Monitoring and Characterization of the Meadowview Lane Landslide: Boyd County, KY

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Outline

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• Meadowview Lane Landslide
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  ➢ Slide history
  ➢ Objectives
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• Preliminary results
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  ➢ Rainfall and groundwater
  ➢ Slope movement
• Geophysics: Electrical resistivity
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• Geotechnical-Geophysical correlation
• Communicating with the geotechnical community
Acknowledgements

- Kentucky Geological Survey
- Francis Ashland – U.S. Geological Survey
- Chris Yohe and James Martin – Terracon, Lexington
- Junfung Zhu, Steve Webb, and Max Hammond – KGS
Kentucky Landslides

- 843 KYTC landslide geotech reports (1973-2013, unknown $)
- 2008-2009 KYTC spent $6.6 million on landslide and rockfall repair
- April-May 2011 storms caused ~50 slides, cost KYTC District 6 over $4 million
- KYEM-FEMA landslide mitigation projects ~ $5.3 million
Landslide Inventory
Meadowview Lane Landslide: Project Location

Slide location

Boyd County
Geology

Excerpt from the Geologic map of the Boltsfork and Burnaugh quadrangles, Kentucky by F.D. Spencer, 1964

Most landslides in the area occur along the underclays of the Breathitt Formation, but a few occur in the shales and shaly siltstones of the Conemaugh Formation where hillsides are steep, as along Chadwick Creek. Landslides are so prevalent in and near the outcrops of the Princess coal beds 6 and 7 that these beds can be located by failures of roads that cross them. Many small landslips have occurred along these beds in hillside excavations for houses.
Landslide Background

**Trigger and Causes** – Slide failed late April 2011. The Lawrence County precipitation monitoring station run by the Kentucky Mesonet measured over 8 inches of rain in April 2011. Causes are a complex interaction between bedrock, clayey colluvium, steep slopes, excess water, and slope modification.

**Type** – Shallow, roto-translational slide (upper rotation morphing into translational flow)

**Material** – Mixture of disturbed colluvial soil and bedrock derived from excavation of house and natural colluvial soils covering hillside.

**Dimensions** –
- Width of displaced mass = ~220 ft
- Length of displaced mass = ~140 ft
Project Objectives

• Determination of depth, shape, and velocity of the sliding mass

• Monitor groundwater conditions

• Correlate movement with increase in rainfall and pore pressures

• Measure electrical resistivity of the slide material to correlate with subsurface data

• Monitor site for approx. 1 year
Methodology

• Reconnaissance – geology, soils, aerial imagery, slope history

• Total Station monitoring (surface movement)

• Groundwater – 2 Standpipe piezometers

• Movement – 2 slope inclinometer boreholes

• Rain gage installation

• Surface and borehole electrical resistivity

• Geotechnical lab analysis – material index properties, Atterberg tests, and CU Triaxial shear tests
Preliminary Results: Boring Logs
Effective stress parameters: CU with pore pressure
Sample from B-2, 4.5-6.5 ft., gray clay with weathered shale
\[ \phi' = 36.6^\circ \quad c' = 144 \text{psf} \]
Rainfall and Groundwater Measurements

Rainfall (in)

Height of water in piezometers

Water level transducer data, B-2
Inclinometer Data

• Biaxial probe – two perp accelerometers

• Readings spaced once a week for 2 months, bi-weekly for 2 months, now monthly
Recent measurements reflect increased rainfall and complex flow near toe of slide.
B-3 (near toe) cumulative

FILL - SANDY LEAN CLAY W/GRAVEL

LEAN CLAY (CL), stiff

CLAYEY SHALE (soft)

Failure surface?
B-1 (near scarp) incremental

Slight increase in movement measured 7/2 and 7/18
Movement Summary

• Slow-moving, shallow landslide

• Complex hydrogeologic regimes including porous colluvial fill on top of impermeable clay shales creating perched water. This slide holds a lot of water!

• Potential failure location approximately 3 m below the surface coinciding with a sandy-clay colluvial fill and stiff clay interface.

• Rainfall collected to-date totals 16.5 in (419mm)

• Cumulative displacement to-date is approximately .25 inches in B-1 (near head scarp) and .30 inches in B-3 (toe)

• Slight acceleration recently correlates to a wet July and series of rain events

• Continued monitoring will reveal more correlations
Geophysics: Electrical Resistivity
AGI Supersting 8-channel resistivity meter
Surface ERT Image Profiles

Dipole-dipole arrays, 5 ft electrode spacing

Parallel to slope

Perpendicular to slope, near head scarp
Surface ERT Image Profiles

Parallel to slope
Geotechnical-Geophysical Correlation

- ERT can detect landslide morphology, depth to slide plane, key lithologic interfaces and hydrogeologic regimes.

- Thorough landslide investigations and slope stability assessments require additional parameters such as porosity, void ratio, and hydraulic conductivity used to assess shear strength.

- Attempt to further interpret ER and correlate it with laboratory geotechnical data and extrapolate the necessary parameters to improve slope characterization and advance ability to quantify landslide hazards.

- Can ER data in shallow, heterogenous colluvial slides be interpreted beyond moisture content and key boundaries to establish relationships with hydraulic conductivity, porosity, and void ratio?

\[ \omega, k, \theta \gggggg n, \text{matrix suction} \gggggg \mu \gggggg c' \]

- If so, can these parameters then be connected and put into unsaturated soil mechanics shear strength models?
Conclusions

• KGS is gathering landslide monitoring data in order to characterize the Meadowview Lane Landslide

• Potential failure location approx. 9 ft (3 m) below the surface coinciding with a sandy-clay colluvial fill and stiff clay interface.

• Cumulative displacement to-date is approx. .25 inches in B-1 (near head scarp) and .30 inches in B-3 (toe)

• Continue to monitor movement, groundwater levels, and rainfall. Attempt will be made to correlate and geotechnical properties

• Apply information to other parts of Kentucky susceptible to landslides
Communicating with Geotechnical Users: KGS Landslide Information Map

- Known landslide locations
- Areas susceptible to debris flows
- Landslides located from LiDAR and aerial photography
- LiDAR hillshade layer (where available)
Landslide Information Map Service (cont.)

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Landslide Information Map

This map shows the locations of known landslides and areas susceptible to landslides in a geologic and geomorphic context. The purpose of the map is to provide an overview of landslide hazards across the state. There are several landslide data layers represented as points, lines, and polygons. Locations come from Kentucky Geological Survey research, published maps, state and local government agencies, and the public. The map is derived from a comprehensive landslide inventory of Kentucky compiled by the Kentucky Geological Survey. The map can be used to identify existing landslide locations and serve as a basis for landslide hazard assessment and risk reduction. It is not intended for site-specific investigations. The absence of landslides in an area does not infer that a landslide does not exist or that the ground is stable. A professional geologist or geotechnical engineer should be consulted for planned construction at identified landslide locations or in identified landslide areas. A professional geologist or geotechnical engineer should also be consulted for control and mitigation efforts of existing slides.

The full extent of the Landslide Information Map shows landslide points, landslide areas, counties, and roads. The “areas susceptible to debris flows” become visible when zoomed in. The light gray areas are a LiDAR hillshade layer (ESF) and are present in all parts of the state. The LiDAR layer can be used for varying amounts of transparency in the Data Layers list. If LiDAR is not present, the 30 m DEM hillshade draped with topographic maps are visible when zoomed in.

Landslide Map Layer Descriptions

Five layers are contained within the "KGS Landslide Data" layout. Their descriptions are as follows:

- **KGS landslide inventory data**: This map layer contains known landslide locations (points) across Kentucky compiled in a landslide inventory database. The locations come from Kentucky Geological Survey research, state and local government agencies, and the public. Many of the points represent larger landslide features that have not been mapped in detail and may fall within different parts of the slide area (crest, head scarps, middle, or toe). The landslides are active or have historically been active. Slide locations are collected at different times and contain varying amounts of attributes. The inventory does not capture work by private industry or other agencies that document landslides but does not map them available. Many attribute values are "NA" and data is only present if the slide was visited or could be collected another time. Landslide inventory points that fall within a landslide polygon layer represent the contrast of that polygon so it could be cataloged in the inventory database.

- **LiDAR derived landslide extent**: These landslide locations (polygons) were mapped on the 7.5-minute, 1:24,000-scale topographic quadrangles published jointly by the Kentucky Geological Survey and USGS Kentucky Survey from 1966 to 1978. Attributes include original map symbol and formation name, as well as county, quadrangle, and Area Development District. Landslides were not mapped on all quadrangles. Search source data on the KGS publications page: [http://kgs.uky.edu/kgsweb/PubsSearch/PubsSimpleSearch.asp](http://kgs.uky.edu/kgsweb/PubsSearch/PubsSimpleSearch.asp)

- **LiDAR data derived from LiDAR**: These landslides (polygons) were mapped using 1-m resolution (horizontal) Light Detection and Ranging (LiDAR) data. Using hillshade digital elevation models, potential landslide locations were identified and digitized. Locations were verified where possible. Comments included are notes and observations taken during the mapping of these slides. For more information regarding these landslides and LiDAR see KGS Publication 10-17: [http://kgs.uky.edu/kgsweb/PubsSearch/PubsSimpleSearch.asp?PubID=17514&mrg=0](http://kgs.uky.edu/kgsweb/PubsSearch/PubsSimpleSearch.asp?PubID=17514&mrg=0)

- **LiDAR data derived from aerial photography**: This layer (polygons) represents mapped landslides including earthflows, debris slides, and slump. The data come from a series of published Landslide and Related Features Maps and Landslide Potential Maps that cover most of southeastern and south-central Kentucky. Landslides were interpreted from aerial photographs and historical records. The features (polygons) depict generalized slope conditions as they existed at the time of field checking (1977-1981). Slope stability may decrease by excavation, loading, and changes in drainage patterns. The data are from preliminary map types and are suited for general planning purposes only.

- **Areas susceptible to debris flows**: This layer (lines) represents debris flow deposits or areas susceptible to debris flows. Primarily these areas are shallow, narrow ravines containing variable accumulations of caliche. The data come from a series of published Landslide and Related Features Maps and Landslide Potential Maps that cover most of southeastern and south-central Kentucky. The features (lines) depict generalized slope conditions as they existed at the time of field checking (1977-1981). Areas of thick caliche are susceptible to rapid movement during intense rainfall. The data are from preliminary map types and are suited for general planning purposes only.

Landslide Basics

Landslides are the downslope movement of rock, soil, or both under the influence of gravity. A combination of steep slopes, excessive pore water levels, geology, and slope modification are the main causes of landslides.

**Types**: translational, rotational, etc.) vary by the rate of movement, type of material involved, and structure of the failure plane. Increased population, rapid urbanization, and development will likely cause an increasing trend in landslide activity.

**Causes**

General causes of landslides include water, steep slopes, easily weathered rock, natural erosion, and artificial slope modification. These cause combinations with certain triggers create areas susceptible to sliding.

**Triggers**

- Intense rainfall or rapid snowmelt
- Groundwater level changes
- Poor drainage
- Vegetation removal
- Higher temperatures
- Temperature changes
- Earthquakes
- Veins or fractures
- Building construction
- Cutting and grading

**Effects**

- Runoff
- Flooding
- Property damage
- Loss of life
- Erosion
- Compaction
- Road closures
- Infrastructure damage
- Water quality issues
- Habitat alteration
Communicating with Geotechnical Users

• Why are landslide inventories important?
  • Planners/engineers
  • Transportation officials
  • Emergency managers
  • The public

• How can we best communicate with the geotechnical and other audiences? COOPERATION

• Most planners or local gov officials do not adequately address landslide hazards...do not have the appropriate resources to id hazards.

• Users can minimize activities that cause landslides (poor road construction, construction on hillsides, poor drainage practices, etc.) by taking advantage of this information. They have the means...geotech site analysis, design, regulations, zoning, and disclosure to address the hazard
Communicating with Geotechnical Users

KYTC District 9 @KYTCDistrict9

@matt_m_crawford KGS landslide map's an awesome tool! Copying link to our engineers today. Thanks! kgs.uky.edu/kgsmap/kgsges...
Water Can Cause Landslides

- Tree removal/water runoff
- Roof runoff may seep into the soil and cause settlement
- Road ditch infiltration
- Failure due to septic field drains

Thanks!

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