Mass Wasting

I. Slope Stability
II. Classification of Mass Wasting Processes
III. Landslide Prevention and Mitigation
**Mass wasting** is the downslope movement of rock and soil under the direct influence of gravity.

This is a particularly important geologic activity in the S.F. Bay Area - we deal with "landslides" every year during the rainy season (Oct. -April).

Although these are often small-scale events — some are very large and are responsible for thousands of deaths.

Examples:

- Peru (1970) - 20,000 people died during a gigantic rock avalanche.
- Colombia (1985) - 25,000 people died in the lahar flows after the eruption of Nevado del Ruiz.
- Italy (1960) - a rock slide caused a 90 meter high wave of water in a mountain reservoir that killed 2,600 people.

USGS
I. Slope Stability

One key factor that affects slope stability is the steepness of the slope.

In A, the pull of gravity is downward. On a slope, the force of gravity can be resolved into two components: a component acting perpendicular to the slope \((g_p)\), and a component acting parallel to the slope \((g_s)\).

In B and C, more of the rock’s weight \((g_s)\) is directed downslope as the slope increases (vector \(g_s\) becomes larger).
Another important factor in slope stability is the nature of material - some materials are inherently stronger (granite v. shale). The figure shows the slope profile for the walls of the Grand Canyon. Differences in the strength of the different rock types where resistant layers (limestone and sandstone) form steeper walls than weaker rocks such as shale.
Although gravity is the controlling force in mass wasting, other factors may play an important role in mass wasting:

1. Water
2. Oversteepened slopes
3. Vegetation
4. Earthquakes
The Role of Water in Mass Wasting

When the pore spaces between grains in a sediment become filled with water - cohesion between the grains is destroyed. Water saturation reduces the internal resistance (friction?) of materials to flow - the sediments are less coherent and may flow under the influence of gravity.

Water adds considerable weight to a package of sediments - the added weight may be enough to initiate flow under the influence of gravity.

In the S.F. Bay Area, CalTrans and other government agencies install plumbing systems in steep slopes to help drain them (prevent oversaturation) in hopes to prevent slope failure (ex. Highway 92 near Half Moon Bay).
Loss of cohesion in unconsolidated sediments by oversaturation from water.
The Role of Oversteepened Slopes in Mass Wasting

Unconsolidated particles assume a stable slope called the *angle of repose*. This is the steepest angle at which the material remains stable (usually varies from 25 to 40°).

If a slope angle is greater than the *angle of repose* for a particular material, the slope is *oversteepened* and is subject to failure.
Many activities are responsible for oversteepening of slopes:

1. A stream may undercut a valley wall.
2. Pounding waves against the base of a cliff may undercut the cliff (we are seeing this happen along the CA coast (Daly City).
3. People commonly oversteepen slopes by construction of roads and landscaping.
The Role of Vegetation in Mass Wasting

Plants protect against erosion and help stabilize slopes - their roots bind soil together.

Mass wasting is enhanced where plants are lacking - by fire, urban development, logging, etc. The image shows multiple landslides resulting from deforestation in Colombia.

In the S.F. Bay Area, CalTrans plants "at risk" slopes in the hope to help stabilize them.
The Role of Earthquakes in Mass Wasting

Earthquakes play a major role in triggering landslides. Although the conditions for a slope may be favorable for a failure (slide), it sometimes requires an additional factor to "trigger" the movement.

Earthquakes can provide the "nudge" that is required for an oversteepened slope to fail. Remember that the eruption of Mount St. Helens was triggered by a giant landslide. In turn, the landslide that was responsible for the eruption was itself triggered by an earthquake due to the movement of magma underground.
The general types of mass wasting processes and the classification scheme is based upon

1. **Type of Material** - classification depends upon whether the material began as unconsolidated sediments (and soil) or as bedrock.

2. **Type of Motion** - Kind of motion may be described as fall, slide or flow
   - **Fall** - free-fall of detached material. Common on slopes so steep that there is no accumulation of material on the slope. Many falls may result from mechanical weathering such as frost wedging and the action of tree roots.
   - **Slide** - material remains fairly coherent and moves along a well-defined surface such as a joint, fault, or bedding plane.
   - **Flow** - material moves downslope as a viscous fluid.

3. **Rate of Movement** - can be very rapid (> 125 miles/hour) or imperceptibly slow - ranges from sudden to gradual movement.
Falls
A fall involves rapid movement of material in free fall.
Rock falls occur when a slab of rock travels mostly vertically through the air, then after hitting the ground, rolling and bounding. Triggers tend to be heavy rain, frost wedging, earthquakes, animals and people.
Although falls are a hazard, they are an important process that helps to widen valleys and erode mountains over geologic time.

The above image shows the damage at Curry Village after a rockfall.
Slides occur when blocks of bedrock and/or soil break loose and slide down a slope - these are fast and destructive types of mass wasting events.

Rockslides occur where layers are inclined or where joints or fractures are parallel to the slope. These are most commonly triggered by heavy rains or snow melts which "lubricate" the slide surface.
On July 10, 1996, a giant rockslide occurred in Yosemite. The left image shows the detachment zone of the rockslide and the impact areas (C/D, B). In addition, an air blast from the impact flattened 10 acres of forest. The blast area is shown in the lower left region.

The right figure shows a close-up of the blast zone. Rock fragments were embedded in trees for hundreds of feet into the forest.
The Chaos Jumbles in Mt. Lassen NP were formed by a huge rockslide that occurred ~300 years ago when the volcanic peaks of the Chaos Crags collapsed. The slide had a lot of horizontal motion because the debris rode on a bed of compressed air.
**Slump**

A *slump* is a downward sliding mass of rock or unconsolidated sediment as a unit along a curved surface — this is very common in the S.F. Bay Area.

A slump commonly occurs because a slope has been oversteepened. A crescent-shaped scarp is created and the block's upper surface is sometimes tilted backwards.

The slump may occur as a single mass or as a series of blocks. Water can percolate down through the fracture and cause more movement.
Slumps on Mars.
Flows

A flow is a relatively rapid type of event involving a flow of soil &/or rock &/or mud containing a large amount of water.

Because of their fluid properties, debris flows follow canyons and stream.
Two main types of occurrences of flows:

1. In semiarid regions - cloudburst or snowmelt creates a sudden flood that entrains a lot of soil because there is no vegetation to anchor the surface material. The result is a lobe- or tongue-shaped fan of well-mixed soil, mud and rock.

2. Lahars - occur on stratovolcanoes. Eruptions suddenly melt snow and glaciers that release a tremendous amount of material - ex. Mount St. Helens.
Debris flows are very common in the Coast Range of California.
The images show Mt. Kazbek in S. Russia before and after the recent collapse of the Kolka Glacier that triggered a debris flow that traveled more than 15 miles. The avalanche buried small villages killing dozens of people.

The long, dark grey streak running upward through the center of the scene shows the gorge that was overrun by the debris flow. The deep reds show vegetated land surfaces, grey areas are bare rock, and white shows ice-covered lands.
Earth flows are common on hillsides in humid areas, during times of heavy precipitation. When the soil saturates, the material may break away, leaving a scar on the slope and forming a tongue- or teardrop-shaped mass downslope -common in the S.F. Bay Area. The materials are most commonly rich in clay and silt. Since earth flows are viscous, they move slower than debris flows and may remain active for a long period of time.
Map shows areas of equal landslide potential. Red areas have very high potential, orange areas have high potential, and yellow areas have moderate potential. Landslides can and do occur in the green areas, but the potential is low.

Dataset USGS/National Atlas 2002

Landslide Hazard of the Conterminous United States
III. Landslide Prevention and Mitigation

There are several ways to try to prevent landslides. Most prevention methods employ various engineering controls to minimize the hazard and stabilize a slope.

If a landslide occurs, mitigation means reducing the effects or the intensity of the landslide.

After a landslide occurs, the first task is to remove the landslide material and stabilize the slope. Most methods of mitigation overlap with preventive measures.
1. Vegetation. Planting vegetation is particularly effective in stabilizing slopes that consist of sediment. The roots bind the loose sediment and may penetrate to the underlying rock to anchor the sediment. Vegetation with deep roots is more effective. Vegetation also helps stabilize slopes by absorbing water from the soil.
2. Retaining Walls. The purpose behind a retaining wall is to strengthen an oversteepened slope. Retaining walls are especially common along roadsides where a flat or level surface has been cut into a slope for the roadway.
3. Controlling Water. We saw that water plays an important role in mass wasting. Various engineering controls are employed to “dewater” a slope to increase its stability in wet conditions.
4. Terracing. Terracing involves a series of benches on a hillside. Frequently, retaining walls are also used to stabilize the steepened portions of the slope.

Terracing is effective where it is not feasible to build a single large retaining wall.
5. Rock Bolts. Rock slides and falls are common where the slope consists of fractured rock. Rock bolts are used to anchor fractured rock to more massive rock. Rock bolts are installed by drilling a hole through the slope then inserting and anchoring the bolt. Rock bolts are frequently installed with flexible metal mesh to help stabilize the slope and prevent material from falling.