Chapter 13  Unsafe Ground: Landslides and Other Mass Movements
What is the controlling force for mass wasting?

What factors influence mass wasting?
Classification of Mass Wasting

Mass wasting events are classified by:

- Nature of material (consolidated or unconsolidated)
- Speed (few cm/yr to km/hour).
- Nature of movement (as one unit or as a fluid)
Mass movements are classified according to the dominant material, water or air content, and velocity of the movement.

<table>
<thead>
<tr>
<th>Material</th>
<th>Nature of Motion</th>
<th>Slow (1 cm/year)</th>
<th>Moderate (1 km/hr)</th>
<th>Fast (5 km/hr or more)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock</td>
<td>Flow</td>
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<td>Slide or fall</td>
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<tr>
<td>Unconsolidated material</td>
<td>Flow</td>
<td>Earth creep</td>
<td>Earthflow</td>
<td>Debris flow</td>
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**THE EARTH SYSTEM**
- Atmosphere
- Hydrosphere
- Lithosphere
- Outer core
- Inner core
- Plate tectonic system
- Geodynamo system

**Rock movements**
- Rock avalanche
- Rockslide
- Rockfall

**Unconsolidated material movements**
- Slump
- Mudflow
- Debris slide
- Debris avalanche
Mass Wasting classification

- Fall
- Slide
- Slump
- Flow
Rock Fall

Fig 12.7
Talus
Soil Creep
Classification

**Slide** - Single mass of rock or sediment is released and moves rapidly along a plane of weakness.
Rock Slide

Gros Ventre, Wyoming

(1925)

("Grow-Vaunt")

(a) Before slide

Water-saturated shale beds lubricated base of slide

Former land surface

Slide debris in valley

(b) After slide
What type of mass wasting?

Slump
What should you look for as indicators of potential problems?

- evidence of prior mass wasting
  hummocky topography, irregular surface, scars on mountain side, accumulation of rock and unconsolidated material at base of slope
- open cracks on the surface
- look for planes of weakness (beds parallel valley wall)
- unnatural steep slopes
- Structural damage – Settling and cracking of building foundations
- Toppling, bowed, or pistol-butt trees
- Gullying and surface erosion
- Springs -- Mid-slope ground-water seepage from the bluff face;
Triggers

1. **Heavy rain** –
   - undercutting slopes by running water
   - increased weight of wet soil
   - increased fluid pressure reduces frictional resistance

2. **Earthquakes**
   - ground shaking can trigger landslides
Triggers

3. Volcanoes
   - ground shaking can trigger landslides
4. Human activity

Impact of Human Activities

- Added mass of building on slopes
- Removal of vegetation
- Increasing angle of slopes
- Addition/removal of water
Triggers

(a) After construction activities

(b) Slide after prolonged rain
Chapter 14  Running Water: The Geology of Streams and Floods
Water reservoirs

- Oceans: $1.40 \times 10^9 \text{ km}^3; 95.96\%$
- Glaciers and polar ice: $4.34 \times 10^7 \text{ km}^3; 2.97\%$
- Lakes and rivers: $1.27 \times 10^5 \text{ km}^3; 0.009\%$
- Underground waters: $1.54 \times 10^7 \text{ km}^3; 1.05\%$
- Atmosphere: $1.5 \times 10^4 \text{ km}^3; 0.001\%$
- Biosphere: $2 \times 10^3 \text{ km}^3; 1 \times 10^{-4}\%$
Stream Channel Patterns

- Straight
- Braided
- Meandering
Braided River: High-sediment load, high velocity
Meandering Channel

• Meander – to wander
• One main (trunk) channel that winds back and forth across the floodplain.
• Forms on low slopes through easily eroded bedrock.
Meandering River

- Cut Bank
- Point Bar
Meandering Stream (cont.)

- **Point Bar**
- **Cut Bank**
Life stages of a river

Youthful

Mature

Mature
Old age
What is the life stage of this river?
Drainage Patterns

Drainage controlled by underlying structures.

Dendritic = Flat Lying Layers
Trellis = Folded Rock Layers
Rectangular = Joints or Faults
Radial = High Mtn. Peak (Volcanoes)
Dendritic drainage

Fig 14.20
Rectangular drainage
Note rectangular change in river path
Trellis drainage

Fig 14.20

Ridges of resistant rock

Anticline

Syncline
Trellis drainage
Radial drainage
Other Features of Streams

After many floods

Natural levee
Other Features of Streams

Terraces – Mark previous level of floodplain. Formed by renewed down cutting to lower base level.
River terraces
Fig. 14-18 Geology 2nd edition - Chernicoff
Alluvial Fan
Delta

Atchafalaya River

New Orleans

Mississippi River

Silt carried by Mississippi River discharge
Chapter 16  A Hidden Reserve:
Groundwater
**Water table** – boundary between unsaturated and saturated zone

- Soil
- Weathered bedrock
- Porous bedrock (sandstone)
- Groundwater table
- Unsaturated zone
- Saturated zone
- Water fills all pore spaces
- Water and air both occupy pore spaces

**Fig 13.8**
How does it get there?

Porosity – Total volume of pore (void) space in sediment or rock. May be fractures within rock or spaces between grains.
How does it get there?

Permeability – The ability of water to flow through spaces in rock or sediment. (Spaces must be connected!)
Groundwater Storage

Aquifer – material (sediment and rock) that store and transmit groundwater in sufficient quantities.

High porosity and high permeability.

Rock types?

*unconsolidated* | *consolidated*
gavel, sand       | sandstone, conglomerate
Groundwater Storage

Aquicludes (also called Aquitards or Confining Beds) – Beds/Rocks through which water cannot move, or moves very slowly.

Low Permeability (Porosity varies).

Rock Types?

- **unconsolidated**
  - mud, clay

- **consolidated**
  - mudstone, shale, slate
The two types of aquifers are:

**Unconfined aquifer** - open to the surface (unsaturated zone and saturated zone) with a water table

**Confined aquifer** is sandwiched between two aquicludes and is not open to the surface at that location

Any rock type can be considered an aquifer if it is fractured and the fractures are interconnected!
Groundwater storage

Unconfined aquifer

Confined aquifer

Aquiclude

Aquifer

Water table

Well

Sand and gravel

Clay

A. Before extensive pumping of well
Groundwater storage

Artesian Well

Confined Aquifer

Fig. 13.10
**Springs:** Where the surface intersects the water table
Geysers: Intermittent hot fountains/columns of water
Managing Groundwater

Groundwater Withdraw is greater than Groundwater Recharge

• Cone of Depression
  Excessive pumping draws down the water table into a cone-shaped depression around a pumping well.
When a well pumps water out of an unconfined aquifer faster than recharge can replenish it, the water level in the aquifer is lowered in a cone-shaped area around the well, called a **cone of depression**.

Think of an ice cream shake or malt as an analogy.
Saltwater Intrusion

(a) Before extensive pumping

(b) After extensive pumping by many wells
Managing Groundwater

Groundwater Withdraw is greater than Groundwater Recharge

• Subsidence
  When water is removed from pore spaces/cracks in sediment/rocks, the weight of overlying materials causes compaction, and sinking of land surface.
Subsidence
Subsidence  (from pumping out water faster than replenishing)
Erosion by Groundwater

Dissolution

- Chemical weathering process by which slightly acidic water dissolves rock.
- Most commonly limestone
- Water picks up CO$_2$ from the atmosphere and from the soil and becomes slightly acidic (carbonic acid).
- Acid is strongest at the level of the water table.
- Dissolves along fractures, enlarging them into a network of caves and other features called Karst.
Karst topography

Limestone is subjected to chemical weathering
Cave Formation

1. Dissolution occurs near the water table, enlarging previous fractures.
2. Water table drops - leaves a cavity full of air
3. Water infiltrates from above and minerals precipitate as water enters void space.
4. Minerals (Calcite) precipitate as formations known as speleothems.

Website for virtual cave: http://www.goodearthgraphics.com/virtcave.html
Stalactite

Speleothems

Column

Stalagmite
Sinkhole in Winter Park, Florida  This sinkhole was created when the roof of a cave collapsed. Collapse can happen very quickly and suddenly.

Fig. 12.19  Understanding Earth
Contamination of our Water Supply

Groundwater Pollutants

- Sewage
- Leaking gasoline tanks
- Pesticide / Herbicides / Fertilizer
- Feed lots
- Cleaning solvents
- Radioactive waste
Contamination of Water Supply

Buried gasoline or industrial chemical storage tank
Waste-disposal or injection well
Septic tank or cesspool
Land spreading, irrigation, and pesticide application
Pumping well
Waste lagoon or basin
Groundwater table
Unconfined aquifer (fresh)
Confined aquifer (fresh)
Confined aquifer (saline)

Infiltration
Discharge
Artificial recharge into aquifer

Entry of surface-source contamination into groundwater
Movement of contaminants in groundwater
Contaminants in wells
Groundwater review

What are some materials that form aquifers?

What are some materials that form aquitards?

What is an unconfined aquifer?

What is a confined aquifer?

What creates a spring?

What rock type are dissolution caves formed in?
Consider the following questions:

You bought a piece of land in the country to build your house; you need both a water well and a septic system. Where are you going to put them? Where would you go for information to insure that you have a safe water supply?

You just bought a house in the country, the water tastes a little strange. What are you going to do?
Chapter 15 Restless Realm: Oceans and Coasts
Major Physiographic Features in the Atlantic Ocean

- continental margin
  - continental shelf
  - continental slope
  - continental rise
- abyssal plain
- seamounts and guyots
- amid-ocean ridge
  - abyssal hills
  - central rift valley
**Abyssal Hills**

Linear ridges of basalt covered with a thin veneer of deep-sea sediment on the flanks of the Mid-ocean ridge.

- **2-km high** submarine mountain belt

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**Diagram**

- Abyssal plain
- Abyssal hills
- Mid-ocean ridge
- Rift valley
- Sediment
- Fresh volcanic rock and talus
- Faulted valley walls
- Lava

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**Fig. 17.5**

Abyssal Hills

Linear ridges of basalt covered with a thin veneer of deep-sea sediment on the flanks of the Mid-ocean ridge.

- **2-km** high submarine mountain belt
Waves are due to wind

Higher waves can be caused by:
1) Higher wind speed
2) Increased storm duration (time)
3) Longer *fetch* (distance over which wind blows)

Map of satellite data showing the geographic correlation between surface wind speeds and significant oceanic wave height in the first half of October, 1992. The highest winds and waves are found predominantly in the circum-Antarctic region at this time, the southern hemisphere spring. This is a result of both wind speed and fetch.
Wave characteristics

- Wave length – distance between crests
- Wave height – vertical distance between crest and trough
- Period – time between successive waves to pass

Wave base is 1/2 wave length – there is negligible water movement due to waves below this depth
How do breakers form?

- As the swell approaches the shore where the bottom shallows to less than ½ the wavelength, the wave touch bottom causing it to slow.
  - The wave period remains the same so the wavelength decreases and the waves height increase (making the wave steeper).
- As bottom shallows further the water can no longer support itself and the waves breaks and crashes in the surf zone.
Major Parts of a Beach

**Surf zone** – offshore belt along which breaking waves collapse as they approach the shore

**Swash zone** - zone where water run up on the beach from a wave

**Tidal flats** – the area that lie above low tide but are flooded at high tide
Formation of rip currents
-- rapid current draining beach area through shallow nearshore bars
-- fast and dangerous (most beach rescues)

What do you do if caught in a rip current?
Far from shore the lines of swells are parallel to each other but are usually at some angle to the shoreline.

**Wave refraction** occurs as waves slow down in progressively more shallow water depths allowing the wave fronts to bend and approach the shore nearly parallel.
Wave refraction moves sediment along the beach in a zigzag motion known as **longshore drift**.
Many coastal depositional features are formed by longshore drift.

The “River of Sand”

A composite diagram of the large-scale features of depositional coasts. Not all of these features would be found in such close proximity or in this order on a real coast.
San Diego spit

Sand spit

Sand Spits

-- common wherever sand is supplied and a longshore current is present

End of a spit
Tombolos

-- island shields beach from wave energy
-- leads to sand build up
Emergent coasts

- Uplifted, tectonically active coasts often rocky
- Rocky headlands alternate with pocket beaches
- Formed by wave erosion
Wave cut platforms

-- abrasion across surf zone erodes bedrock flat – common feature on rocky coasts
Sea stacks and arches - remnants of erosion
Uplifted beach terraces

-- can be either wave cut platforms or beaches or both

-- common on emergent coasts

-- EX: CA, OR, WA, entire west coast of US
Preventing beach erosion

- **Structural** approaches (e.g., groins, breakwater, jetties): typically cause increased erosion down-current of structure
- **Non-structural** approaches (e.g., beach nourishment, land use planning): expensive, but doesn’t cause erosion in new areas

**Groins** - catch part of the “river of sand” from longshore drift

**Breakwater** - reduces local wave energy so sand is deposited, not carried away
Groins and breakwaters

New Jersey groins

Groins - which direction is sand flowing?

Italian breakwater