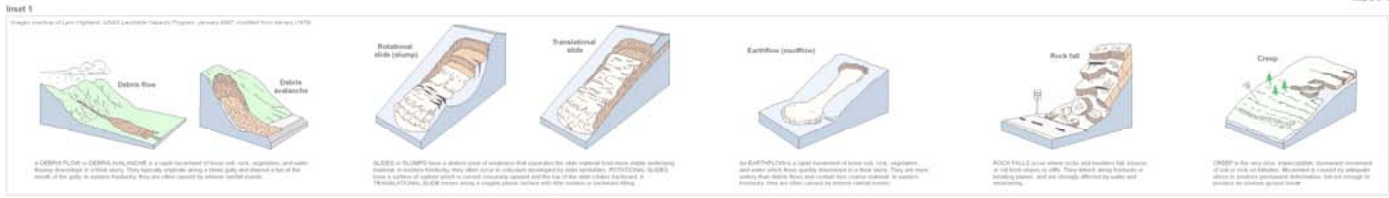


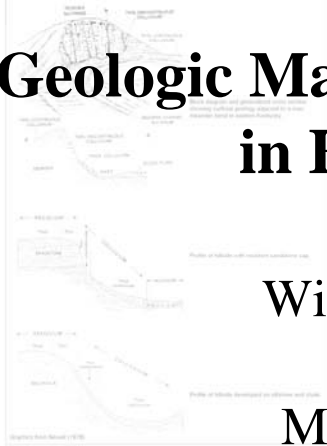
Map Discussion

Landslide are events that occur on individual hillsides, but knowledge of general conditions throughout a region, when combined with well-developed data on individual landslides, can be used to predict future landslides. This map of the Hazard North 15-minute quadrangle provides a good overview of an entire geographic area, but knowledge of slope stability is required to make specific predictions.

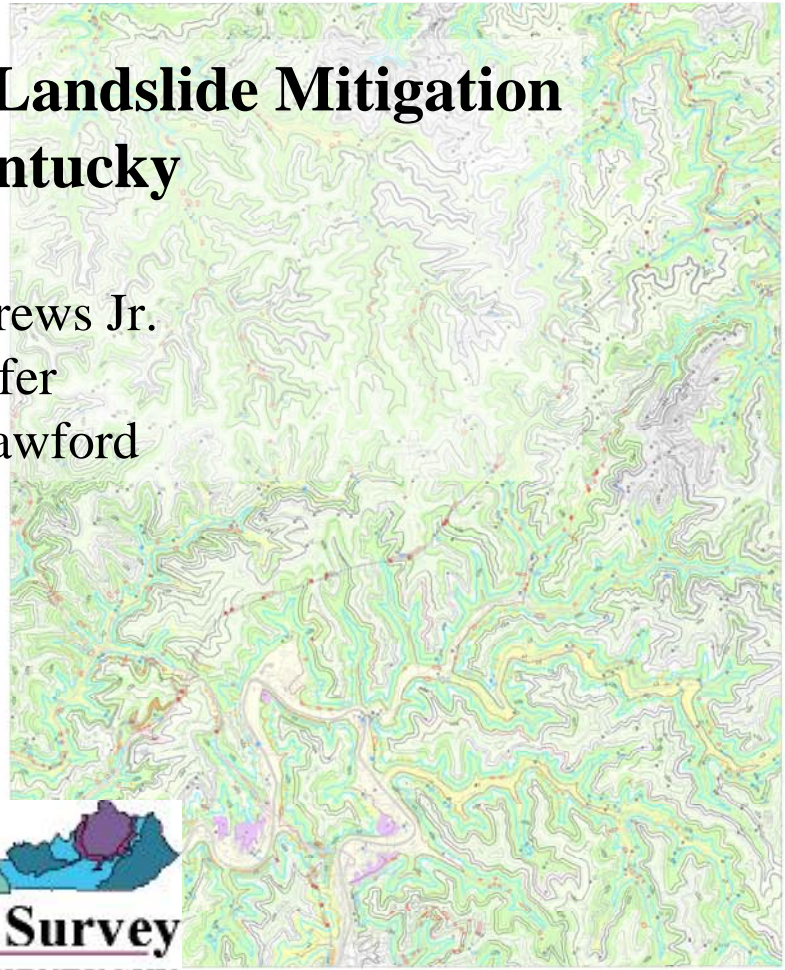
The various geologic features throughout a region may be used to predict landslides. Eastern Kentucky is characterized by low-relief, rolling hills. The Hazard North 15-minute quadrangle is a small portion of this region. The Hazard North 15-minute quadrangle is highly erodible because of its highly erodible geologic materials: claystone, shale, sandstone, and limestone. The intensity of the erosion has created a landscape of rolling hills and valleys. The intensity of the erosion has also created a landscape of steep hills and valleys. The intensity of the erosion has also created a landscape of steep hills and valleys. The intensity of the erosion has also created a landscape of steep hills and valleys.



Inset 2



- Map Symbols**
- Alluvium (unconsolidated)
  - Alluvium (consolidated)
  - Residual
  - Residual and bedrock
  - Highway cuts and highways (post-1978)
  - Surface mine
  - Water Wells
  - Coal Borings
  - Channels
  - Channels and bedrock
  - Coal Beds
  - Coal bed, down dip from underground mine



# New Geologic Mapping for Landslide Mitigation in Eastern Kentucky

William M. Andrews Jr.  
John D. Kiefer  
Matthew M. Crawford

**Water Can Cause Landslides**

**What Are the Factors That Cause Landslides?**

1. Steep slopes: A steep slope is a liability.
2. Water: Water saturates soil and increases its weight. Water also weakens the soil by increasing pore pressure.
3. Poor soil: Poor soil is a liability.
4. Poor vegetation: Poor vegetation is a liability.
5. Poor construction: Poor construction is a liability.
6. Removal of trees and other vegetation: The removal of trees and other vegetation can cause landslides.
7. Poor construction: Poor construction is a liability.

**What Are Some Ways to Prevent Landslides?**

1. Avoid steep slopes: Avoid steep slopes when building.
2. Avoid water: Avoid water when building.
3. Avoid poor soil: Avoid poor soil when building.
4. Avoid poor vegetation: Avoid poor vegetation when building.
5. Avoid poor construction: Avoid poor construction when building.
6. Avoid removal of trees and other vegetation: Avoid removal of trees and other vegetation when building.
7. Avoid poor construction: Avoid poor construction when building.

From U.S. Department of Agriculture, National Resources Inventory, Science Institute on Landslides.

Table 1. Landslide characteristics of map units

Map Unit	Description	General Instability	Slides	Rock Falls	Flowing
1001	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1002	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1003	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1004	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1005	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1006	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1007	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1008	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1009	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High
1010	Unconsolidated to moderately consolidated, claystone, shale, sandstone, and limestone, with thin to thick beds of sandstone and shale.	High	High	High	High

**References**

- Andrews, W. M., 2003. Soil survey of Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1977. The geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1979. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1981. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1983. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1985. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1987. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1989. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1991. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1993. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1995. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1997. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 1999. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 2001. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 2003. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 2005. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.
- Blair, R. G., 2007. Geology of the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.

**Acknowledgments**  
 The author would like to acknowledge the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007. The author would like to acknowledge the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007. The author would like to acknowledge the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007. The author would like to acknowledge the Hazard North 15-minute quadrangle, U.S. Department of Agriculture, National Resources Inventory, Series KH, 2007.

**Kentucky Geological Survey**  
 UNIVERSITY OF KENTUCKY  
 Dr. James C. Cobb, Director and State Geologist  
 William M. Andrews Jr., Matthew M. Crawford, and Michael L. Murphy  
 December 2006

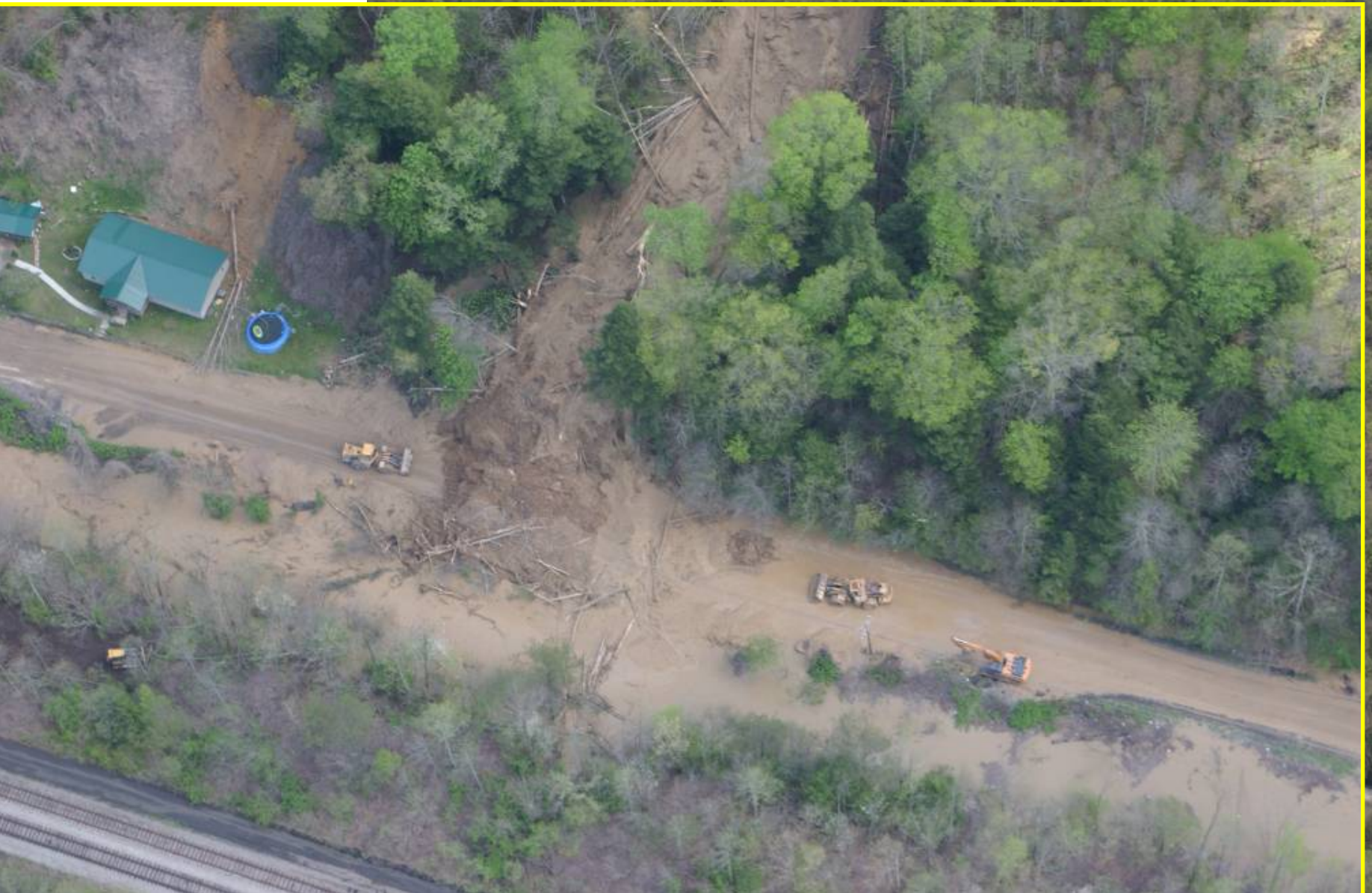
Surficial Geology of the Hazard North 15-minute Quadrangle, Hazard North 15-minute Quadrangle, Kentucky for Landslide Susceptibility



# Slemp Landslide

April 2006

Perry County





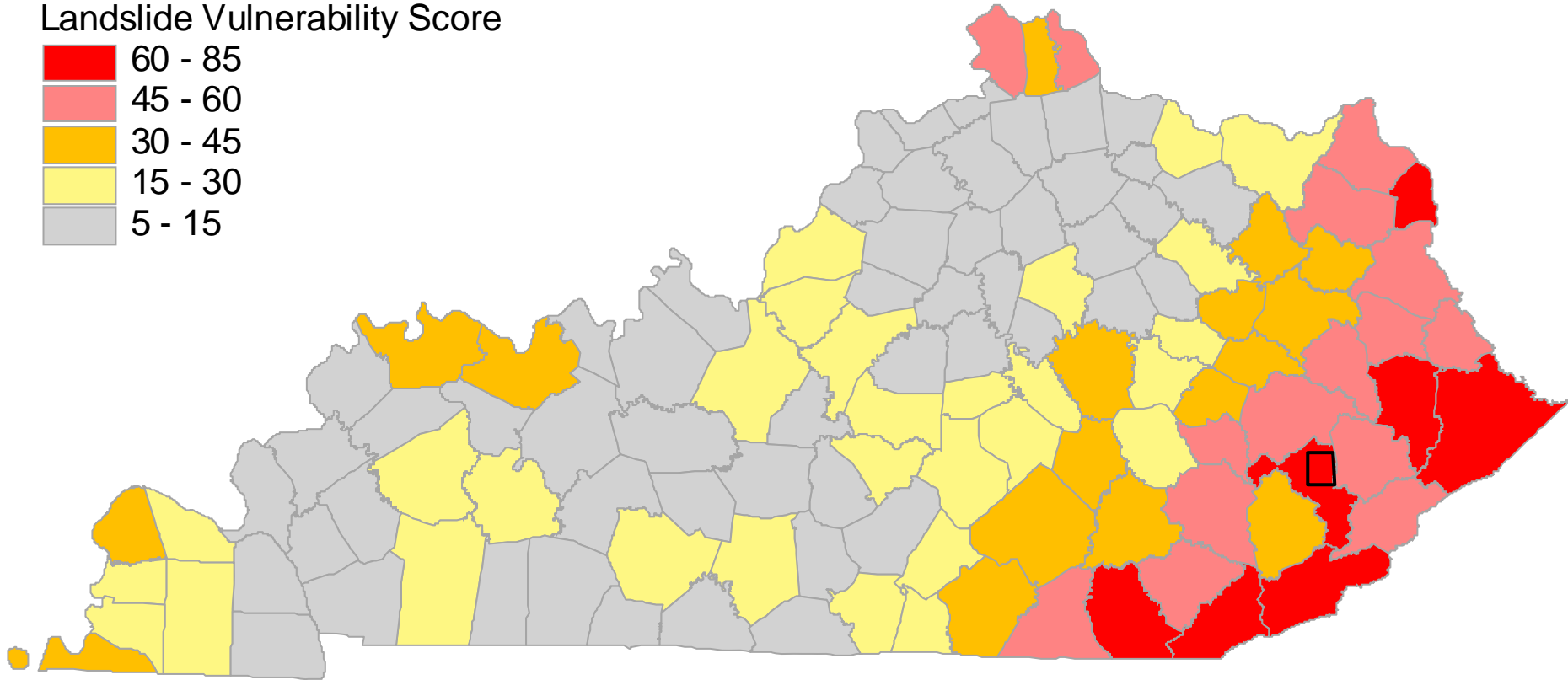
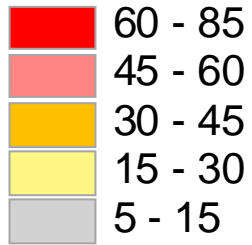
Alluvial fans / debris flow fans  
Johnson County



# Landslide Hazards in Kentucky

Kentucky State Hazards Mitigation Plan

## Landslide Vulnerability Score



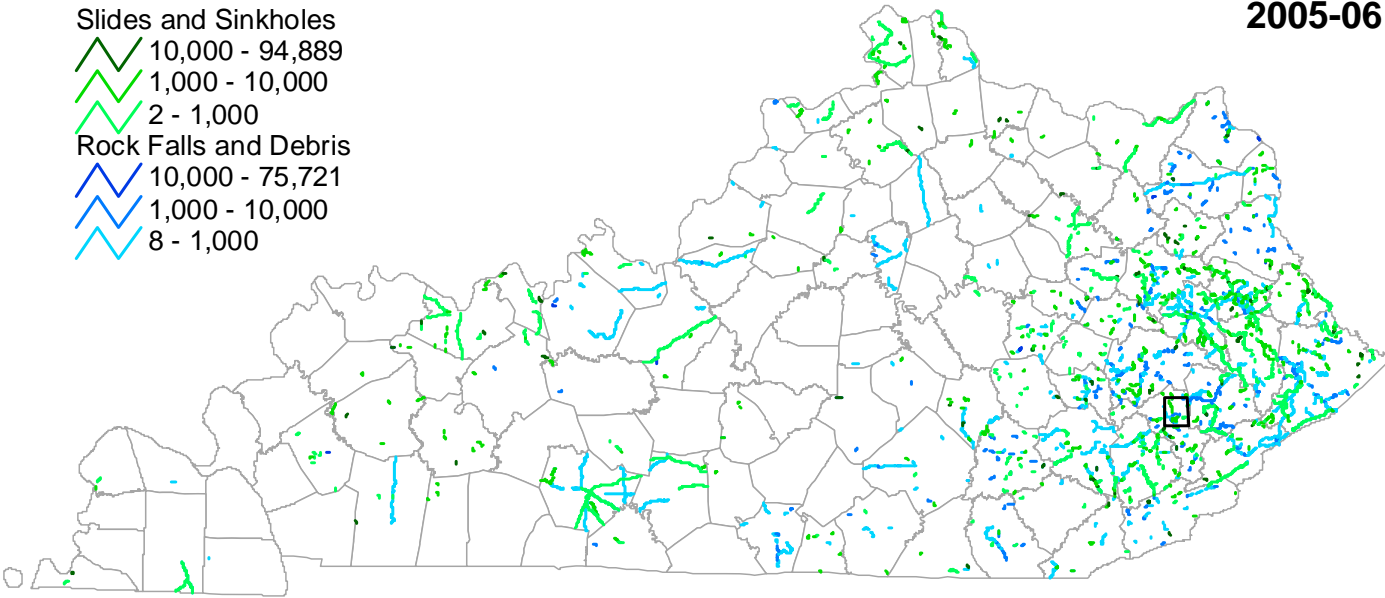
Data courtesy of R.J. Human, University of Louisville,  
Center for Hazards Research And Policy Development



# Highway Maintenance Costs (\$ per mile)

2005-06

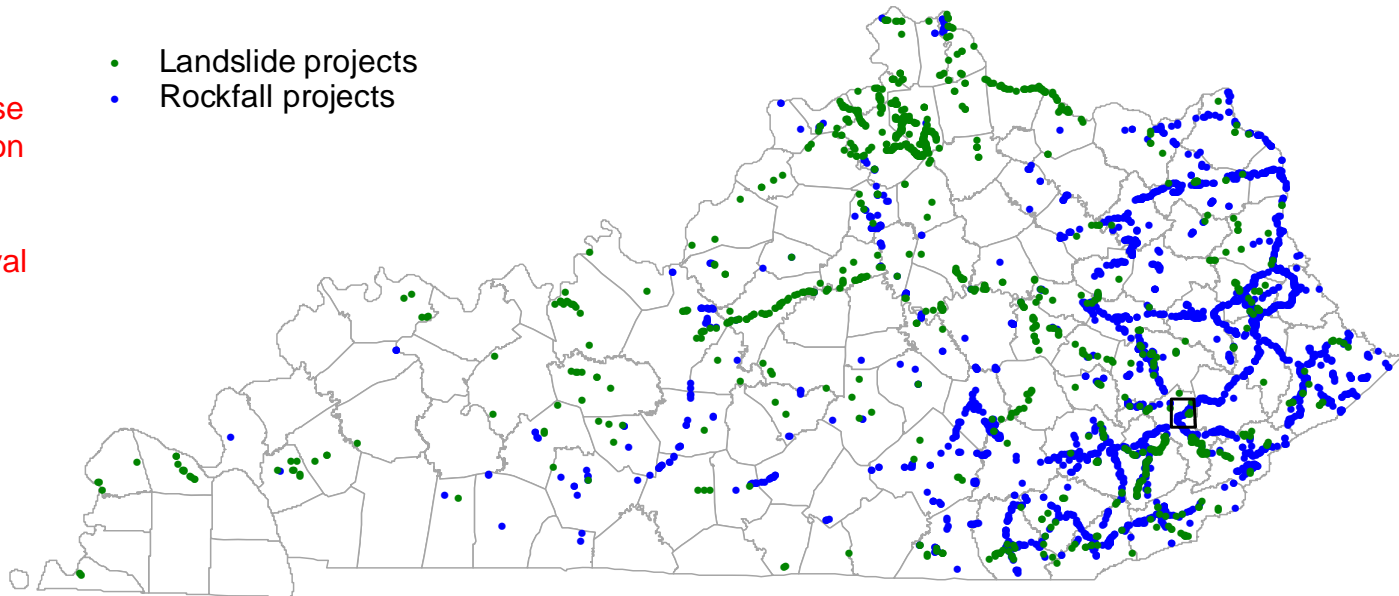
- Slides and Sinkholes
  - 10,000 - 94,889
  - 1,000 - 10,000
  - 2 - 1,000
- Rock Falls and Debris
  - 10,000 - 75,721
  - 1,000 - 10,000
  - 8 - 1,000



Data courtesy of Geotechnical Branch,  
Kentucky Transportation Cabinet

Kentucky Transportation Cabinet data are used with limited permission, and are for internal use only. Any sharing of the information outside of KGS or USGS through reports, presentation or data transfer will require written approval from the KTC.

- Landslide projects
- Rockfall projects



Data courtesy of Geotechnical Branch,  
Kentucky Transportation Cabinet

The background image shows a steep, eroded hillside with exposed soil and rocks. A group of people is standing on a dirt path at the top of the slope, observing the area. The scene is outdoors with some green vegetation at the base of the slope.

# Eastern Kentucky Landslide Overview

**Topography:** steep, narrow, dissected

**Bedrock:** coal measures, laterally variable lithologies

**Structure:** generally flat-lying strata, regional and local fractures

**Hydrology:** complex, controlled by coal beds and fractures

**Processes:** debris flows/avalanches, slides/slumps, creep, rock fall

**Costs:** extensive, significant, prohibitive



# Eastern Kentucky landscape

Perry County





# Eastern Kentucky stratigraphy





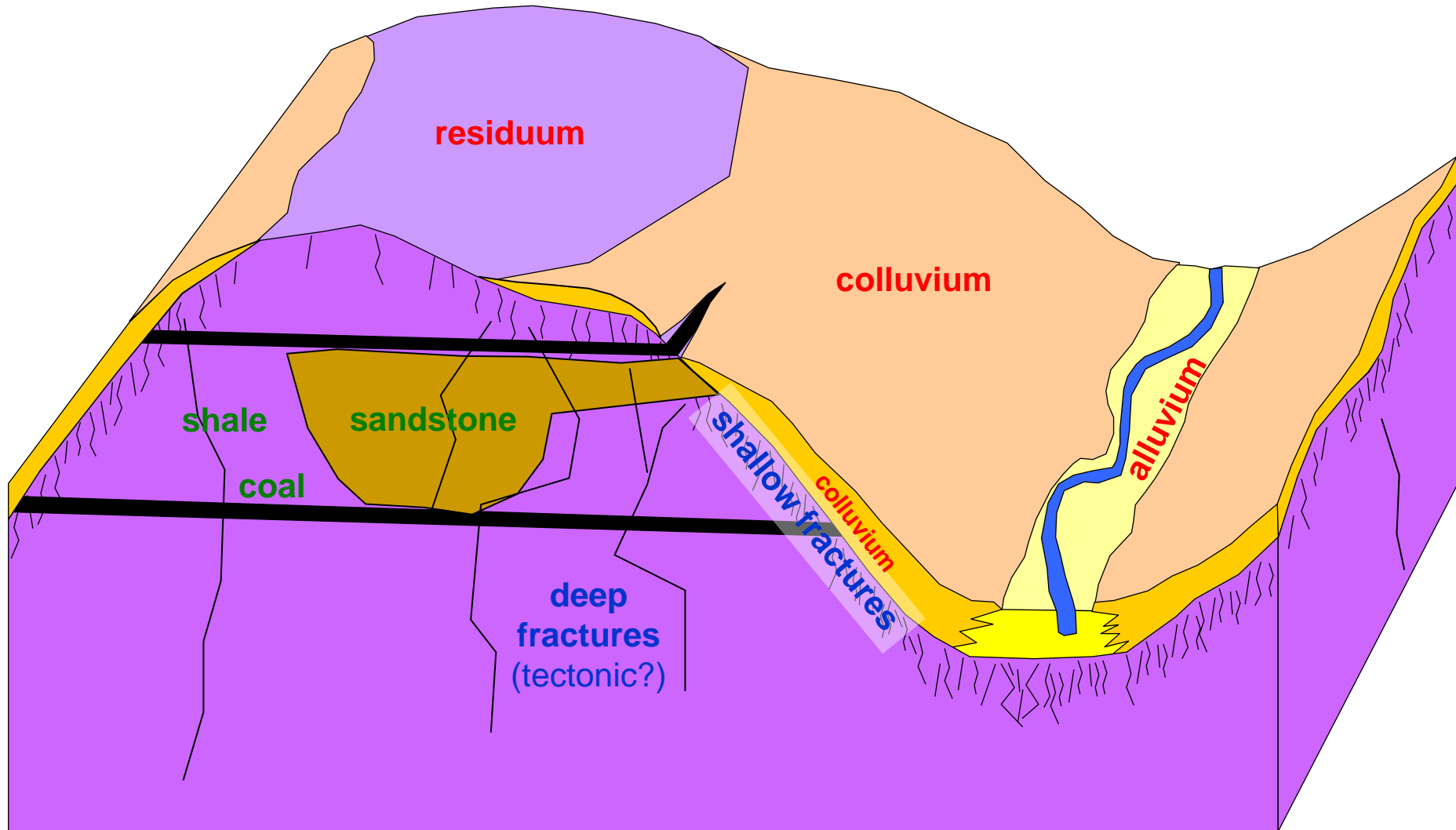
# Failure along bedrock joint Floyd County



Photos courtesy of  
Kentucky Transportation Cabinet

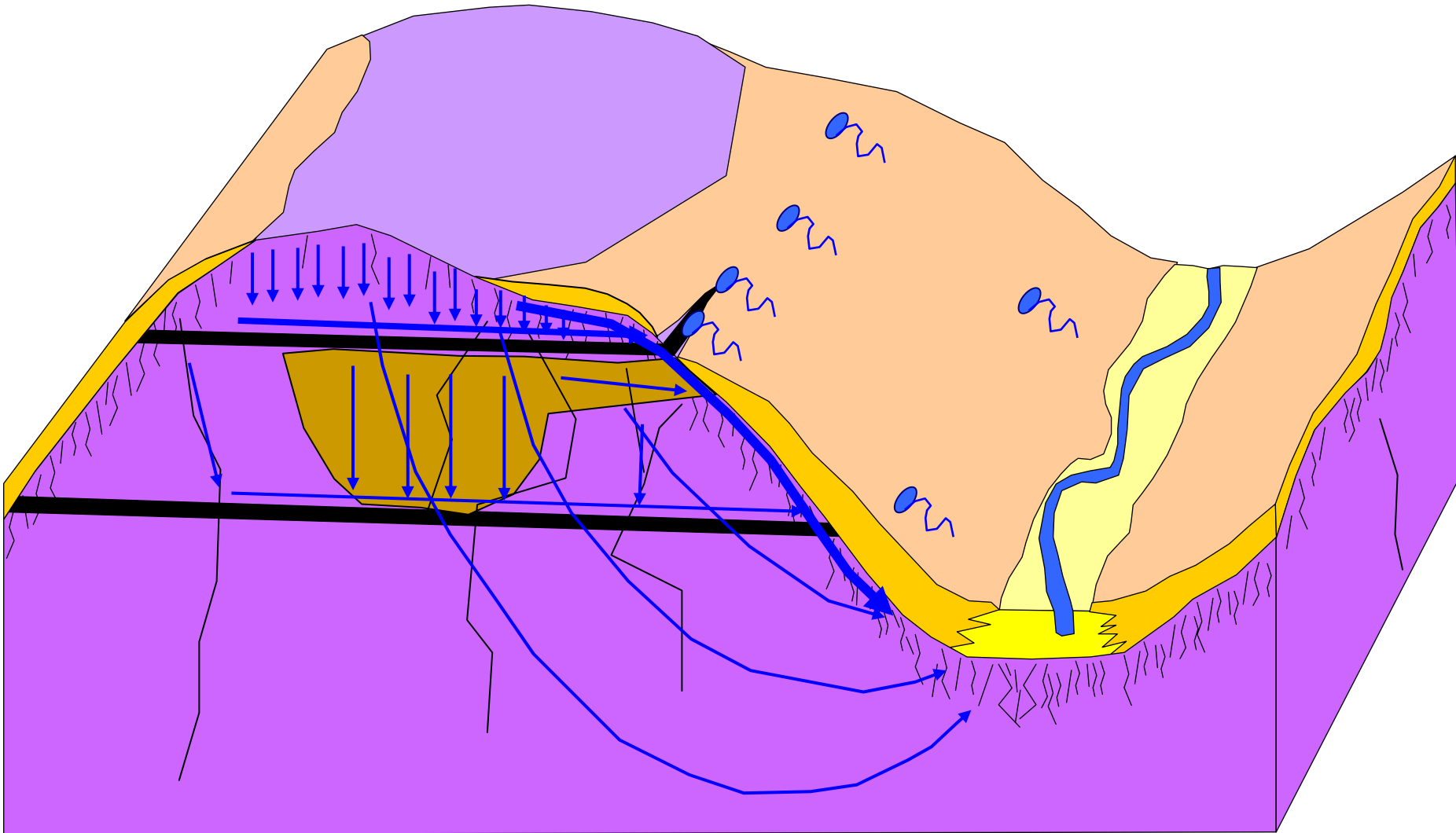


# Generalized landscape model Eastern Kentucky coal field





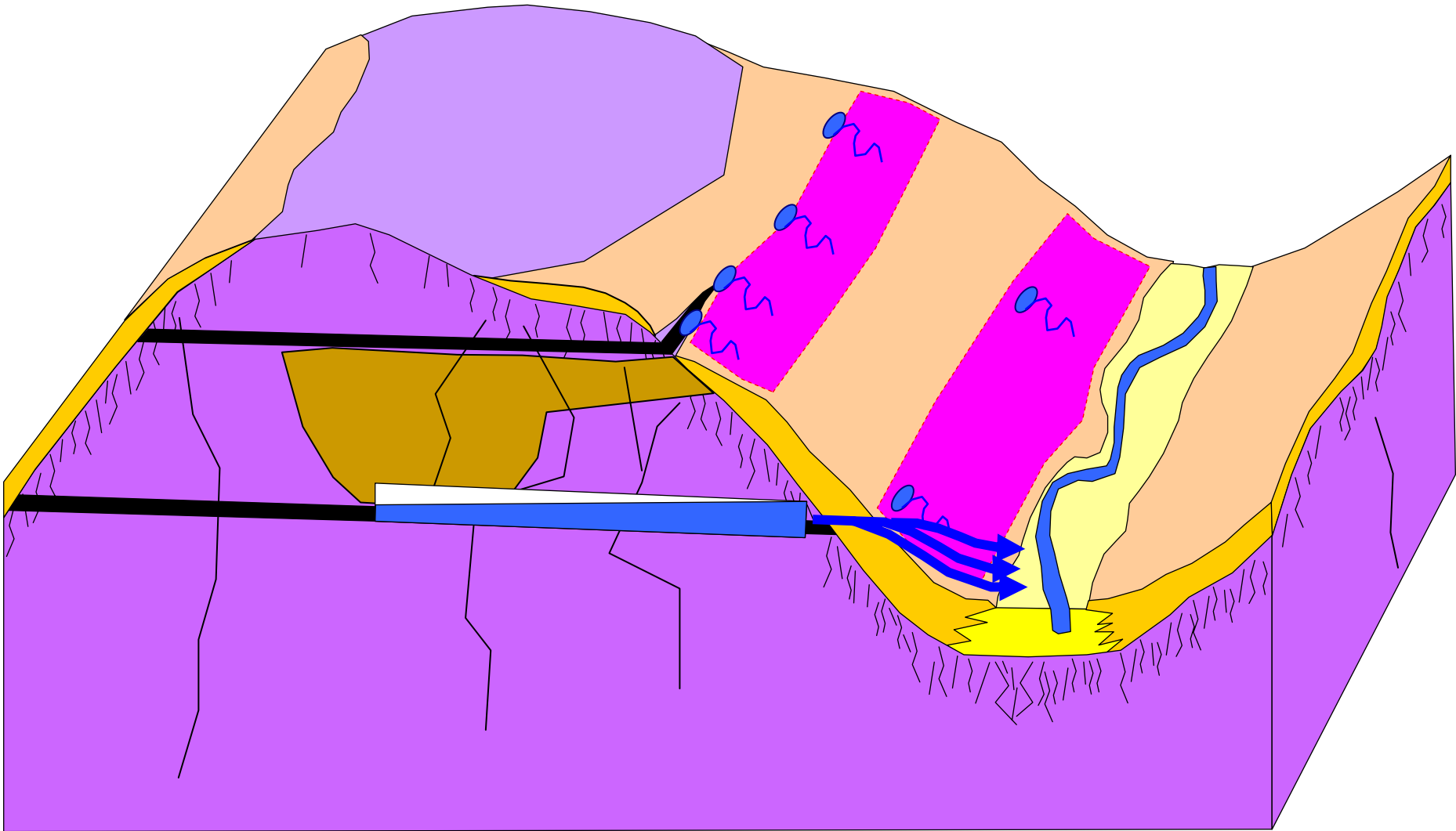
# Conceptual groundwater flow Eastern Kentucky coal field



Modified from Wunsch, 1993

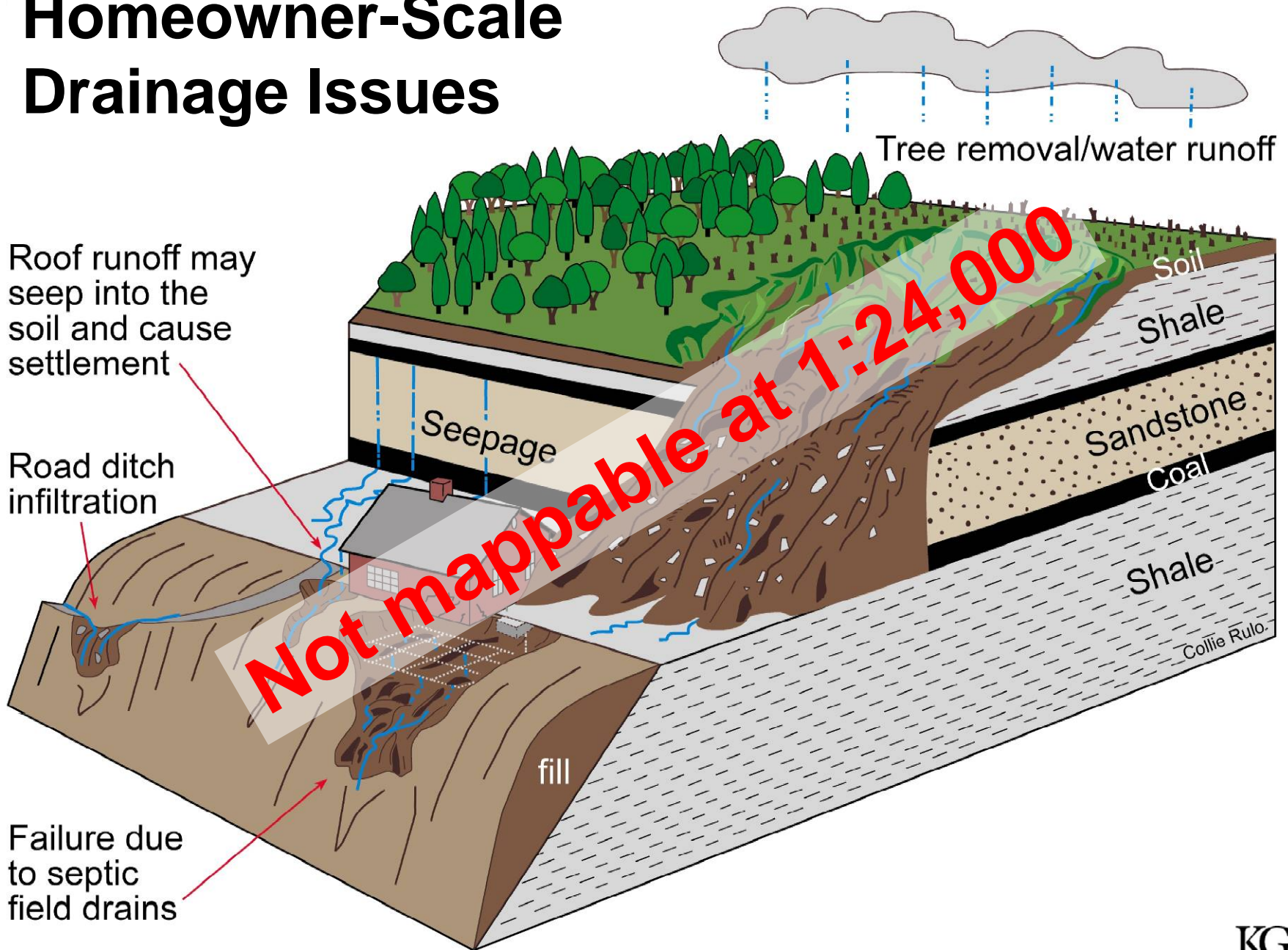


# Conceptual groundwater flow Eastern Kentucky coal field



Modified from Wunsch, 1993

# Homeowner-Scale Drainage Issues





# Landslide Mapping

Eastern Kentucky

## Previous

Newell (1977): surficial geology

Newell (1978): application for land-use planning

Outerbridge (1979): landslide map (inventory)

## New/Future

New surficial geologic mapping

Derivative maps for land-use planning

Engineering geologic map

GIS-based modeling

Digital data delivery

User-education workshops



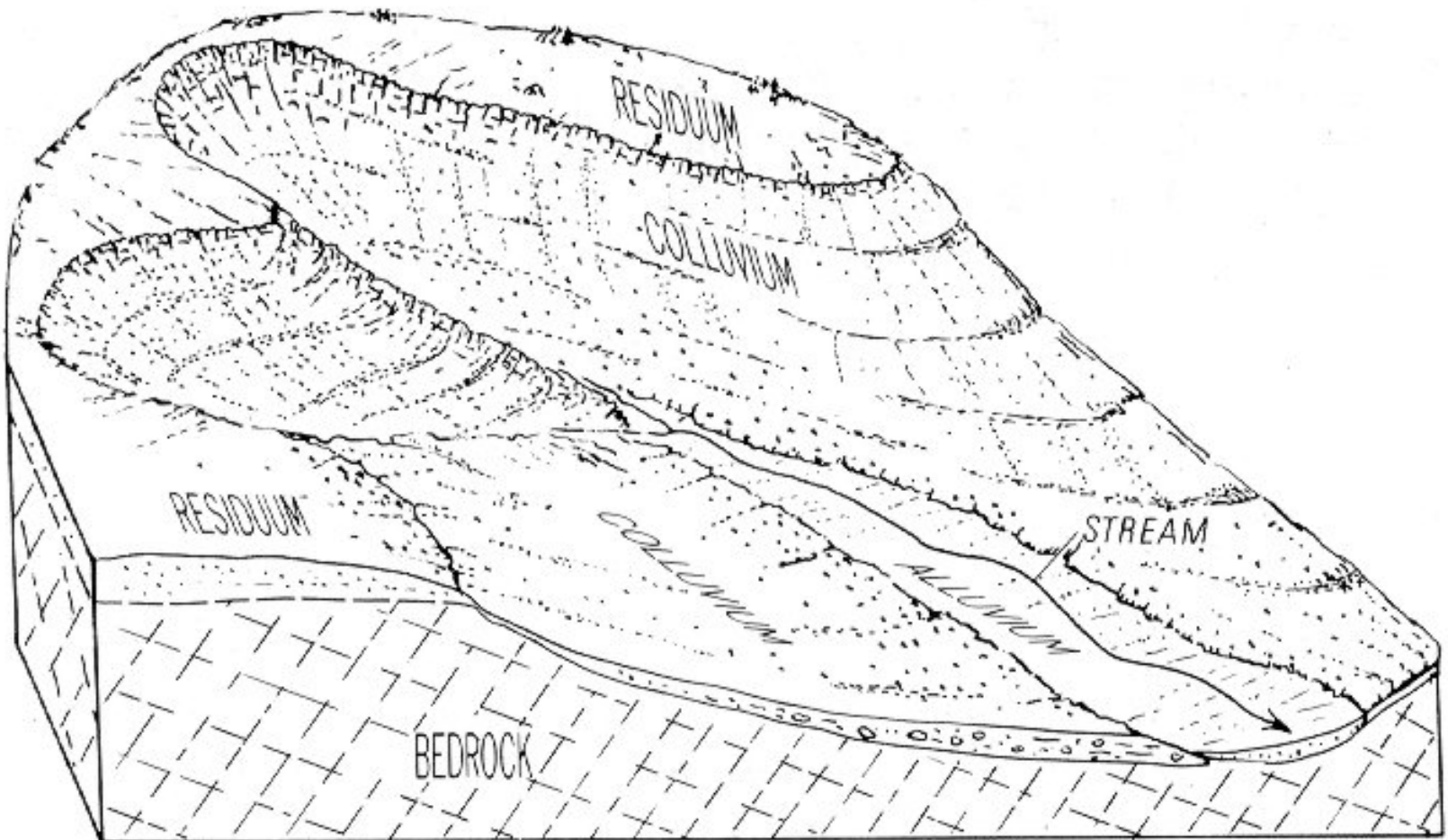
**Landslide map from aerial imagery: esp. slumps, debris-flow chutes, highwalls**

*Outerbridge, 1979*





**Mapping concept of Newell (1977)**



**From Newell, 1978**



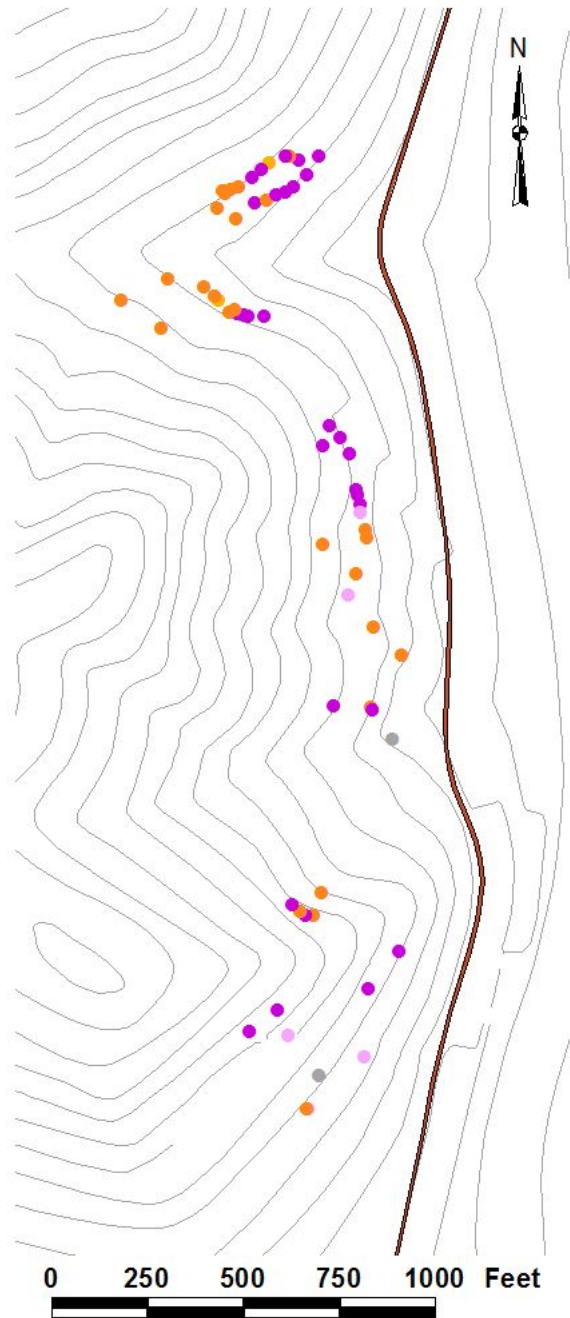












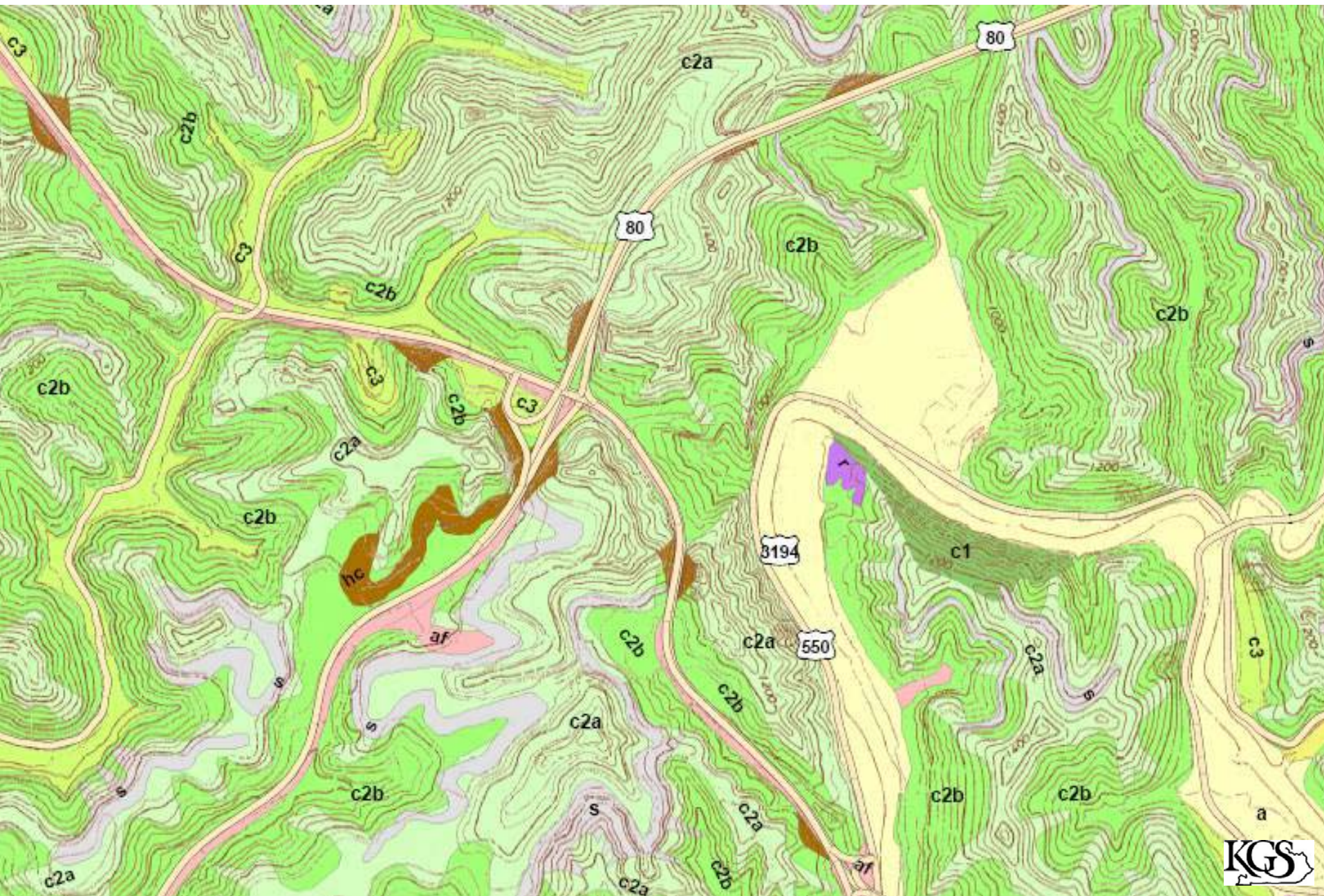
## KY Hwy 7 Depth to Bedrock study area





# Surficial Geology: colluvium, alluvium, residuum, surface cuts

Updated from Newell (1977)





# Map for Land-Use Planning

### Map Discussion

Landslides are commonly viewed as unpredictable, but knowledge of general conditions (topographic, geologic, climatic) combined with well-planned construction can reduce exposure to the hazard. This map of the Hazard North quadrangle provides a visual inventory of available geologic and landscape data relevant to landslide assessment.

The natural geology of western Kentucky is highly susceptible to landslides. Eastern Kentucky is subjected to coal-bearing Appalachian beds. The Triassic-Jurassic beds, which constitute the bulk of the Appalachian belt, produce a highly resistant sequence of sand, siltstone, shale, and stone limestone. The strata of the region have deeply eroded into the region, the long, narrow, crest of the eroding ridge can be damaged by erosion of colluvium. Heavy precipitation or other triggers can initiate landslides which can damage other infrastructure, roads, bridges, and houses. These landslides take the form of debris flows, debris avalanches, debris slides, and debris flows. These landslides take the form of debris flows, debris slides, and debris flows. These landslides take the form of debris flows, debris slides, and debris flows.

The basic form of the map is a digital geology as requested by FEMA (1971) and updated by KGS personnel. The geologic data are based on the geologic map of the Hazard North quadrangle, which is a digital geology as requested by FEMA (1971) and updated by KGS personnel. The geologic data are based on the geologic map of the Hazard North quadrangle, which is a digital geology as requested by FEMA (1971) and updated by KGS personnel.

The basic geology of an area plays a big role in determining which geologic processes affect the landscape. The basic geology of an area plays a big role in determining which geologic processes affect the landscape. The basic geology of an area plays a big role in determining which geologic processes affect the landscape.

**Inset 1**

Images courtesy of Lynn Highland, USGS Landslide Hazards Program, January 2007, modified from Stearns (1976)

**Rotational slide (slump)**

**Translational slide**

**Earthflow (mudflow)**

**Rock fall**

**Creep**

**DEBRIS FLOW or DEBRIS AVALANCHE** is a rapid movement of loose soil, rock, vegetation, and water flowing downhill in a thick mass. They typically originate along a steep gully and descend a low angle of the gully, or within Kentucky they are often caused by intense rainfall events.

**SLIDES or SLUMPS** have a distinct plane of weakness that separates the slide material from mass stable underlying material. In western Kentucky they often occur in claystone bedrock. ROTATIONAL SLIDES take a surface of rupture which is curved concavely upward and the top of the slide often tilts backward. A TRANSLATIONAL SLIDE moves along a roughly planar surface with little rotation or backward tilting.

**EARTHFLOW** is a rapid movement of loose soil, rock, vegetation, and water which flows quickly down a steep slope. They are often caused by intense rainfall events.

**ROCK FALLS** occur where rocks and boulders fall, bounce, or roll from steep cliffs. They often occur along fractures or bedding planes, and are strongly affected by water and weathering.

**CREEP** is the very slow, insipid, downward movement of soil or rock in thin, shallow, downward A caused by gradual erosion to produce permanent deformation, but not enough to produce a distinct ground break.

**Inset 2**

**Map Symbols**

**Surficial Geology**

- Alluvium, undifferentiated
- Alluvium, active channels
- Artificial fill
- Colluvium, thin discontinuous
- Colluvium, thin continuous, low slump incidence
- Colluvium, thin continuous, high slump incidence
- Colluvium, thick continuous
- Highway cuts and highwalls (pre-1978)
- Highway cuts and highwalls (post-1978)
- Residual and bedrock
- Surface mine
- Water Wells
- Coal Boreholes
- Springs
- Landslides (from Ky Transportation Cabinet database)
- Rock Falls (from Ky Transportation Cabinet database)
- Debris Flow Channels (from Outerbridge, 1979)
- Slumps (from Outerbridge, 1979)
- Marine zone outcrop (shale)
- Coal Beds
- Coal bed, down structural dip
- Coal bed, down dip from underground mine

**Inset 3**

**Water Can Cause Landslides**

**What Are the Factors That Cause Landslides?**

- Steep slopes. Avoid other structures on a building site.
- Water. Water stability decreases as water enters the soil. Springs, leaks, roof water, groundwater, water systems, and site grading that cause ponding or runoff are sources of water that often contribute to landslides.
- Changing the natural state to create a level area where some structures added.
- Fill site selection for roads and driveways.
- Inappropriate placement of landscape.
- Removal of trees and other vegetation. Soil cohesion often results in the stabilization of trees and other vegetation. Plants, especially trees, help remove water and stabilize soil with their extensive root systems.

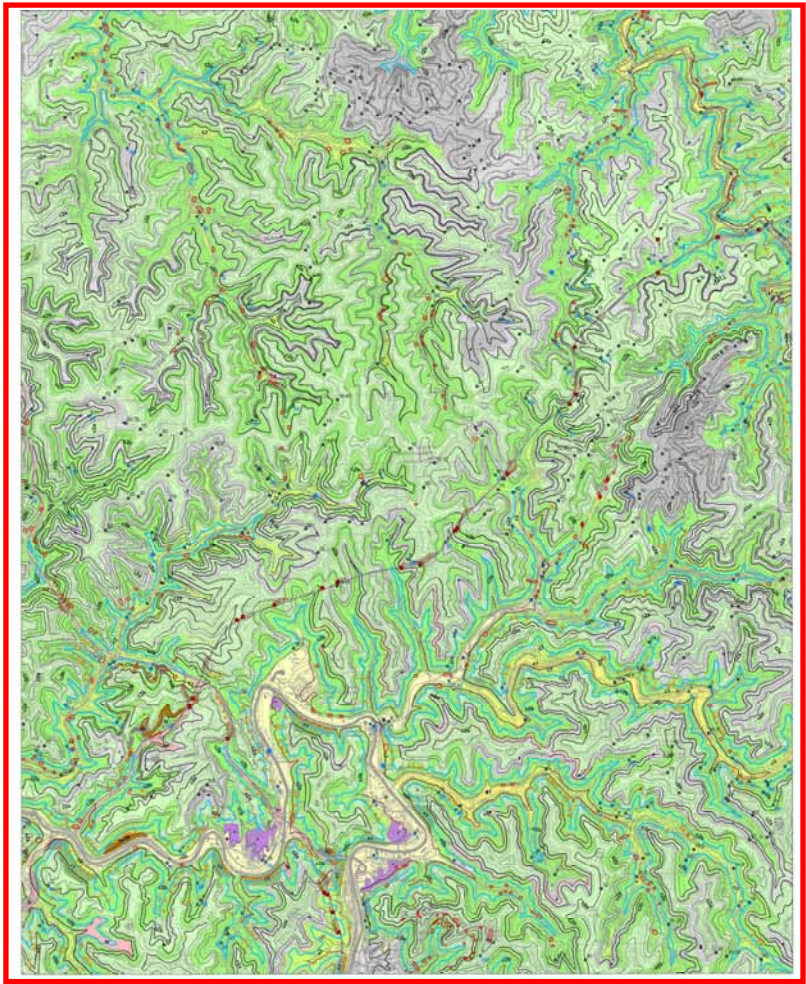
**What Are Some Ways to Prevent Landslides?**

- Soil professional assessment prior to construction.
- Proper site selection. Some sloping areas are actually prone to landslides. Investigate the site for springs, leaks, roof water, groundwater, water systems, and site grading that cause ponding or runoff are sources of water that often contribute to landslides.
- Alter the natural slope of the building site as little as possible during construction. Never remove soil from the top or bottom of the slope or fill to the top of the slope. Landslides are less likely when soil where disturbance has been minimized. Avoid professional assistance before earth retaining systems.
- Remove soil from the site and other vegetation as possible. Trees develop extensive root systems that are very useful in slope stabilization. Trees also remove large amounts of groundwater. Trees and other permanent vegetation covers should be established as rapidly as possible and maintained to reduce soil erosion and landslide potential.
- Household water disposal system. Avoid professional assistance in selecting the appropriate type of system and in proper installation. Trees also remove large amounts of groundwater. Trees and other permanent vegetation covers should be established as rapidly as possible and maintained to reduce soil erosion and landslide potential.
- Properly designed retaining walls. Retaining walls to stabilize the existing soil in the most common cause of landslides in eastern Kentucky. Properly located drainage channels are helpful in reducing runoff from areas disturbed during construction. Retaining walls should be designed and water runoff should be discharged piped to stable areas at the bottom of the slope.

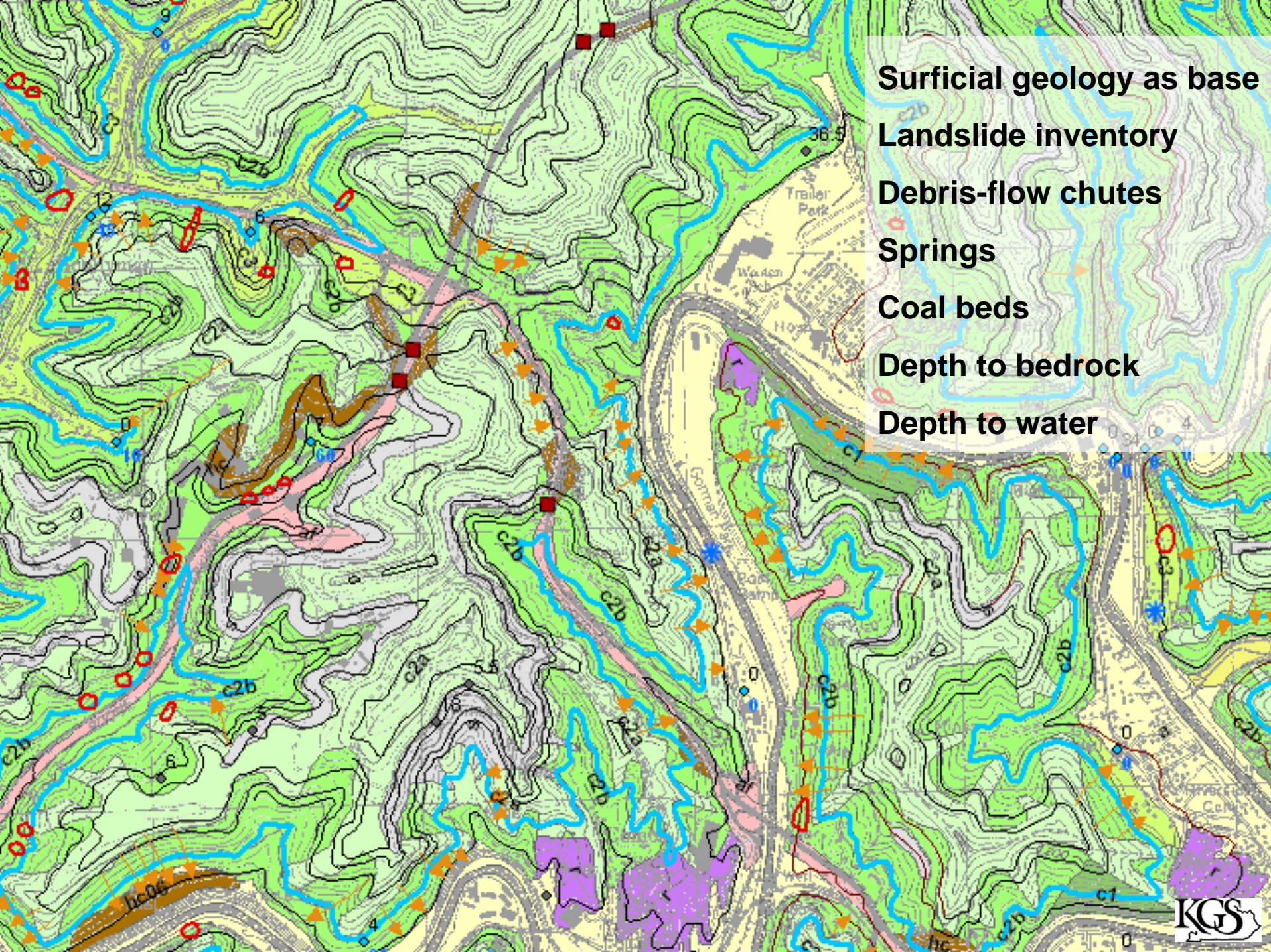
(From U.S. Department of Agriculture, Natural Resources Conservation Service brochure, no. 686)

**Table 1. Landslide characteristics of map units**

Map Unit	Description	General Occurrence	Slumps	Rock Falls	Creeping
ALLUVIUM active channels	Unconsolidated sand, silt, and clay with gravel and cobbles. Occurs in active channels and flood plains and grab-basins low-land areas.	Common in lowlands and flood plains.	Highly susceptible		
ALLUVIUM thin discontinuous	Unconsolidated sand, silt, and clay with gravel and cobbles. Occurs in flood plains and grab-basins low-land areas.	Common in lowlands and flood plains.	Highly susceptible		
ALLUVIUM thin continuous	Unconsolidated sand, silt, and clay with gravel and cobbles. Occurs in flood plains and grab-basins low-land areas.	Common in lowlands and flood plains.	Highly susceptible		
ALLUVIUM thick continuous	Unconsolidated sand, silt, and clay with gravel and cobbles. Occurs in flood plains and grab-basins low-land areas.	Common in lowlands and flood plains.	Highly susceptible		
RESIDUAL AND BEDROCK	Residual soil and bedrock. Occurs in highlands and flood plains.	Common in highlands and flood plains.	Highly susceptible		
ARTIFICIAL FILL	Artificial fill. Occurs in flood plains and grab-basins low-land areas.	Common in flood plains and grab-basins low-land areas.	Highly susceptible		
COAL BEDS	Coal bed, down structural dip. Occurs in highlands and flood plains.	Common in highlands and flood plains.	Highly susceptible		
COAL BEDS	Coal bed, down dip from underground mine. Occurs in highlands and flood plains.	Common in highlands and flood plains.	Highly susceptible		







**Surfacial geology as base**

**Landslide inventory**

**Debris-flow chutes**

**Springs**

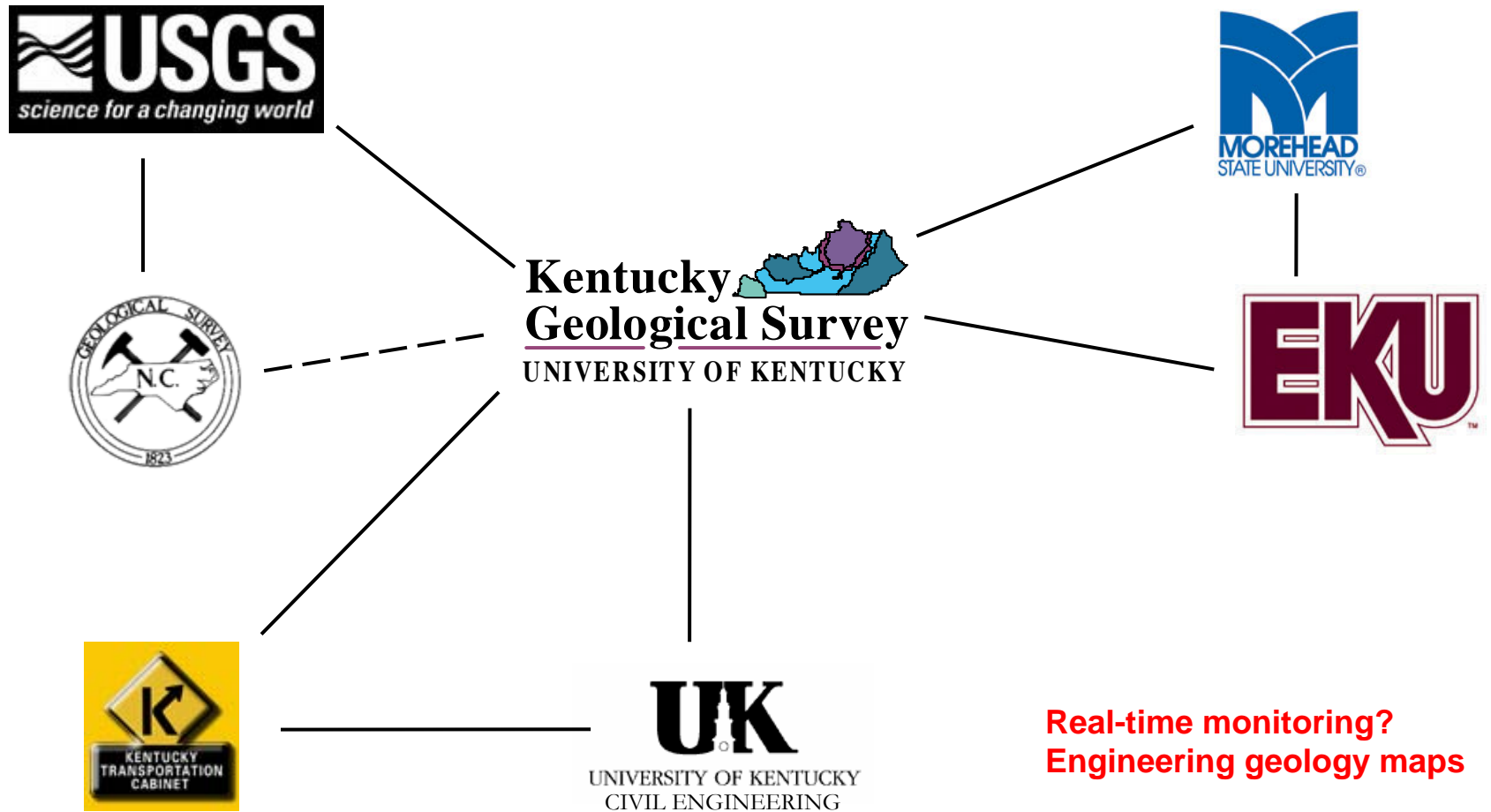
**Coal beds**

**Depth to bedrock**

**Depth to water**

# Program Relationships

Surficial geologic mapping  
Fracture mapping  
Land-use Derivatives



Real-time monitoring?  
Engineering geology maps



# Eastern Kentucky landscape

Hazard, Perry County





# Debris flows and slumps in the landscape: trends in location

Hazard, Perry County





# Surficial geology on landscape

Hazard, Perry County





# Landslides and surficial geology

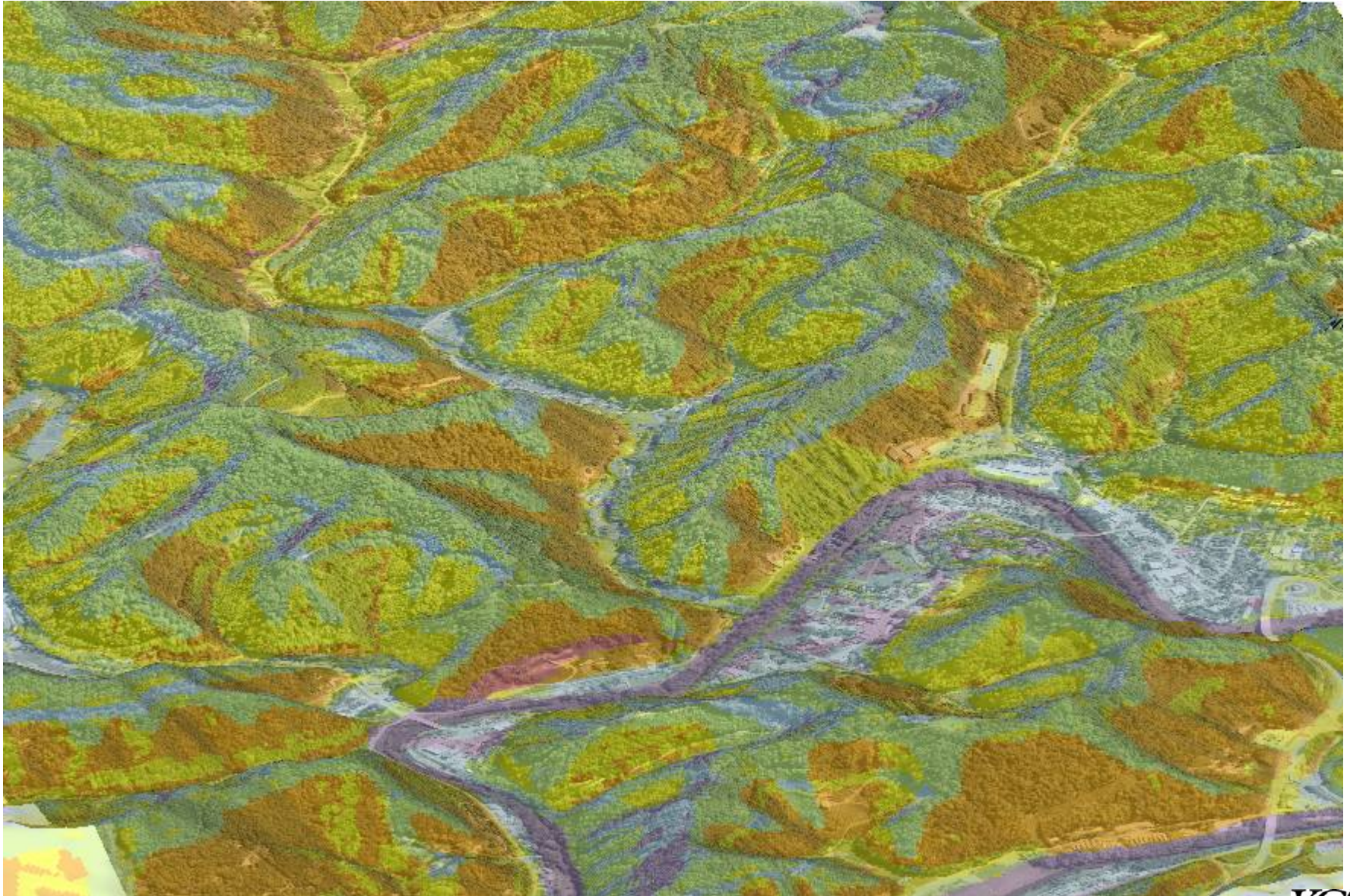
Hazard, Perry County





# Empirical susceptibility model on landscape

Hazard, Perry County





A person in a tan jacket is in the foreground, looking towards a geological site. In the background, a group of people is standing on a dirt path overlooking a rocky, vegetated slope. The scene is outdoors with natural lighting.

## **Audiences and Products**

### **Geological maps: for geologists**

- Geologic quadrangles
- Surficial geology

### **Derivative maps: for non-geological audiences**

- Engineering geology (technical audience)
- Land-use map (less technical audience)

### **Web Products: increased user access**

- Digital delivery of data sets and static maps
- Interactive map and data servers





## Questions?

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Photo courtesy of  
Ky Transportation Cabinet

