**Case History: La Conchita Landslide**

- Landslide occurred in La Conchita on January 10, 2005, destroyed 36 homes and killed 10 people
- Triggered by heavy rainfall, reactivation along an older landslide surface (35,000 years ago, 6,000 years ago and 1995)
- Debris flow up to 45 km/h (30 mph)
- La Conchita should not be built on the landslide deposits and under the foot of the slope
- Total risk exposure over the next 50 years is about $190 million
- Potential solution: Relocate people and better land use regulation

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**Introduction**

- Landslide and other ground failures posting substantial damage and loss of life
- In the United States, average 25 to 50 deaths and up to about 100 to 150 if collapses of trenches and other excavations are included; damage more than $3.5 billion
- Mass wasting: Comprehensive term for any type of downslope movement
- For convenience, definitions of landslide here includes all forms of mass-wasting movements
- Landslide and subsidence: Naturally occurred and affected by human activities

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**Mass wasting:** downhill quickly like an avalanche, or slowly like creep.

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**Slope Processes**

- Slopes: The most common landforms, dynamic and evolving system
- Consists of cliff face (free-face) and talus slope or upper convex slope, a straight slope and a lower concave slope
- Dynamic evolving feature, depending upon topography, rock types, climate, vegetation, water, and geologic time
- Materials constantly moving down the slope at varied rates
Types of Landslides (1)

- Slow or rapid failure of slope: Slope gradient, type of slope materials, amount of water present, rate of movement
- Rate of movement: Imperceptible creep to thundering avalanches
- Types: Creep, sliding, slumping, falling, flowage or flow, and complex movement (sliding and flowage)

Types of Landslides (2)

- Factor of Safety
  - $FS = \frac{Resisting Forces}{Driving Forces}$
  - If $FS > 1.25$, then conditionally safe or stable slope
  - If $FS < 1.25$, then unsafe or unstable slope
- Driving and resisting forces determined by the interrelationships of the following variables:
  - Existing of slip surface
  - Type of Earth materials
  - Slope angle and topography
  - Climate, vegetation and water
  - Time

Slope Stability

- Urbanization, irrigation
- Timber harvesting in weak, relatively unstable areas
- Artificial fillings of loose materials
- Artificial modification of landscape
- Dam construction
**Vaiont Dam (1)**

- On October 9, 1963, in Italy and lasted in less than 7 minutes, killed about 2,600 people
- Caused by a huge landslide in which more than 238 million cubic meters (0.06 mi³) of rock debris moved at speeds of about 95 km per hour (59 mi per hour)
- Generating waves of water up to 300 ft high
- Multiple factors
  - Weak carbonate rocks and clayey layer
  - Geologic fractures, sinkholes
  - Steep slope surface and creep due to the increased water pressure of the reservoir

**Vaiont Dam (2)**

![Image](https://via.placeholder.com/150)

Figure 10.D

**Human Activities and Landslides**

- Human use on the magnitude and frequency of landslides varies from nearly insignificant to very significant
- **Timber Harvesting:** Possible cause-and-effect relationship between timber harvesting and erosion
- **Urbanization:** Human activities are most likely to cause landslides in urban areas, examples from Rio de Janeiro, Brazil, and Los Angeles, California.
- Housing development into steep slopes, inadequate control of stormwater runoff, modification of sensitive slopes, irrigation

**Minimizing the Landslide Hazard (1)**

- Identifying potential landslides
  - Photographic analysis
  - Topographic map and detailed field check
  - Historic data
- Landslide hazard inventory map
  - Grading code from the least stable to the most stable
- Application of geologic and engineering knowledge before any hillside development

**Minimizing the Landslide Hazard (2)**

- Preventing landslides
  - Drainage control: Reducing infiltration and surface runoff
  - Slope grading: Reducing the overall slope
  - Slope supports: Retaining walls or deep supporting piles
- **Warning of Impending Landslides**
  - Landslide warning for critical evacuations
  - Correcting landslides: Draining

**Warning of Impending Landslides**

- Monitoring changes
  - Both human and electrical monitoring systems: Tilt meters, geophones, shallow wells, rainfall
- Landslide warning system
  - Information for public awareness and education
  - Enough time for public evacuation
  - Stop or reroute traffic flow
  - Emergency services
**Warning of Impending Landslides**

*Figure 10.24*

**Snow Avalanche**

- Mountainous region
- Rapid downslope movement of snow and ice
- Thousands of avalanches yearly in the western United States
- More deadly if large-slab avalanches
- Preventive measures:
  - Well-designed explosives
  - Engineering structures to retain, divert, or retard avalanches

*Figure 10.24*

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**Subsidence**

- Form of subsurface ground failure
- Occurred naturally or induced by human activities
- Slow settling or rapid collapse
- Causes: Withdrawal of fluids (water, oil and gas, steam) or removal of solid materials (dissolution, mining)

*Figure 10.25*

**Process of Subsidence**

*Figure 10.25e*

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**Removal of Solid Materials (1)**

- Sinkholes: a circular area of subsidence caused by the collapse of a near-surface subterranean void or room in a cavern
  - Dissolution of carbonate rocks, limestone, and dolomite
  - Affecting most of the conterminous states
  - Natural or artificial fluctuations in water table increasing the problem
  - Triggering other problems: Sinkholes as waste dumping sites

*Figure 10.25*

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**Removal of Solid Materials (2)**

- Salt Deposits
  - Salt dissolution and pumping
  - On November 21, 1980, subsidence associated with a salt mine occurred in southern Louisiana. Lake Peigneur
  - An oil-drilling operation punched a hole into an abandoned mine shaft of the Jefferson Island Salt Dome, a still-active multimillion-dollar salt mine located about 430 m (1,410 ft) below the surface
  - 10 barges, a tugboat, and an oil-drilling barge disappeared in a whirlpool of water into the mine
  - Nine of the barges popped to the surface 2 days later

*Figure 10.25*
Removal of Solid Materials (2)

Removal of Solid Materials (3)

- Coal mining
  - Most common where underground mining is close to the surface of the land or where the rocks left as pillars after mining are weak or intensely fractured
  - Usually, only 50 percent of the coal is removed, the remainder as pillars that support the roof weakens over time in active coal mines and abandoned coal mines
  - Ground failure due to depleted subsurface pressure
  - In the United States, more than 8000 km² (3,090 mi²) of land subsidence due to underground coal mining

Perception of the Landslide Hazard

- Landslide hazard maps not preventing development
- Common perception: “It could happen on other hillsides, but never on this one.”
- Infrequency and unpredictability of large slides reducing awareness of the hazards
- Often people taking the chances and unknown risks

What Can You Do? (1)

- Professional geologic evaluation for a property on a slope
- Avoid building at the mouth of a canyon, regardless of its size
- Consult local agencies for historic records
- Watch signs of little slides—often precursor for larger ones

What Can You Do? (2)

- Look for signs of structure cracks or damages prior to purchase
- Be wary of pool leaking, tilt of trees and utility poles
- Look for linear cracks, subsurface water movement
- Put observations into perspective, one aspect may not tell the whole story

Critical Thinking Topics

- Discuss the reasons why our society could not prevent slope development.
- Assume you have been hired by a community to make the citizens more aware of the landslide hazard in very steep topographic area. Outline a plan of action and defend it.
- Compare and contrast landslide hazards and impact risks in the east coast versus west coast, tropical versus polar regions.
(c) Rock slide

(d) Soil slide

(e) Rockfall

(f) Soil creep

(g) Earthflow

(h) Debris flow
(i) Debris avalanche

(j) Lateral spread

(k) Subsidence

(l) Complex slide

- Head scarp
- Upper slump
- Lower flow
- Toe