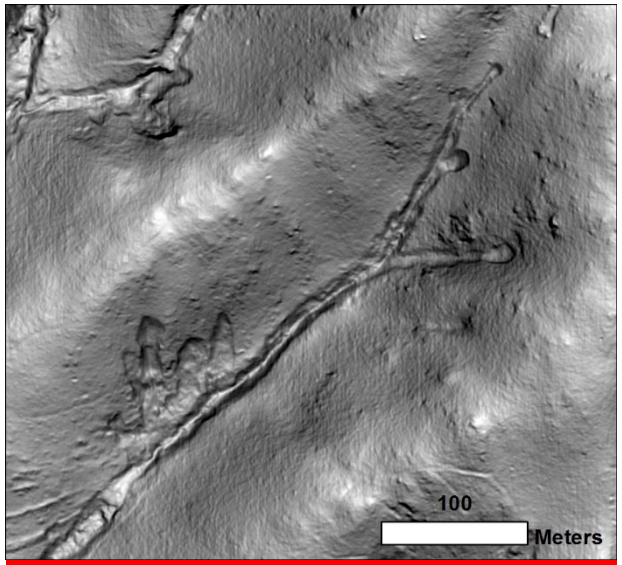
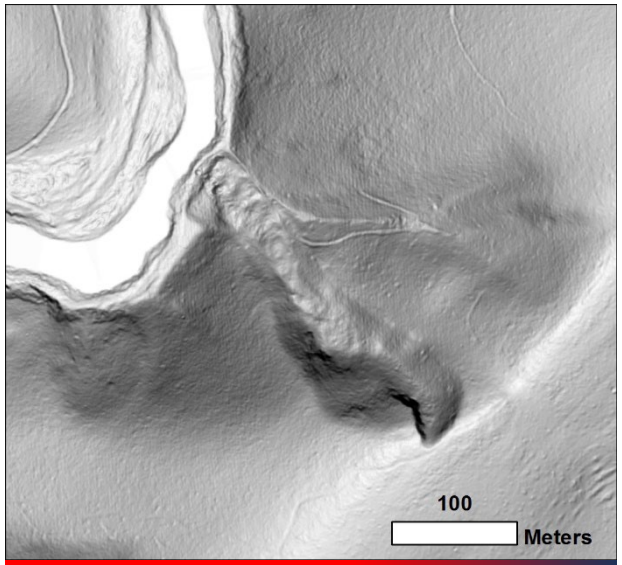
LANDSLIDE INDENTIFICATION USING LIDAR

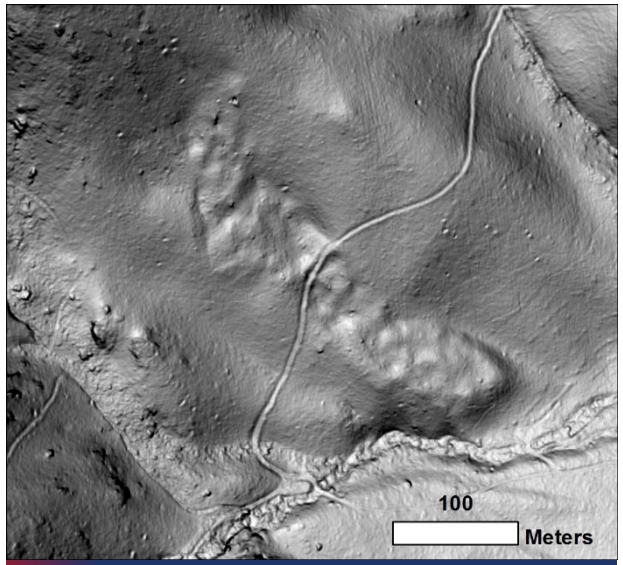
Youngest — Relative Age → Oldest



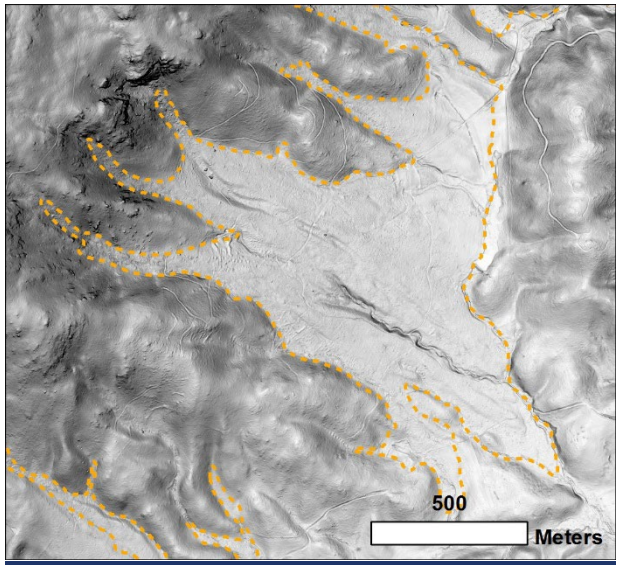
Modern Landslide: track and headscarp sharply defined, can be identified on post-storm aerial photography



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



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



Landslide Deposits: low-relief accumulations of unconsolidated bouldery sediment

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IN THE FIELD…

Take note of the geomorphology

- Type of slope – convex, concave, planar
- Uneven terrain (hummocky)
- How steep is the slope?

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IN THE FIELD...

Water Flow

- How wet is the area?
- Ponding water
- Increased spring or seep activity
- Gullying

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SOIL CRACKING – TENSION CRACKS

SOIL CRACKING – SCARPS

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BENT (PISTOL BUTTED) TREES

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LEANING OR BACK ROTATED TREES

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SUNKEN OR BROKEN ROADS, DRIVEWAYS

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DAMAGE TO PROPERTY

Can also include:

- Sticking doors and windows
- Broken or leaking utilities (water, septic, sewer)
- Growing cracks in walls or ceilings
- Water wells that suddenly run dry

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MATURE LANDSLIDE FEATURES

- As landslides age, vegetation grows back over bare earth
  - Can usually still identify bowl-shaped depression in the slope
  - Exception to this is when the landslide exposes bedrock
- Fine sediment erodes quickly, leaving behind bouldery debris
- Vegetation rots, but large trees may remain entrained in debris
- Evidence of tree damage
- Young trees and understory grows back in the main body of the slide

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MATURE LANDSLIDE FEATURES

BOWL-SHAPED HEADSCARP

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ANCIENT LANDSLIDE FEATURES

BOULDERY DEBRIS

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MATURE LANDSLIDE FEATURES

DEBRIS BEHIND TREES

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MATURE LANDSLIDE FEATURES

TREE DAMAGE

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MATURE LANDSLIDE FEATURES

UNDERSTORY REGROWTH

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NELSON COUNTY, VA 1969 HURRICANE CAMILLE DEBRIS FLOWS FORTUNES COVE REVISITED JANUARY 2015

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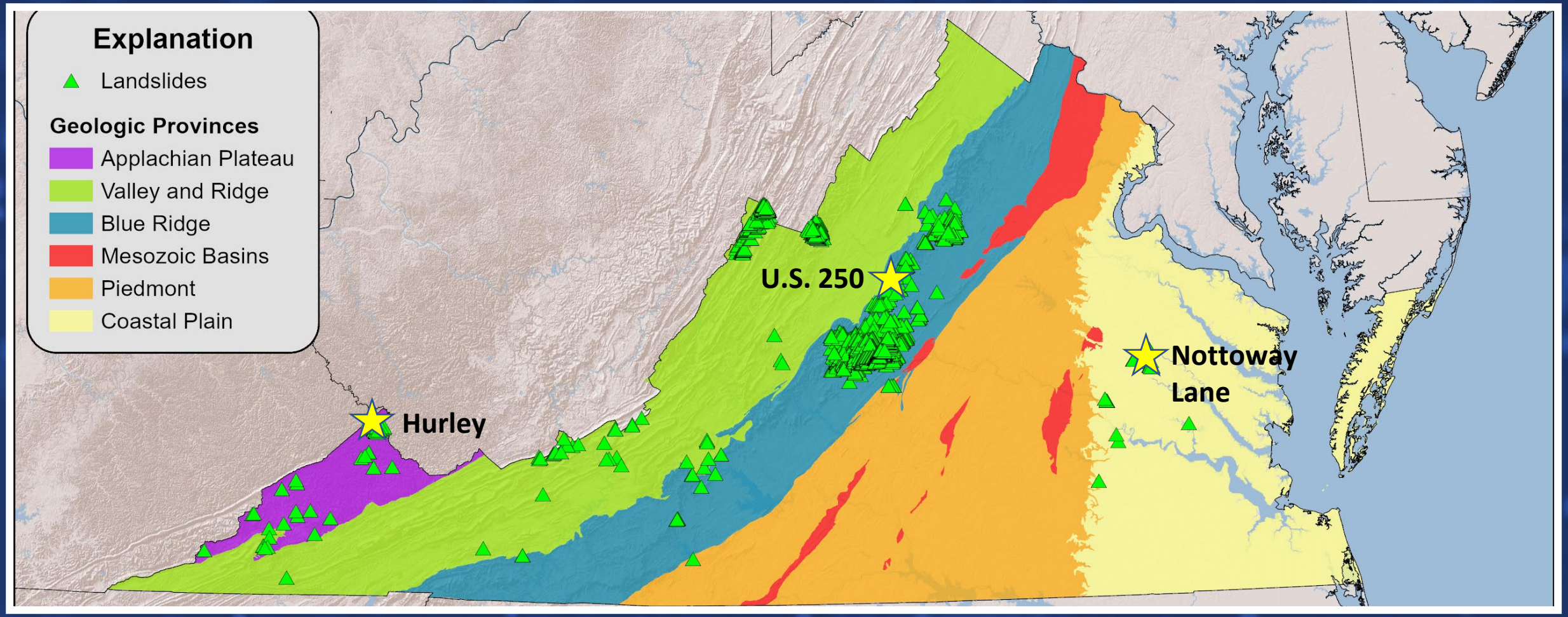

NOTTOWAY LANE LANDSLIDE
KING WILLIAM COUNTY

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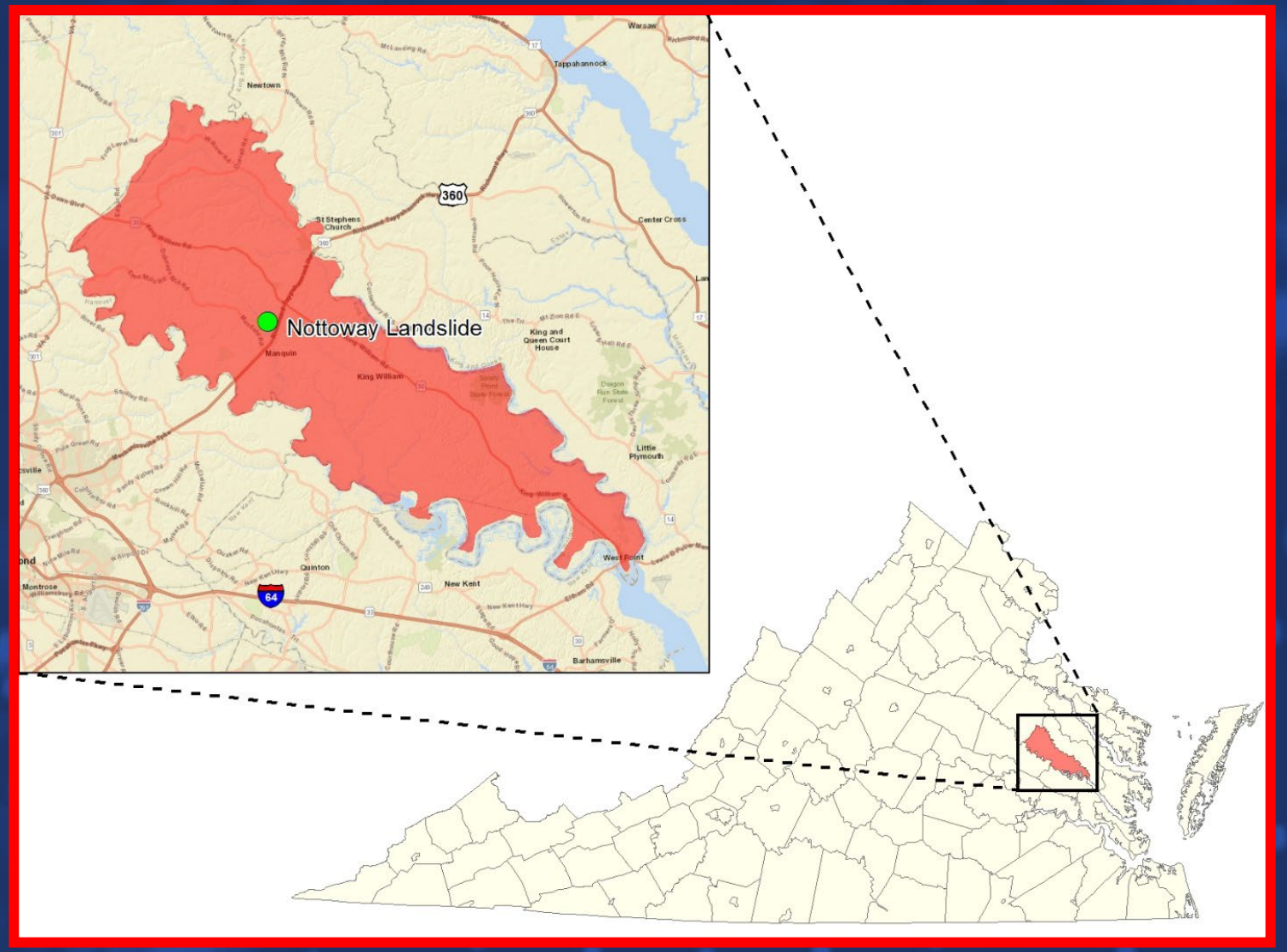
- Based on news reports, the slide occurred in the early morning hours of June 3, 2018
  - May/June 2018 had been particularly wet – monthly precipitation totals were 150-300% greater than normal
  - Rain gauge six-miles to the east received 3.9-inches in 24-hours between June 2-3
  - Several NWS flood watches and warnings issued in the County
- First reported to King William County Building Dept. on June 19



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- GMR was first alerted to the landslide on June 19 as a request for assistance from VDEM and the King William Dept of Emergency Management
- First reported as a sinkhole behind two houses at 360 and 362 Nottoway Lanel
- Both homes were condemned on June 19

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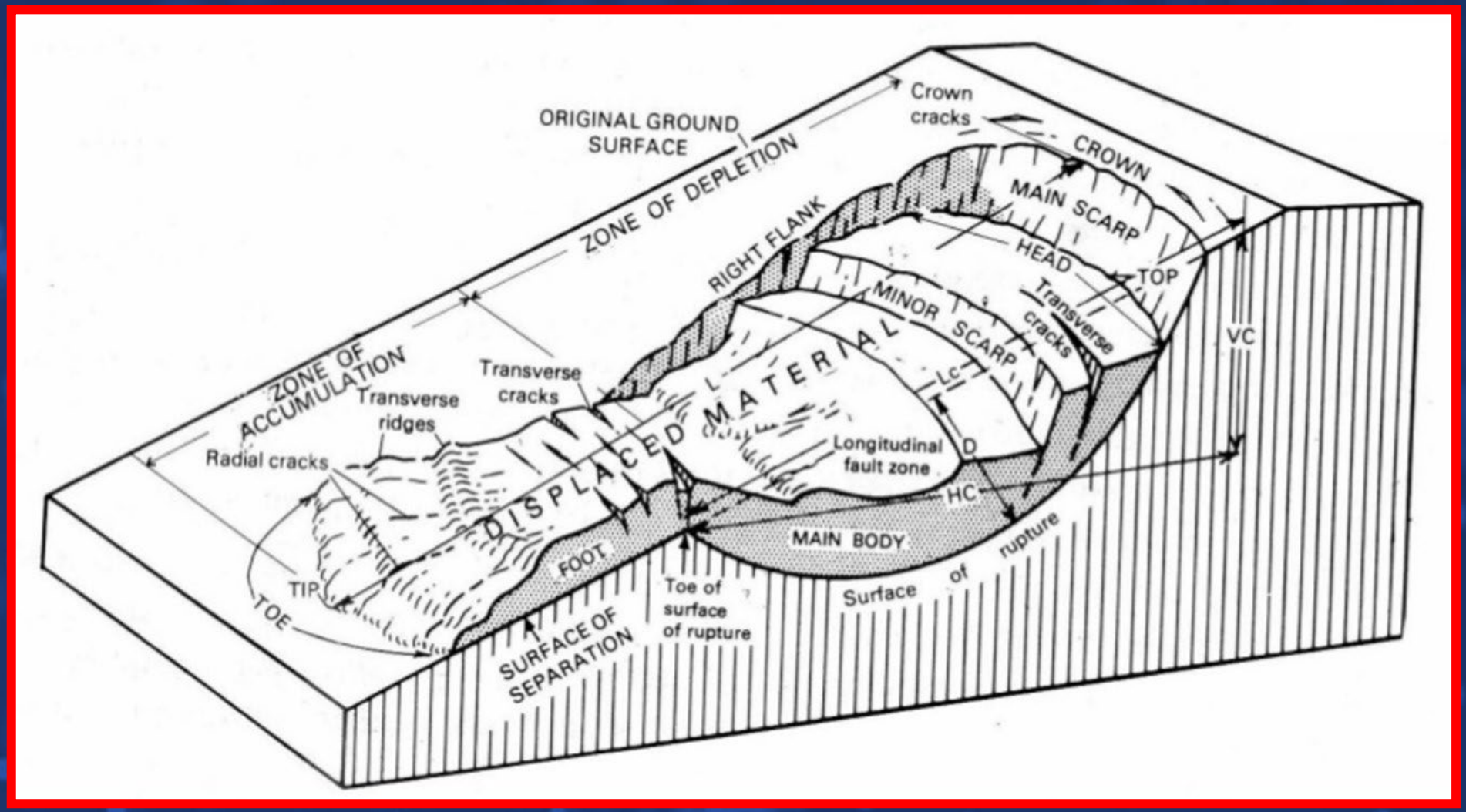
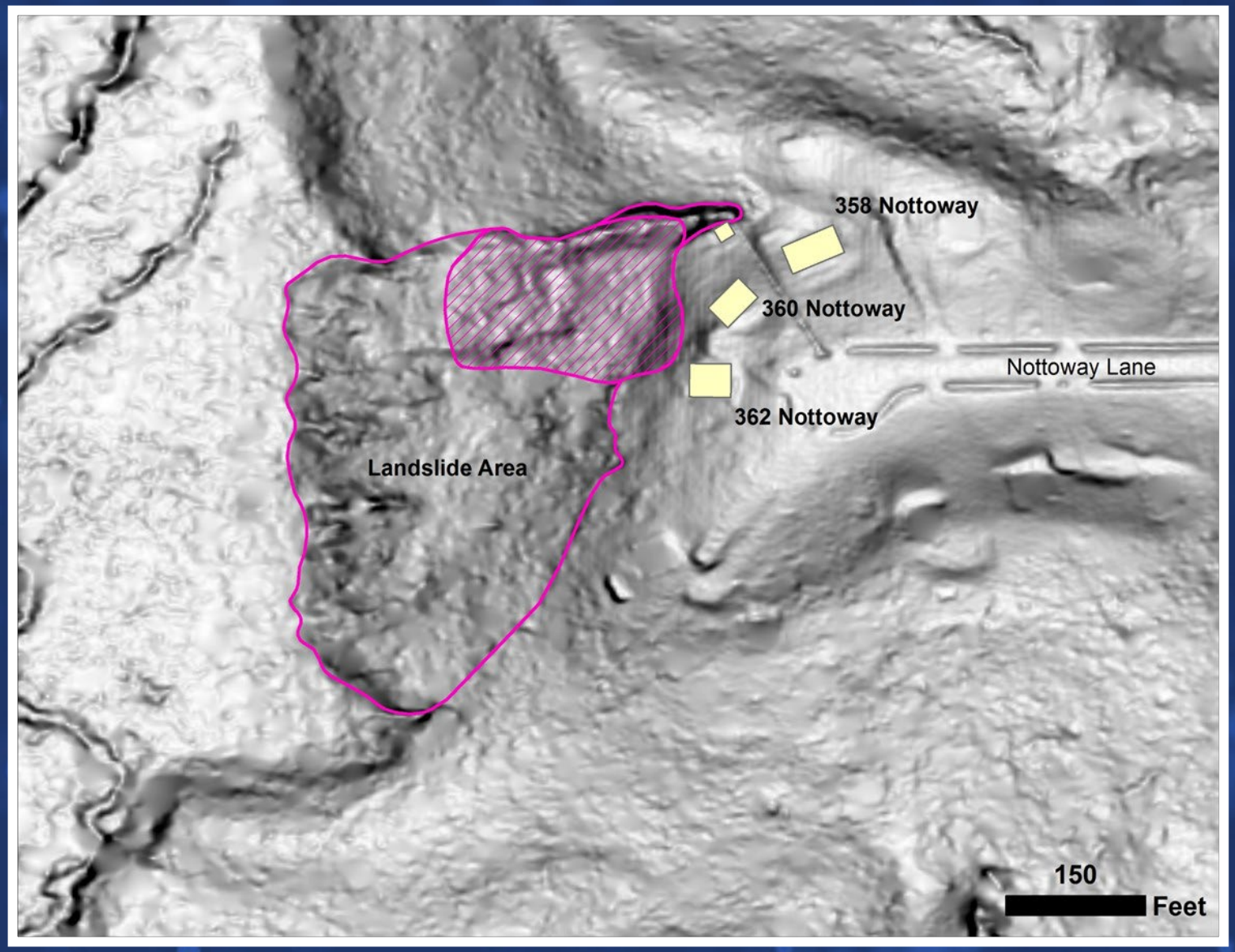


Based on this evidence, the feature was identified as a rotational debris slide-flow based on Cruden and Varnes (1996) classification.



2011 LiDAR Slopeshade – 2.5 foot pixel resolution

Owner of 362 Nottoway confirmed that he had noticed cracking and slumping in his backyard for the past seven years.

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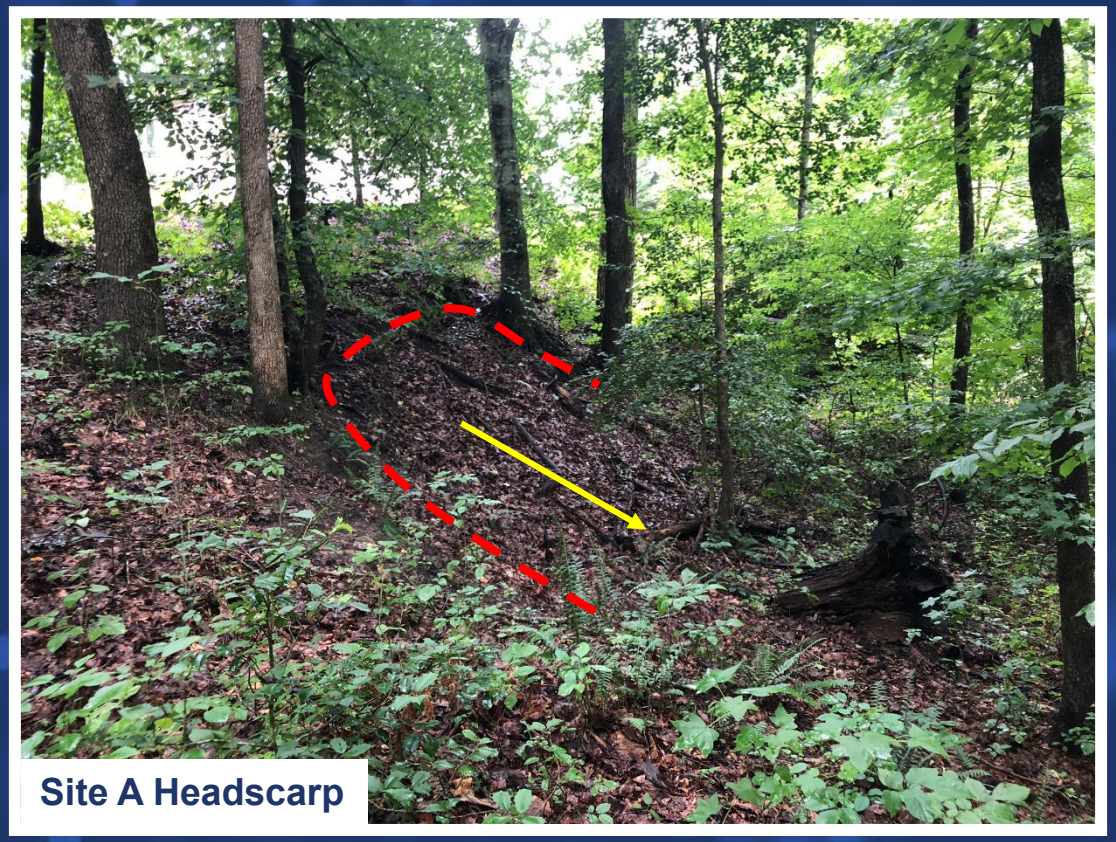
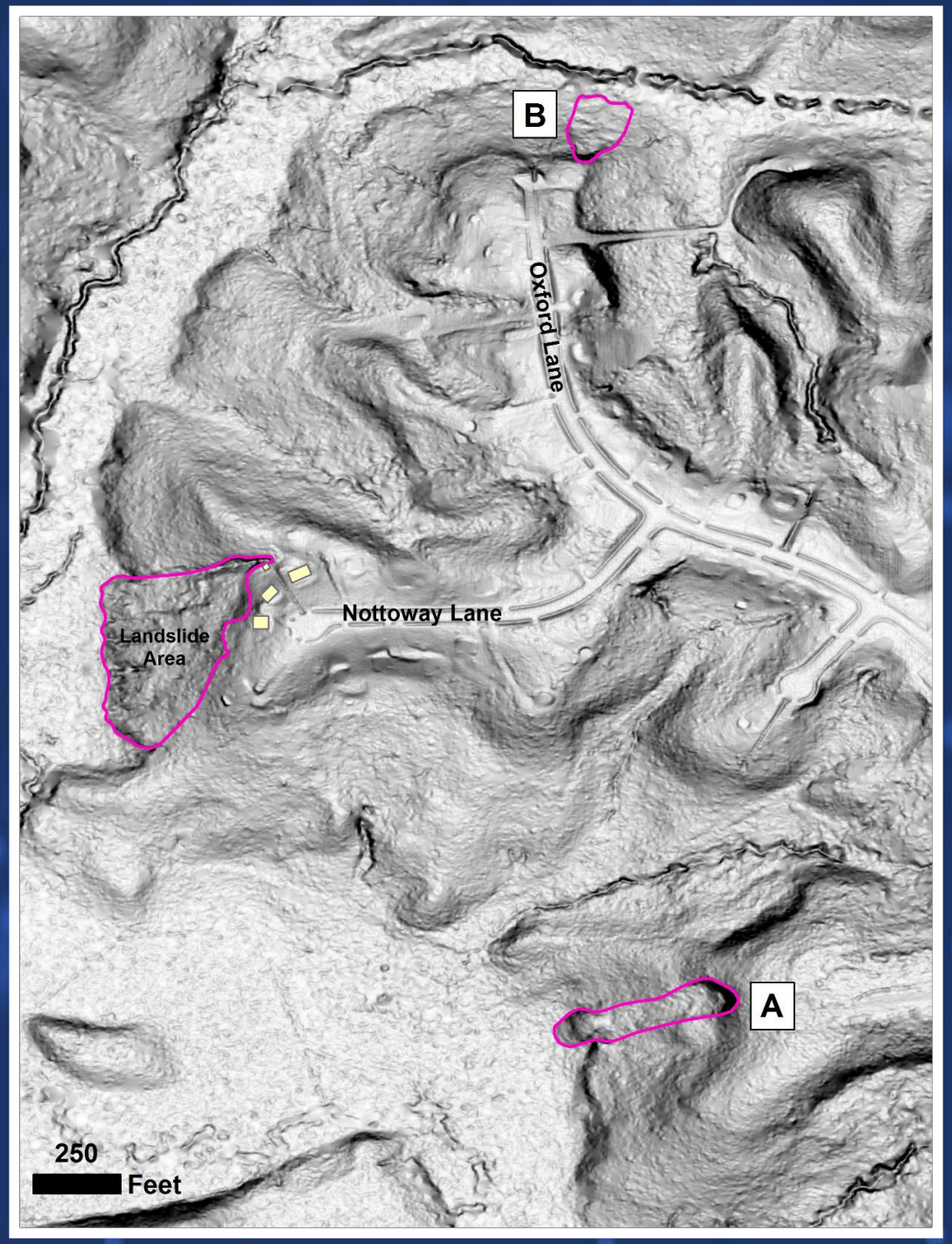
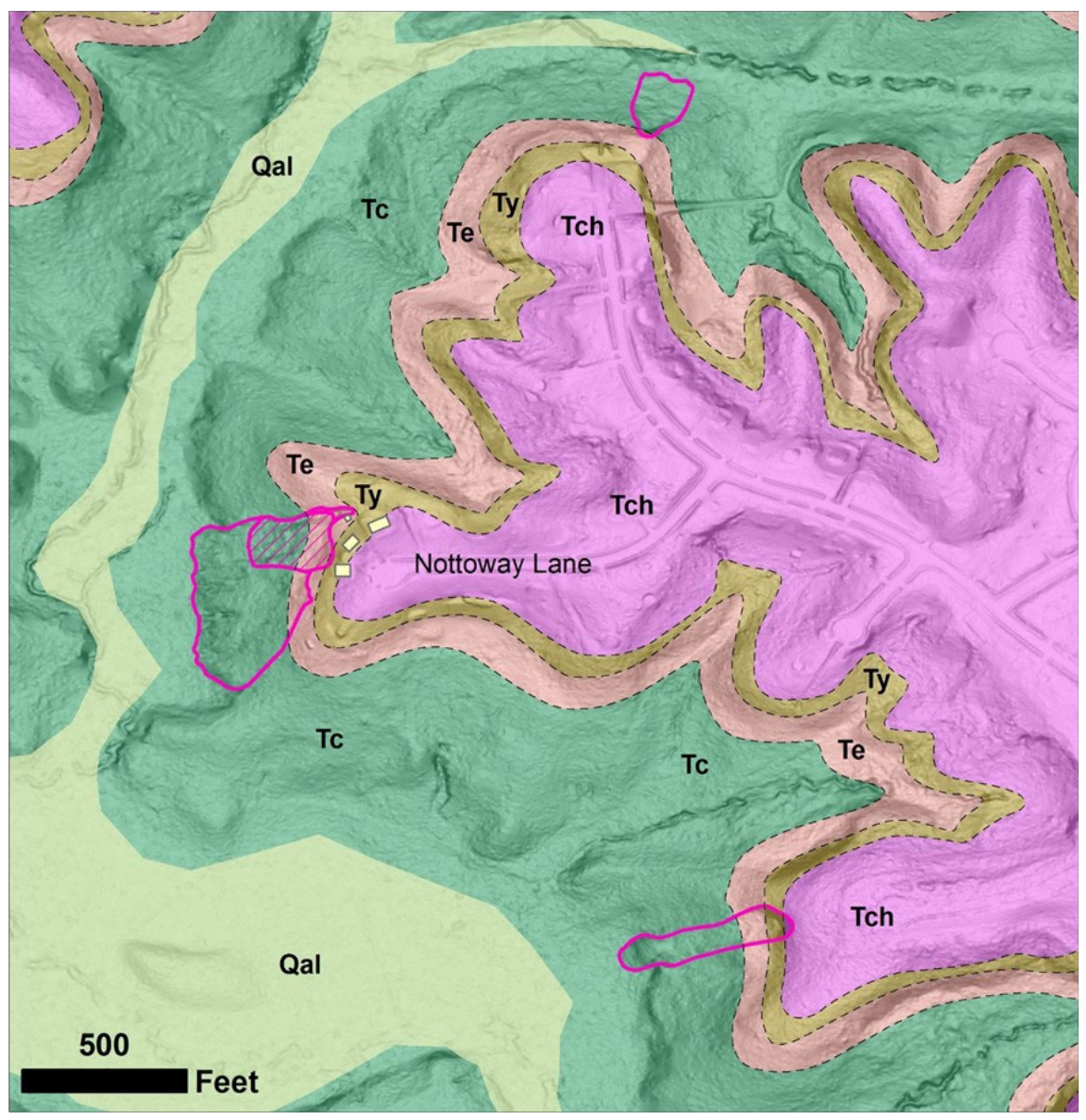
- Revisited neighborhood July 25:
  - Site A = Debris flow
  - Site B = Debris slide
- Both had significant regrowth in the head scarps → landslides were older than 10 years
- Neither posed a threat to life or property


Site A Headscarp



- King William County is in the Virginia Coastal Plain
- Geologically mapped at 1:24,000 scale by GMR in 2015
- Geological Units = gently dipping, unconsolidated marine and nearshore sediments from the Late Pliocene to Early Eocene

Tch	Cold Harbor Formation
Ty	Yorktown Formation
Te	Eastover Formation
Tc	Calvert Formation



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- Stratigraphy of the landslide headscarp examined by DGMR and USGS on August 1
  - Cold Harbor – 0-8.9 ft
  - Yorktown – 8.9-18 ft
  - Eastover – 18 to base of headscarp
- Eastover Formation – well-jointed, firm, silty clay that breaks easily along joint faces and fracture surfaces
  - When exposing with hand shovel, groundwater readily flowed from fractures in the clay

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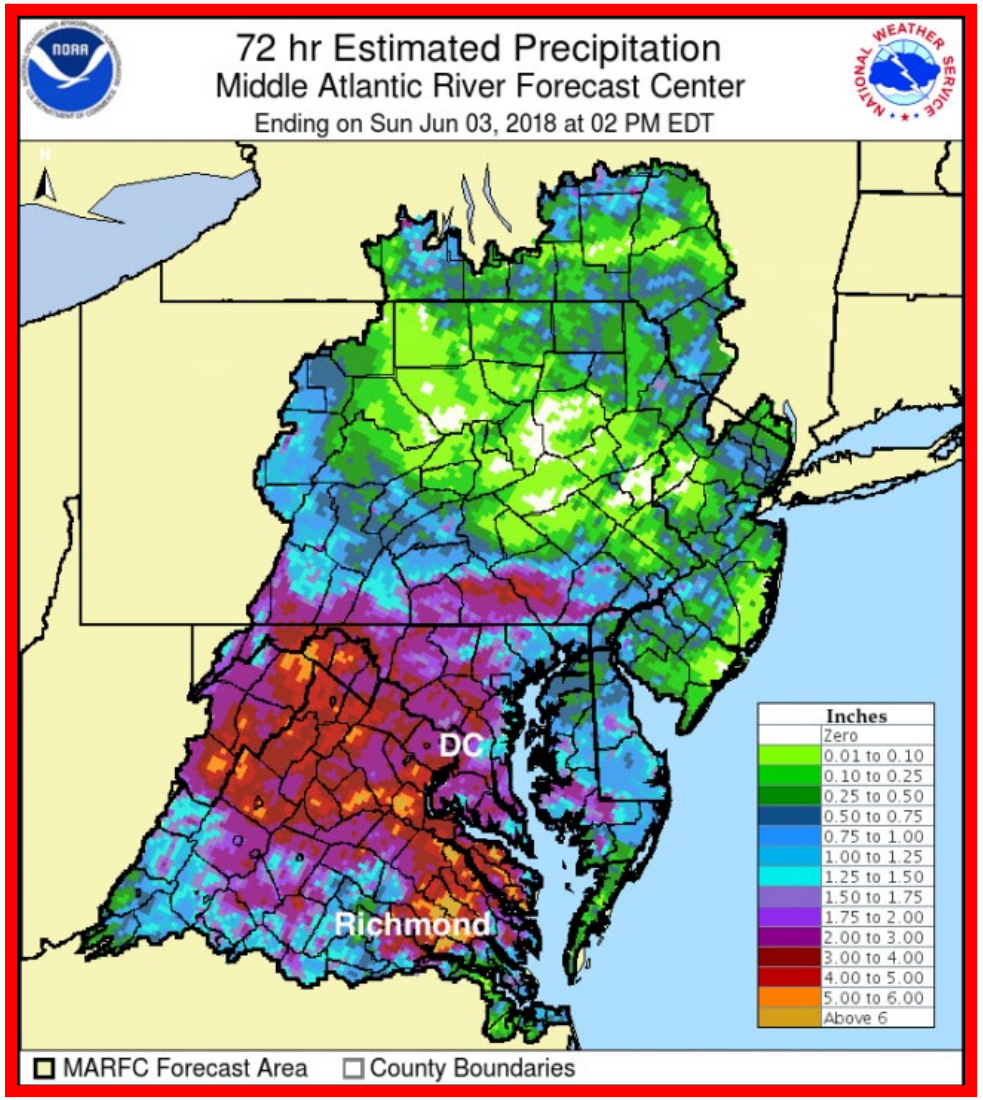
DISCUSSION - RAINFALL

- Precipitation was the likely cause of the Nottoway Landslide
  - May and June 2018 had been particularly wet; monthly precipitation totals 150-300 percent greater than normal
- Between June 2-4, a stationary low-pressure system produced two to four inches of rain across Northern and Eastern Virginia
  - Heavy rain early on June 3 (3.9 in 24-hours by the nearest rain gauge) likely triggered the initial failure
- From June 20-22, thunderstorms along a stationary front also produced significant rainfall → triggered additional downslope movement



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DISCUSSION - RAINFALL

- Storm water runoff also contributed significantly to the slide and probably accelerated the reactivation of the slope
  - Concrete-lined storm drain between 358 and 360 Nottoway drains into the right-lateral flank of the landslide
  - Driveways between 360-362 Nottoway provided conduits for rainwater

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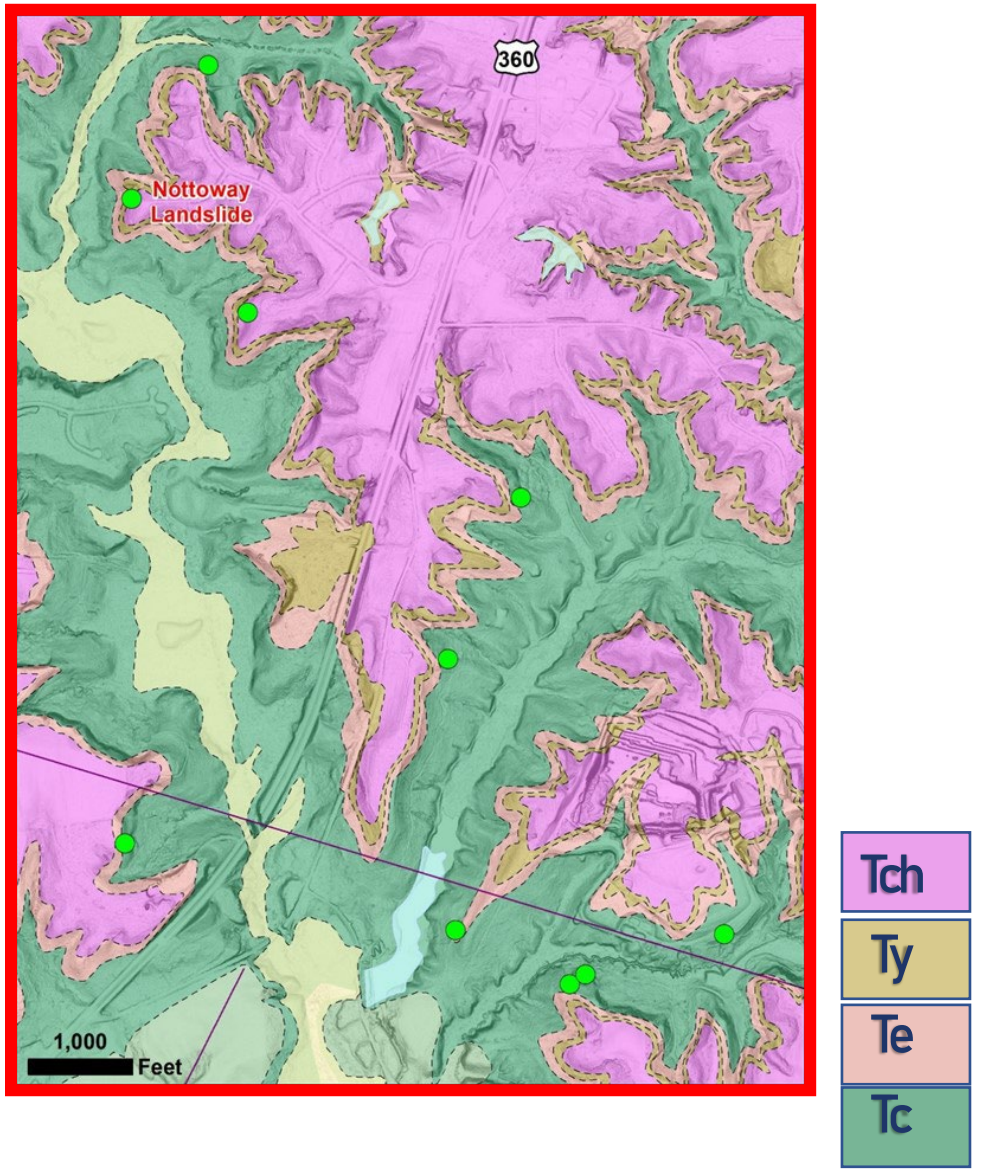
FUTURE WORK

- The Eastover Formation appears to be particularly prone to initiating landslides, especially during heavy rain events
- A first pass through the LiDAR in the immediate vicinity of the Nottoway Landslide identified numerous other debris slides
- Completing a comprehensive landslide inventory for this area using the 2.5-foot LiDAR will be crucial first step to identify areas that are a greater threat to public safety



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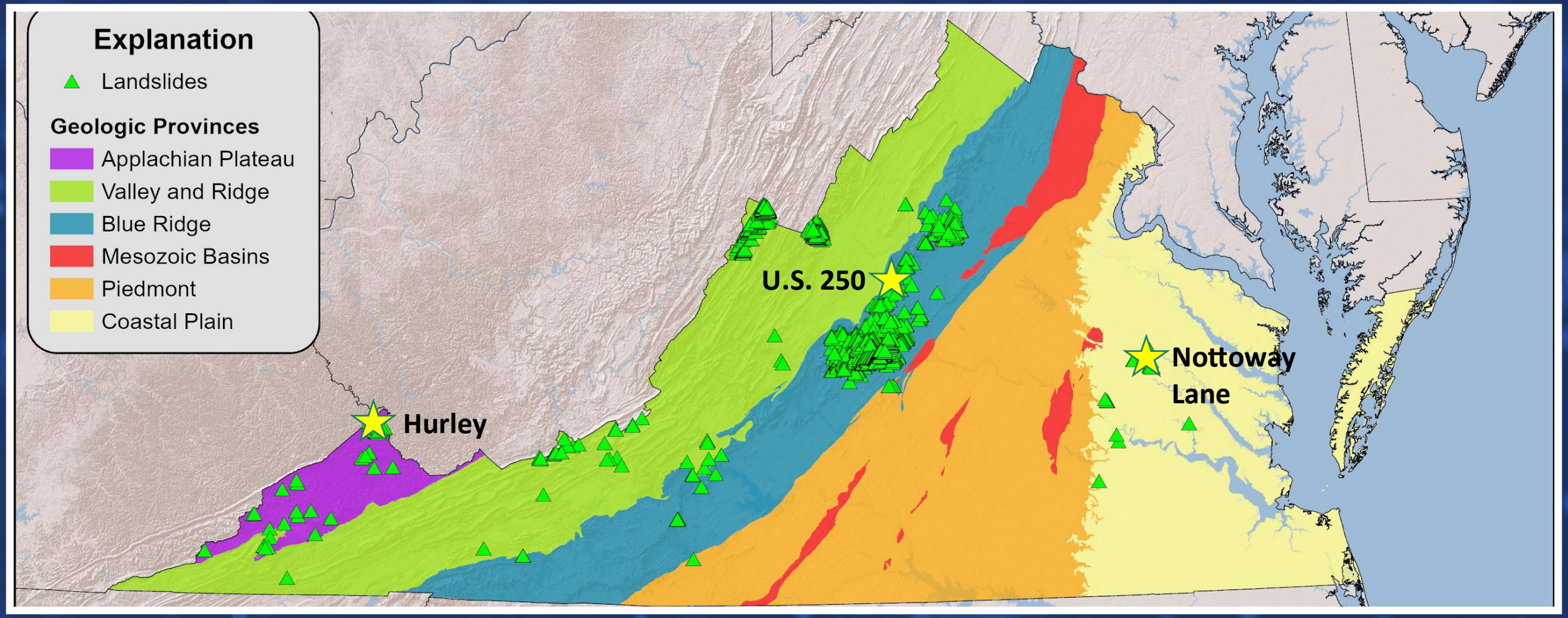

U.S. 250 ROCKSLIDE
ALBEMARLE COUNTY

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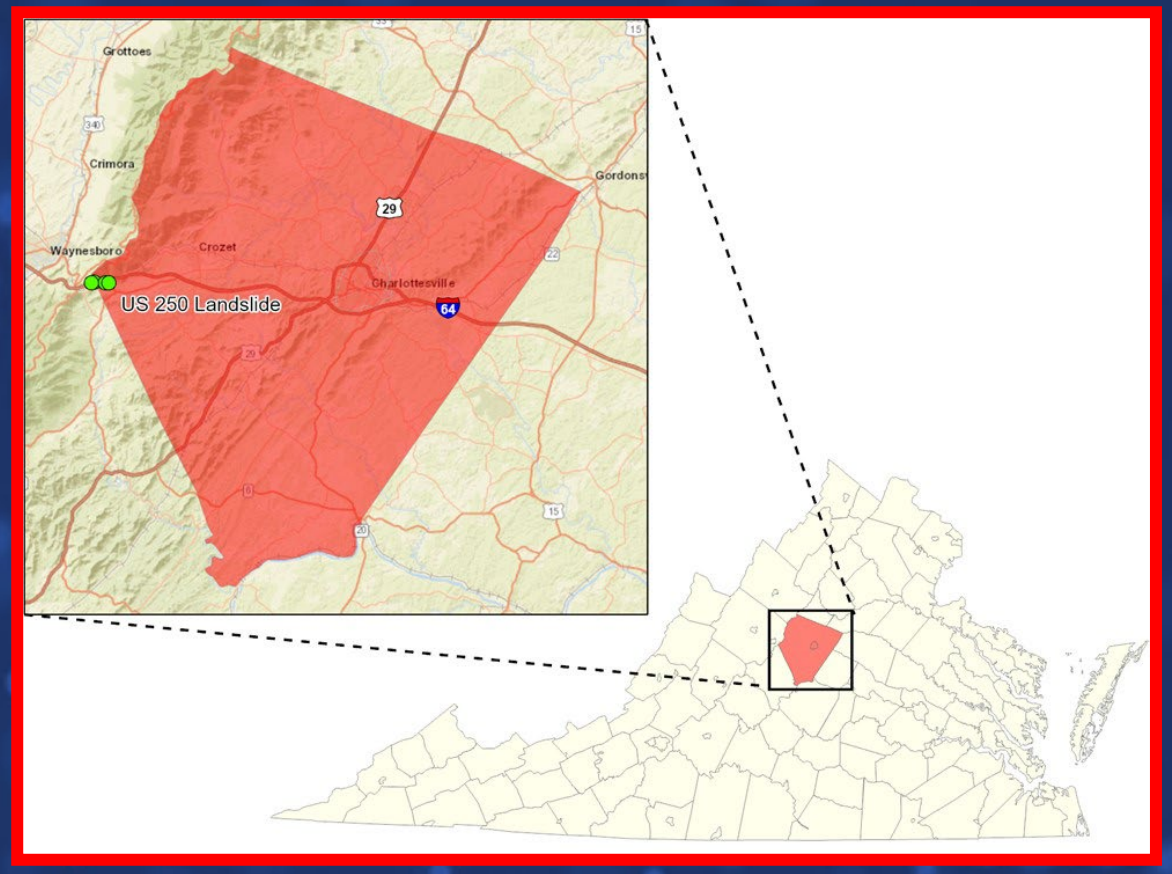

- Occurred on May 3, 2021 near Rockfish Gap
- US 250 closed between Route 6 and US 151 as rock and debris was blocking the westbound (uphill) lane
- Contacted VDOT and was allowed to do a site inspection the next day

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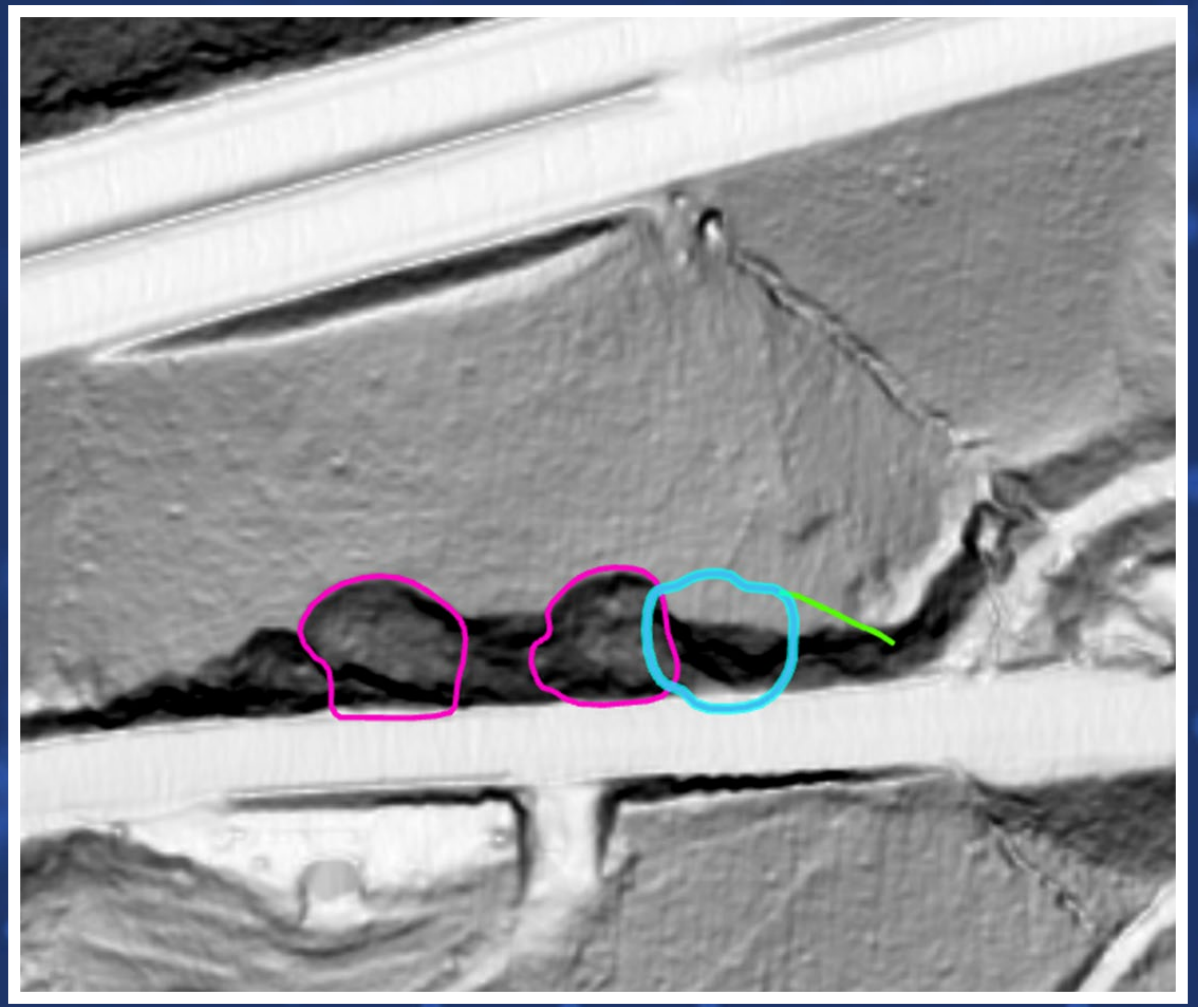
Large tension crack to east of main slide

Headscarp

- This was classified as a rockslide on site, due the material and style of movement.
- A large tension crack to the east indicated that additional movement could occur.
- Also the site of other past rockslides which could be identified on aerial photography and LIDAR.



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FUTURE WORK

- Slide occurred in the Catoctin Formation – 570-million-year-old meta-basalt (greenstone)
- Later metamorphism deformed and sheared the rock creating foliation
- In this area of US-250 and I-64 the foliation dips downhill, parallel to the slope → became the failure surface of the rockslide

I-64 roadcut just the northwest of the US 250 rockslide

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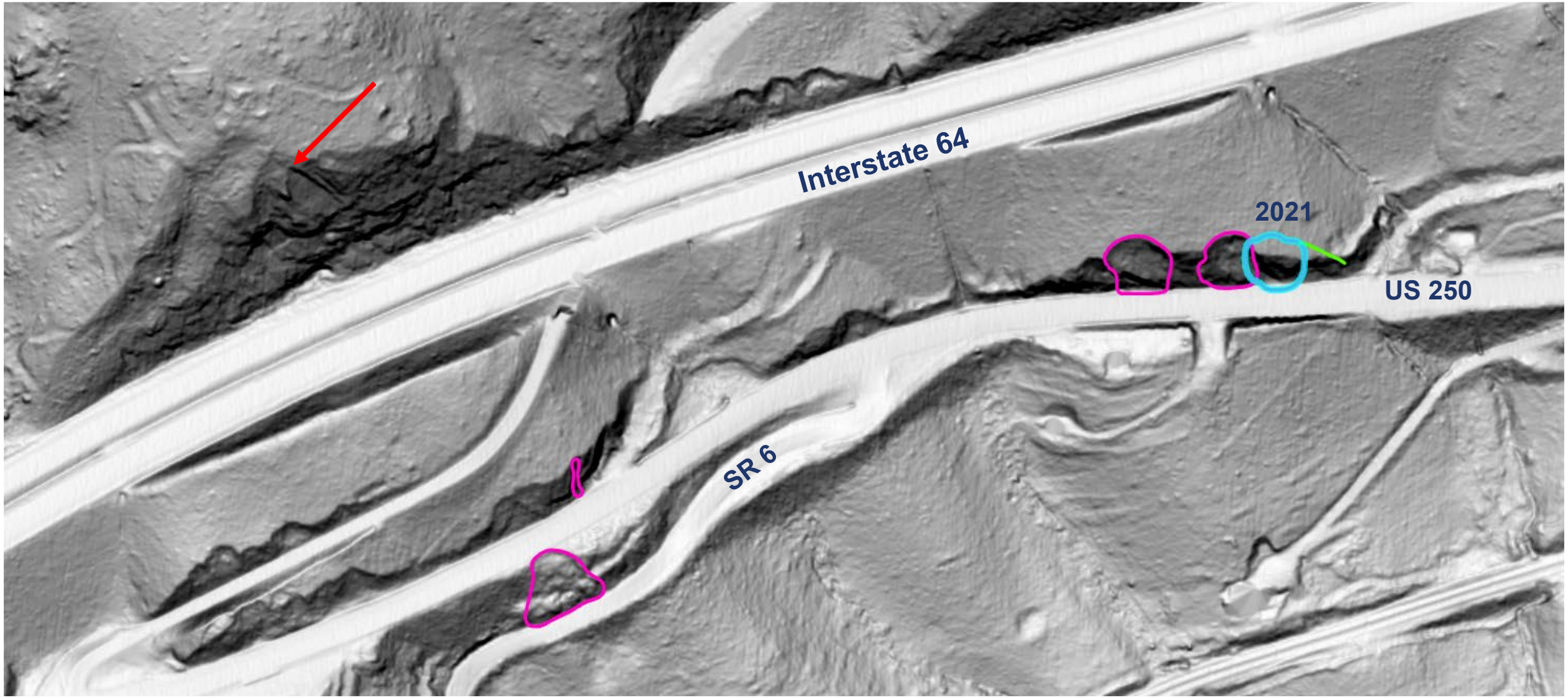
https://wmblogs.wm.edu/sgtresearch/a-mass-movement-in-the-blue-ridge/



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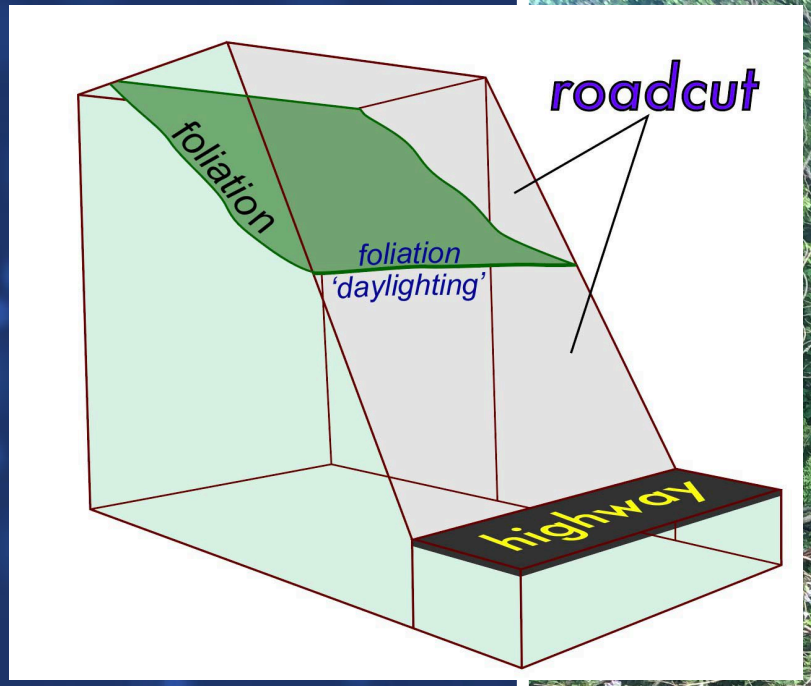

Road cut along US 250 is steep with daylighting foliation surfaces.

https://wmblogs.wm.edu/sgtresearch/a-mass-movement-in-the-blue-ridge/

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Joints (fractures) are also present in the Catoctin. They often form regular patterns and are also natural areas of weakness in the rock.

The green line is a joint that is perpendicular to foliation.

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Joints (fractures) are also present in the Catoctin. They often form regular patterns and are also natural areas of weakness in the rock.

The green line is a joint that is perpendicular to foliation.

There is also a joint surface that is perpendicular to the road. This is the release surface of the rockslide and is parallel to the tension cracks and headscarp.

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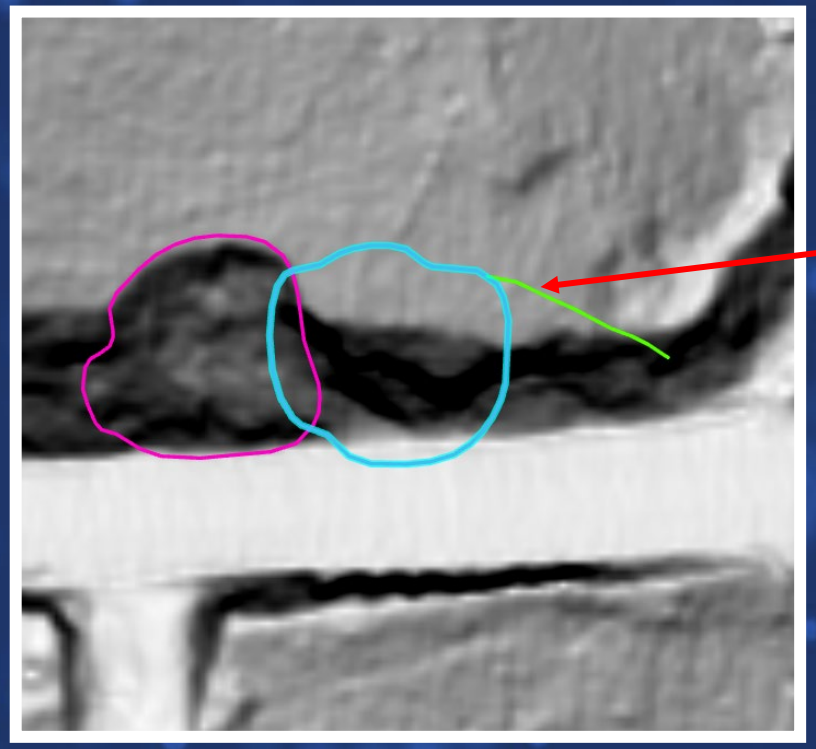
Tension cracks and scarping did not extend very far above the main headscarp, however the large tension crack to the east suggested that more of the area was unstable than previously thought.



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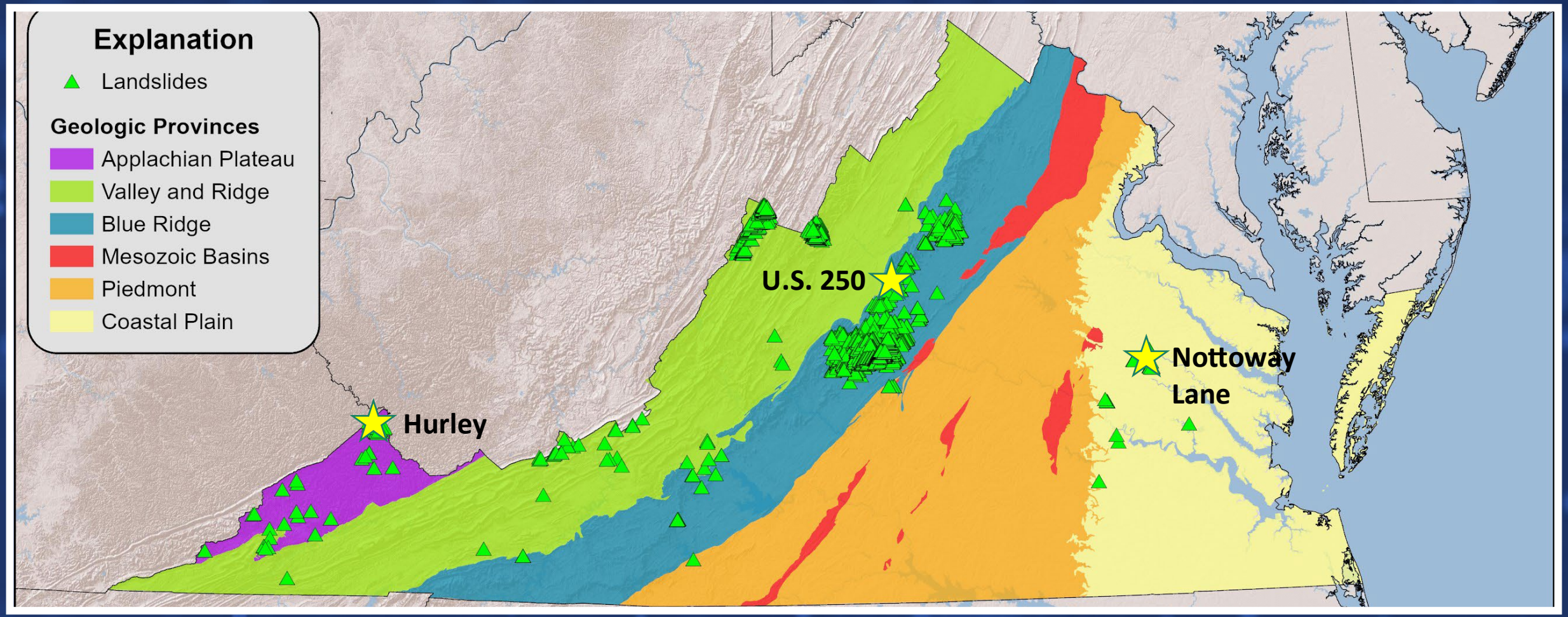
- US 250 was closed for eight weeks and reopened June 30
- 700 dump trucks of unstable material were removed (about 10,000 tons) including the area below the large tension crack
- 350 soil nails were placed to stabilize the slope
- Area covered with anchored steel mesh to prevent soil and rock from falling into the roadway



HURLEY LANDSLIDES
BUCHANAN COUNTY

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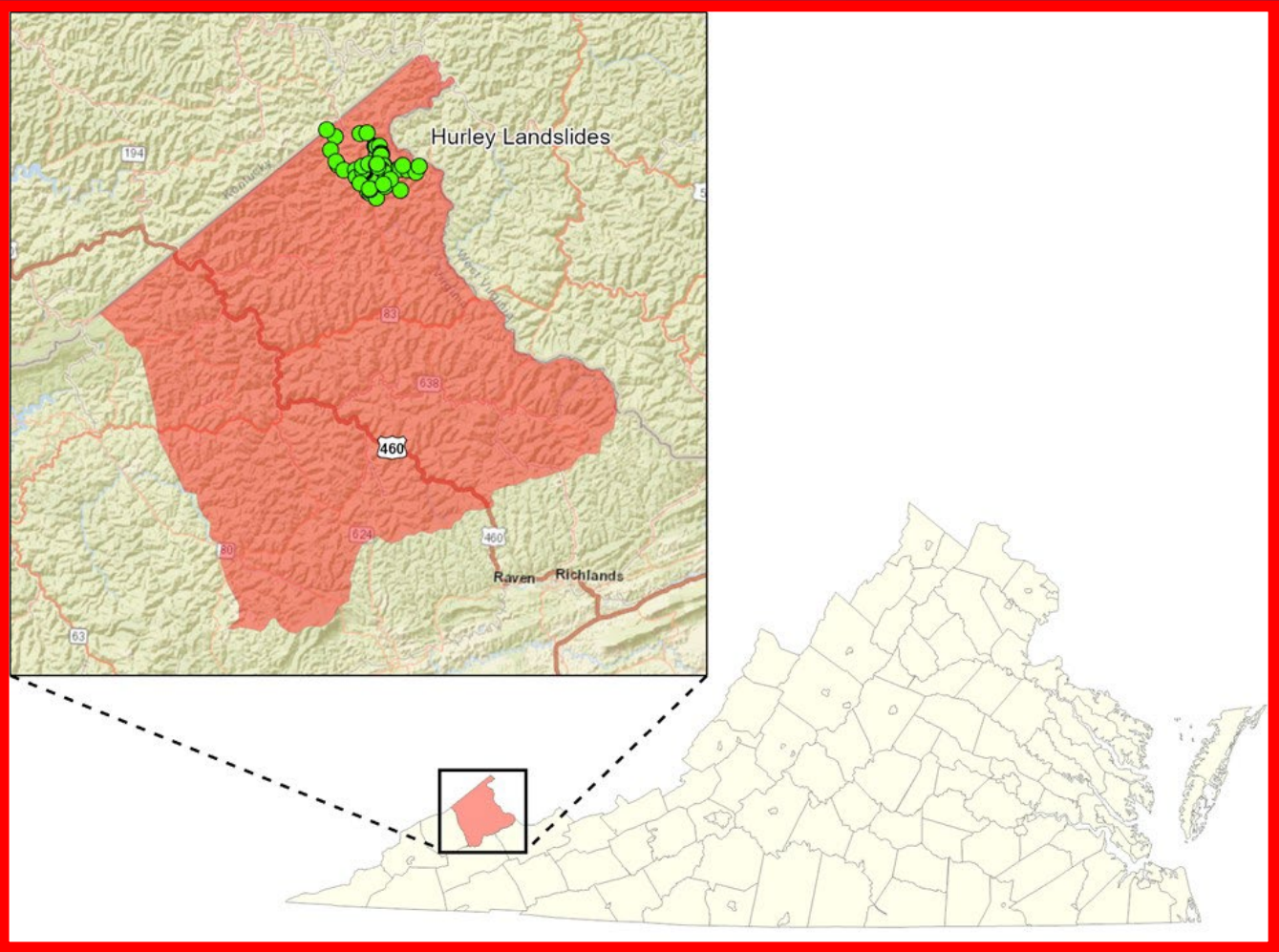

- Occurred on August 30, 2021 near the town of Hurley in SW VA
- “Coal country” – extensive surface and underground mining
- Severe flooding along Guesses Fork – seven-inches of rain in a few hours
- 31 structures destroyed, and 30+ damaged
- One person killed

Kentucky

West Virginia

VIRGINIA Energy

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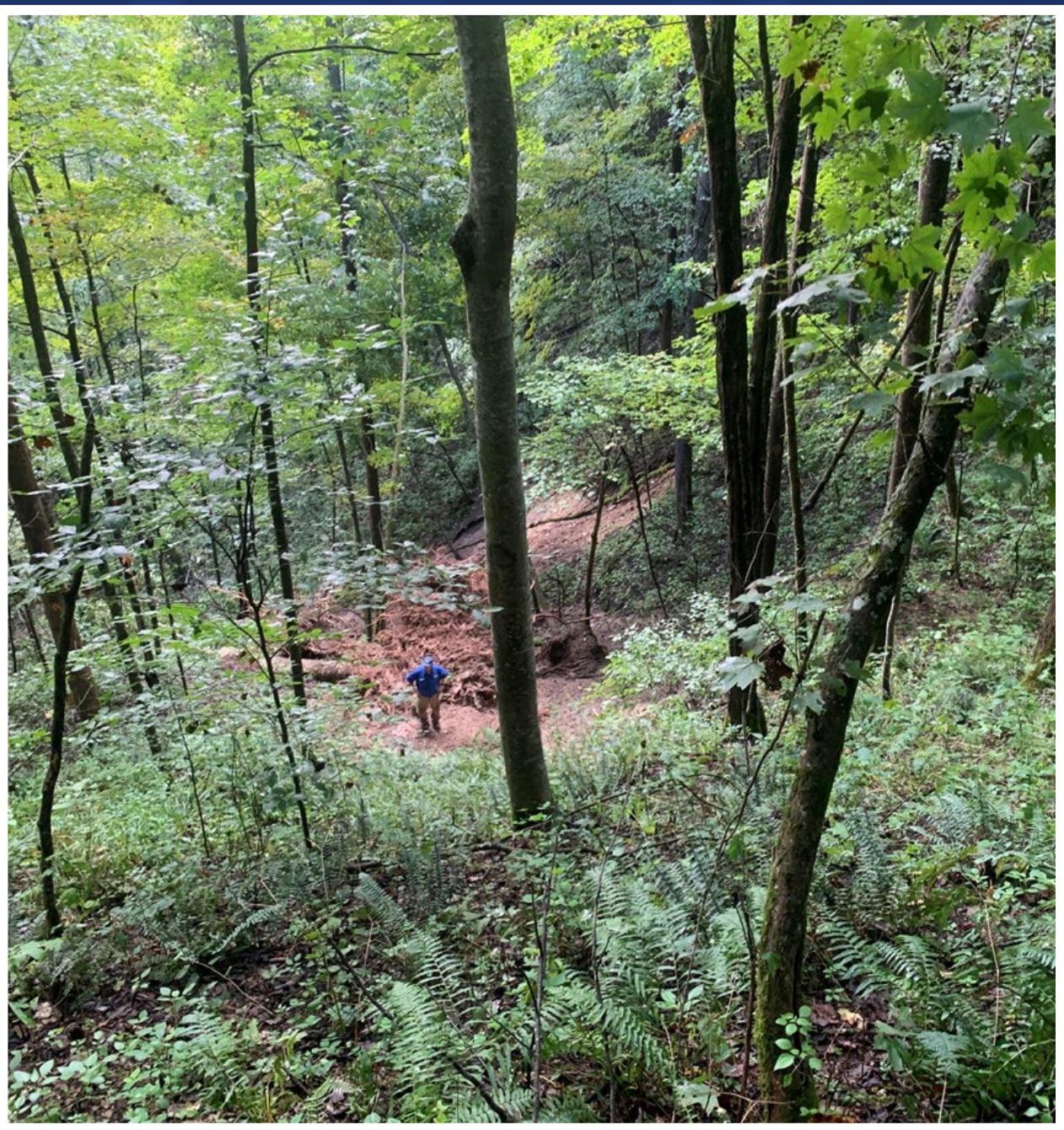
Photo Credit: Ricky Matthews, WCYB

Photo Credit: VDEM

Photo Credit: Red Cross



- VDEM requested emergency assistance related to landslides
- Field work and site assessment occurred Sept 8-9 after rescue operations were completed
- Concern that flooding was related to mine portal blowouts

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DEBRIS FLOWS

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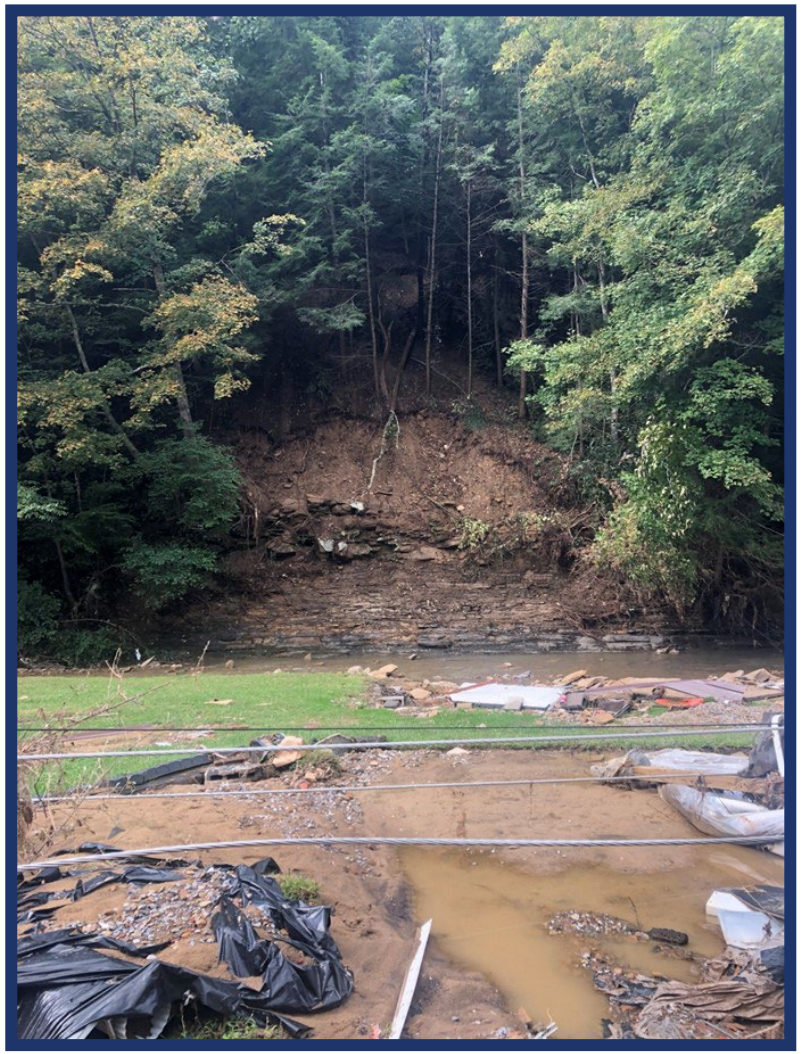
DEBRIS SLIDES



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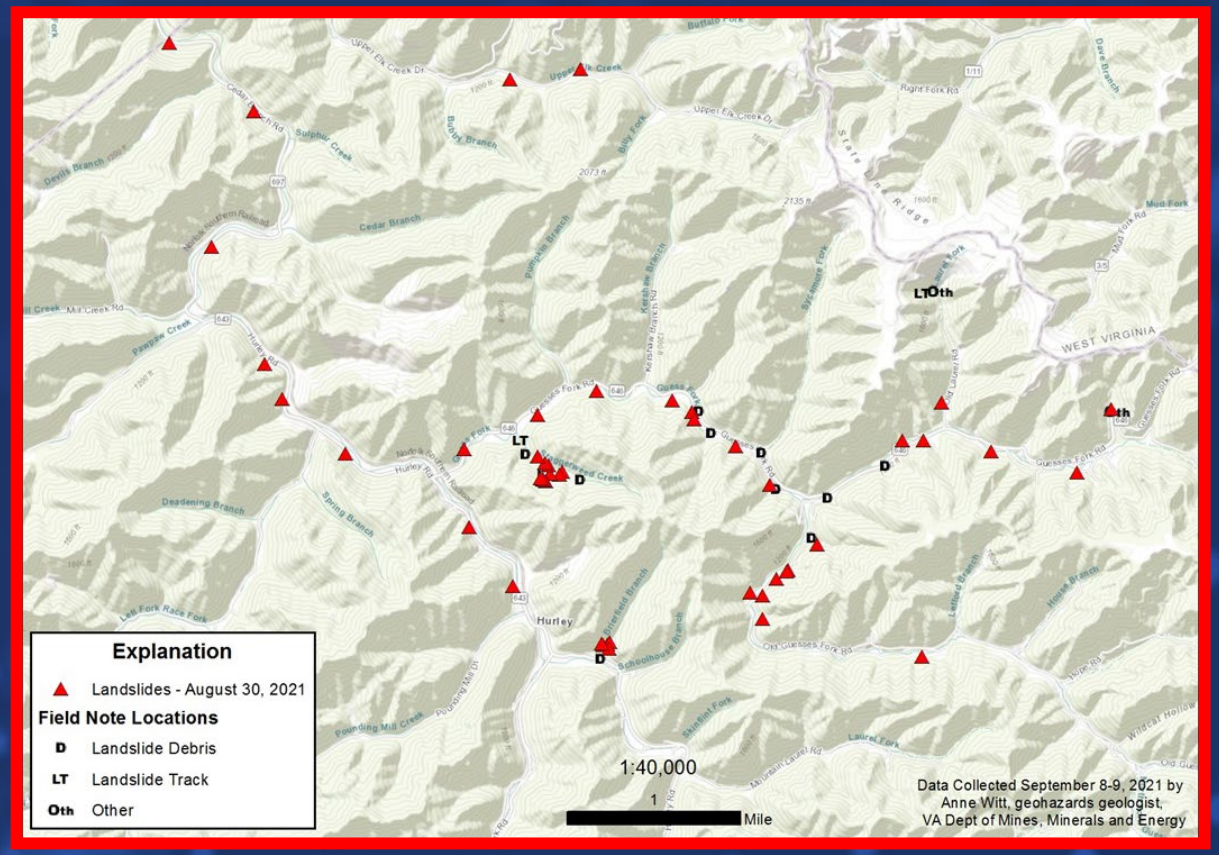
DEBRIS SLIDES

- Mapped 47 landslides
  - Most were debris slides
  - 21 were road related
- Concentrated within a 20 mile area
- Likely more landslides than documented
  - were not visible due to vegetation
  - inaccessible due to storm damage
- Did not see evidence of mine portal blowouts, but a few slides originated from mine benches



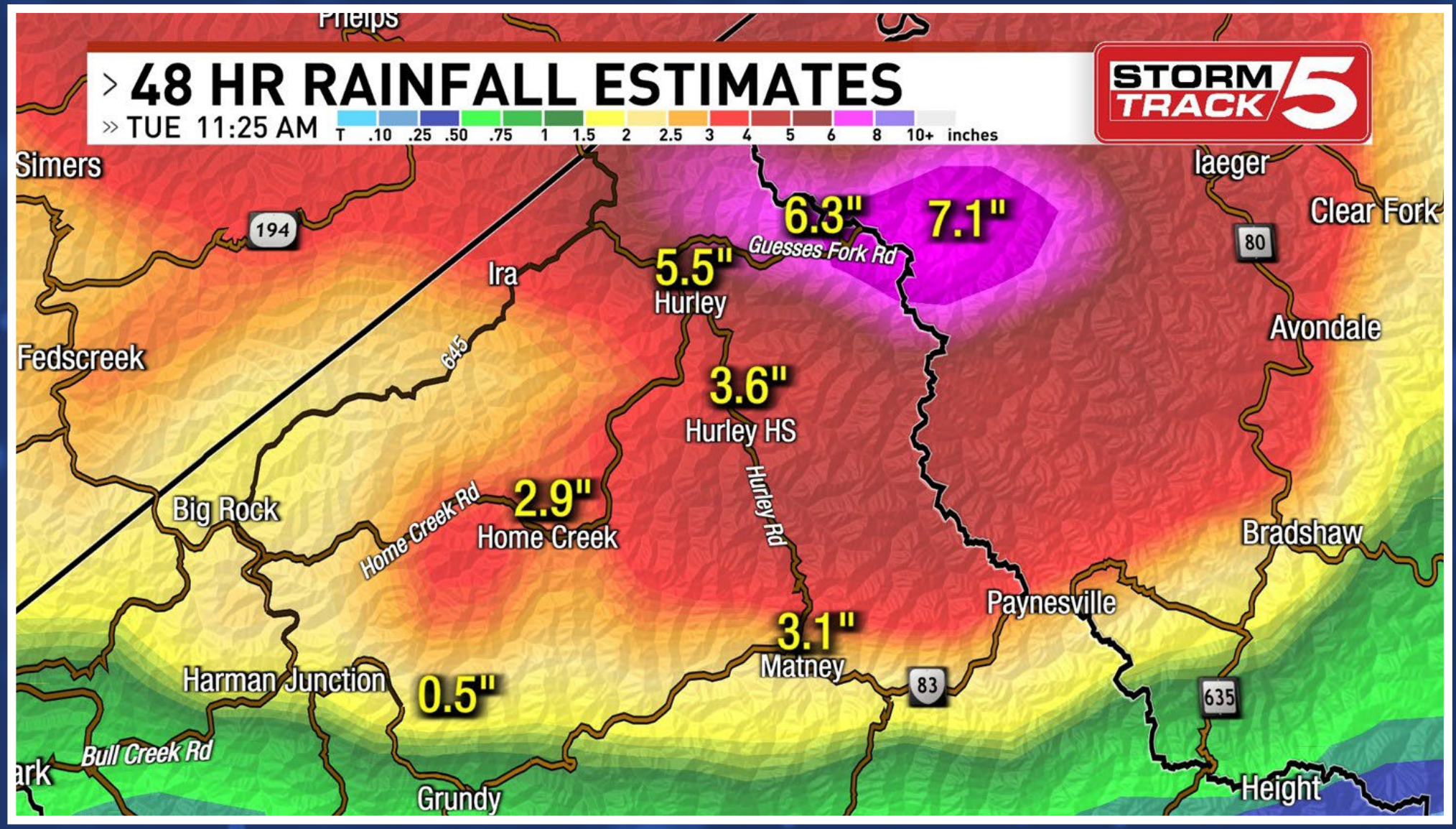


Photo Credit: Ricky Matthews, WCYB

POST DISASTER FOLLOW UP…

Photo Credit: Cardinal News

- Many of the homeowners did not have flood insurance
- VDEM included the GMR landslide data in the Governors request for a major disaster declaration (October 2021)
- FEMA gave $1.6 million to the community for infrastructure repair, but denied individual assistance (twice)
- Current state budget appropriation of $11.4 million to assist homeowners

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CONTACT INFORMATION

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https://energy.virginia.gov/geology/Landslide.shtml