Current Results of Landslide Hazard Mapping in Western North Carolina
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N.C. Landslides 1990 - 2006

**Total**
- 6 Fatalities
- 45 Structures Destroyed - Condemned

**Modified Slopes**
- 1 Fatality
- 28 Structures Destroyed - Condemned
Rainfall increases with elevation
Rock Slides (Blue Ridge Parkway; December 2004 reactivation)
LiDAR Hillshade DEM

- Active Rotational Debris Slide
- Past-Active Debris Deposit

Scarp

Transverse Depression
Landslides in Weathered Rock

- 1.5 acres
- 50 feet deep
- 64,600 cubic yards
- 4 homes severely damaged
- 4 homes endangered
N.C. Slope Movement – Slope Movement Deposit Database

2,046  4,550 Entries

Data and analysis for policy decisions

http://www.nconemmap.com/
Soil Sampling, Testing, and Analysis
Stability of Infinite Slopes with Seepage

Soil Properties
- Friction Angle, $\phi$
- Cohesion, $c$
- Unit Weight, $\gamma$
- Sat. Unit Weight, $\gamma_{sat}$

Factor of Safety Calculation (FS$_s$)

$$FS_s = \frac{c}{\gamma_{sat} T \cos^2\beta \tan\beta} + \frac{\gamma_{sat} \gamma_w}{\gamma_{sat} \frac{\tan\phi}{\tan\beta}}$$

$T = $ Soil Thickness

$D_w = $ Depth of Groundwater

$\gamma_w = $ Unit Weight of Water

Vegetation
- Root Cohesion
- Root Anchoring
- Evapotranspiration
Macon County

All 33 Frances-Ivan debris flows occurred in areas of past debris flow activity
Debris flow tracks – debris deposits

20 ft - 6m LiDAR DEM Hillshade

GPS Mapping

Slow-Moving Weathered Rock Slides
Data and Mapping Products In GIS

- Slope Movements / Deposits – where landslides occurred
  Slow Moving Landslides – where landslides are occurring

- Stability Index Map (SINMAP) Results
  - where debris flows-slides might start

- Downslope Hazards – where debris flows-slides might go

- Bedrock Geology – mapped problematic rock units
The Products: 1) Where Landslides Have Occurred - or Are Occurring

Macon County - 520 mi² or 1347 km²
2) Where Debris Flows and Debris Slides are Likely to Start

Stability INdex MAp

SINMAP – Pack, Tarboton & Goodwin, 1998

- 5 in / 24-hr 125 mm / 24hr rainfall event
- 11% of county classified as “high hazard” (FS < 1)
- 59 naturally occurring debris flows/slides used for calibration
3) Downslope Hazard Map: Where Debris Flows May Go

- Private Land:
  - Low: 16%
  - High: 2%
  - Moderate: 82%

- Public Land:
  - Low: 64%
  - Moderate: 33%
  - High: 3%

Note: Hillslopes derived from 20-foot resolution LIDAR digital elevation data.
Downslope Hazards
Nickajack Creek
• 171 Modern Landslides
• 3% of county covered by pre-existing debris deposits
• Landslides are more likely to occur on modified slopes

Results of Landslide Mapping of Macon County
Some Initial Statistics: Over 2000 1940 Landslides Occurred

- 139 new structures currently reside on 1940 landslide tracks
- 521 landslide tracks cross roads visible on 2005 orthophotos
15 1940 tracks reactivated in 2004
Buncombe County: Landslide Hazard Mapping In Progress
How Can The Maps Be Used?

• Inform public and local governments of potential problem areas - disclosure
• Maps and data - planning tools
• Trigger for more detailed studies
• Emergency Management - Areas of concern when weather conditions favor landslides – landslide advisories
• Landslide point locations on-line at www.nconemap
Summary and Conclusions

- Significant landslide hazard in western North Carolina

- Recurring weather patterns:  - Major regional event 22-29 yrs  
  - Landslide event in region 9 yrs

- Increasing development on steep slopes increases exposure to landslide hazards

- Increased risk:  - destabilizing affects of human activity  
  - development in downslope hazard areas

- GIS landslide hazard maps and outreach help mitigate hazard

- Map 2-3 counties per year

- **Critical:**  - LiDAR and remote imagery (new and archival)  
  - Geologic and soil survey maps

- Maps not a substitute for site specific investigations
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Questions ??

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“Landslide Information”