G473 Summary Notes from Mills' / Debris Flow Hazards Talk

NOTE: Please read the OR Dept. of Forestry report summary by Mills and colleagues that is located in the lab cabinet. That will augment the notes presented here. I have the full report if you would like to copy it or check it out.

I. Introduction
   A. Debris Flow Defined (see class notes)
      1. Debris Flow = rapidly moving landslide
   B. Oregon Debris Avalanch Action Program
      1. historically landslide terminology has been used very loosely
      2. "mudslide" common in media, but is not defined technically
   C. Oregon Task Force on Landslides and Public Safety
      1. OR Dept. of Forestry
      2. OR Dept. of Transportation
      3. DOGAMI
   D. Senate Bill 12 - 1999
      1. Covers issues related to rapidly moving landslides
         a. includes regulation for debris-flow prone areas

II. Cases Studies of Debris Flow
   A. 1996 Feb. Storm
      1. 4-day storm event,
      2. long duration, low intensity, rain-on-snow event
      3. 1 landslide fatality
         a. landslide pushed house into flooded river
         b. person drowned
      4. Natural Resource Impacts
         a. stream channel erosion / deposition
            (1) alteration of fluvial habitat
         b. scarring / erosion of forest land
            (1) loss of forest stands
      5. Local Impacts
         a. Dallas / Laurel Mountain
            (1) Public / Private Land
            (2) 1996 debris flow impact
   B. November 1997 Storm
      1. storm / low pressure system moved north through Willamette Valley through Douglas and Coos County
      2. Great number of debris flows spawned in Coast Range
         a. 5 deaths by debris flow
      3. Public outcry
         a. forestry practices caused debris flows / deaths
      4. Governor initiated: Regulations on Forestry Practice and Public Safety aftern Nov. event

III. Debris Flow Characteristics
   A. Colluvium on top of weathered bedrock
      1. soil depth 2-3 ft up to 6 ft, common
   B. steep slopes, up to 80% slope (40 degrees)

C. Clear Cut vs. Old Growth occurrences

D. Debris flow morphology
  1. head scar zone / source of initial slide
  2. scoured transport zone
    a. channels widened and scoured to bedrock commonly
    b. bedrock plucking / erosion
    c. lateral channel widening during event
      (1) e.g. before channels 2-3 ft wide
      (2) e.g. after, channels up to 150 ft wide
  3. Lobate boulder / woody debris snouts at terminus of flow

E. Velocity of Debris flow
  1. 30-35 mi/hr

F. Material
  1. mixed mass of colluvium
    a. boulders
    b. fine sediments
    c. gravel
  2. Wood Debris
    a. LWD = large woody debris (logs / trees)

G. Debris Flow Bulking
  1. As the debris flow is transported, it scours the channel bottom and increases in volume as it moves down the slope
  2. Case Study / Mills Study / 1997 flows
    a. calculated that final debris flow deposit volume was 10 to 100 times greater than the initial volume of failed colluvium in

H. Deposition of Debris Flow
  1. Common on slopes of 6-10 %
    a. as slope angle decreases, energy is reduced, flow stops

I. Mechanism
  1. Concave / Hollow Loading with Colluvium
  2. High Rainfall Event
    a. saturation of pore spaces
    b. hydraulic lifting / < friction
    c. slope failure
  3. Hollows evacuate then require 1000's of yrs to refill
  4. Method of Hollow Filling / Colluviation
    a. soil creep
    b. tree throw
      (1) trees fall over and roots move soil down slope
    c. burrowing organisms / gophers, etc.
  5. Cyclic process over time
    a. debris flow events recorded in debris fans preserved at the depositional site
    b. question: what is the recurrence interval for debris flow at a give site?

NOTE: to determine hill slope gradient:

Slope = rise / run = change in elevation / change in horizontal distance = $\tan(\theta)$

where θ = slope angle in degrees

Example Slope Determination Problem:

For example, on a topographic map use see that on a hillslope, there is a gain of 51 ft elevation over a horizontal map distance of 100 ft. What is the slope angle in degrees?

$\tan(\theta)$ = rise / run = (51 ft)/(100 ft) = 0.51

Taking the arctan of 0.51 ("inv tan 0.51" on a calculator or "$\tan^{-1}$ 0.51" on a calculator), we find that

arctan (0.51) = **30 degree slope** (to check your answer, take tan(30) = 0.51)

Now, what is the slope in percent?

Slope% = rise/run x 100% = (change in elevation / change in horizontal distance) x 100%

Slope% = (51 ft)/(100 ft) x 100% = **51%** **Thus, a 51% slope = 30 degree slope.**

IV. Observations / Analysis from 1996-1997 Debris Flow Events
- A. Methods
  - 1. Extensive ground-based mapping of debris flow zones
  - 2. Air Photo Analysis
  - 3. Geographic Information Systems Analysis
    - a. Slope analysis using "DEM" = digital elevation models of topographic quads.
- B. Slope Failure Initiation Zones ("head scar" zone)
  - 1. 70-100% slope gradients most commonly failed
    - a. 40% slope gradients were a minimum threshold
- C. Tree Stand Age vs. Debris Flow Occurrence
  - 1. Mixed results
    - a. some old growth failed,
    - b. some new growth failed
  - 2. Mills suggests no clear relation appeared in data
  - 3. Common opinion
    - a. clear cutting / logging reduces root strength and encourages slope failure
    - b. 3-6 years after cutting, the roots rot and debris flows occur
    - c. Mills suggests that the new data is not conclusive in this respect
- D. Some Factors Affecting Debris Flow Occurrence
  - 1. Root Morphology / Tree Root Strength
  - 2. Presence / Absence of Macro Pores
    - a. e.g. burrows, holes, root casts
    - b. heterogeneous soil matrix
      - (1) complex soil permeability pathways
  - 3. Slope angle
  - 4. Slope Shape
    - a. Common to have slides start on concave slopes or colluvium-filled "hollows"
  - 5. Presence of Abundant colluvium
    - a. rock weathering products = "soil"
  - 6. Groundwater focus / concentration of subsurface flow in concave hollows

- 7. Soil Strength
  - a. as related to soil materials
    - (1) texture
    - (2) composition (clay vs. sand, etc.)
- 8. Slope Modification by Humans
  - a. slope cutting (oversteepening of slope)
  - b. slope filling (adding to colluvial thickness)
- 9. Vegetative Cover
  - a. type of trees
  - b. root penetration depth vs. colluvial thickness
  - c. logging history
- 10. Road Positioning / Construction
  - a. Forest Roads
    - (1) fill / thickening of unconsolidated material
      - (a) enhanced loading / sliding
    - (2) Culverts / Drainage ditches
      - (a) focuses / concentrates runoff / infiltration
      - (b) promotes slope failure
    - (3) Oversteepened road cuts
      - (a) > slope gradient

V. Landslide Triggers

- A. heavy rains
- B. snow melt
  - 1. rain/snow
- C. Earthquakes / vibration
  - 1. Large quakes infrequent in PNW, but do occur
- D. Highest Hazard: Quake during Rainy Season
- E. Hydraulic Controls on Landslide Initiation
  - 1. pore pressure
    - a. positive pore pressure, < normal stress, > slope-parallel shear stress, leads to slope failure
  - 2. water saturated pore space in colluvium
    - a. promotes buoyancy / encourages slope failure
    - b. weight of slope material - weight of water = effective normal stress
    - c. > saturation, < molecular cohesion between particles, encourages slope failure
  - 3. Negative pore pressure
    - a. condition of non-saturated or partially saturated pore spaces
    - b. high surface tension of water and molecular attraction between clay particles results in negative (i.e. "suction") pore pressure === promotes slope stability

VI. Depositional Zone

- A. Length of Transport, amount of bulking, total volume of debris controls the aerial extent of the debris flow impact zone
  - 1. predicting debris flow impact zone is important for hazards analysis
- B. Depositional Process
  - 1. Coarse woody debris increases friction
    - a. woody debris dams
  - 2. decreasing slope (<10%) reduces energy --- deposition

C. Fans
   1. debris flow deposits at base / mouth of steep drainages
      a. fan-shaped wedge of debris flow deposit
   2. Hazard
      a. fans represent elevated areas adjacent to floodplains
      b. farmers / homeowners like to build on fans to stay up off the floodplain
      c. danger: the debris flow will get you from behind
         (1) e.g. the Dodson Fan in Columbia River Gorge
            (a) 1997 Dodson Debris Flow

VII. Ongoing Research
A. Dietrich / Berkeley crew
   1. instrumentation in watersheds
   2. examining colluvial thickness, root strength, pore pressures,
B. H.J. Andrews Experimental Forest
   1. Debris Flow Flume
      a. Sediment / debris flow transport data collection

VIII. Oregon / Public Policy Regarding Debris Flow
A. Hazard vs. Risk
   1. Hazard = liklihood of debris flow occurrence
   2. Risk - degree of consequences from debris flow
      a. death / property damage
      b. Habitat Loss / Alteration

B. OR Senate Bill 12
   1. Policy for Rapid Landslides (including debris flow)
   2. DOGAMI charged with risk mapping
   3. OR Dept. of Forestry charged with landuse regulations / forestry practice
   4. OR DOT charged with warning / tracking systems on highways

C. Debris Flow Warning System (by OR Dept. of Forestry)
   1. debris flow warnings issued during heavy rain events
   2. storm forecasting

D. Debris Flow Risk Mitigation (OR Dept. of Lands)
   1. land use regulations
   2. planning
      a. locating structures away from hazard impact zones
   3. Goal 7 - Natural Hazards Planning Goals
   4. Technical Guidance for Local / County Gov't Planning Agencies