Vegetation

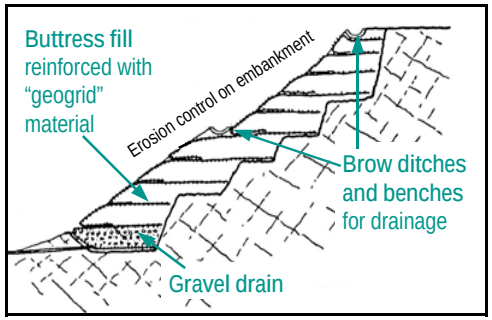
For shallow landslides, successful establishment of vegetation may be an effective way to improve slope stability. The root networks of particular tree and brush species increase resisting forces by improving tensile strength. Large diameter trees at the toe of a failure may provide buttress support, and evapo-transpiration decreases soil moisture.

Slope Modification

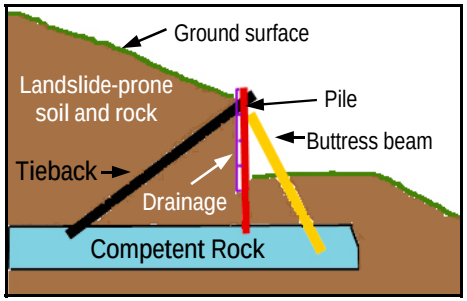
Laying back a slope to a gentler gradient is an alternative that reduces driving forces by removing/unloading the upper portion of the slide. Slopes are often terraced to provide for surface and subsurface drainage and to accommodate narrow right-of-ways. Feasibility and design must consider where the removed material is to be stockpiled or utilized.

Buttress Fill & Soil Reinforcement

Buttress fills increase resisting forces by providing lateral support and/or increasing soil strength. Toe buttresses consist of rock or compacted/reinforced soil placed at the toe of the failure to provide lateral support. An alternative is to remove the entire slide mass and replace it with a buttress fill consisting of compacted soil that may be reinforced with geomembranes or geosynthetics. Ensuring proper drainage is a critical component of design, and larger buttress fills in particular require evaluation and design by a qualified engineer.



Structural Retention



Structural retention systems increase resisting forces by providing lateral support. Measures include retaining walls, pilings, tieback anchors, and anchored gabions. These measures may be used in combination with soil reinforcement measures that increase internal strength. Ensuring proper drainage is a critical component of design. These usually require detailed geotechnical investigations and tend to be expensive to construct.

Landslides

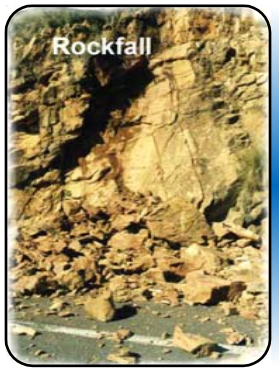
Davis, California

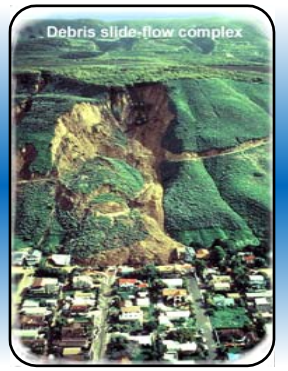
Updated January 19,2005

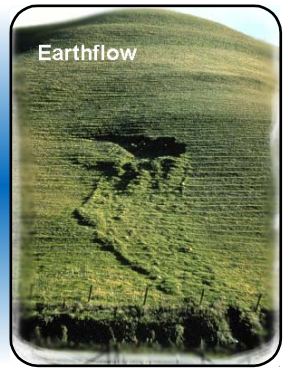
NRCS considers slope stability and landslide potential as a part of everyday conservation planning. For existing landslides, NRCS may also be available to provide assistance, particularly where the failures are small and do not pose a significant risk to life and property. Larger, high hazard landslides are, however, complex geotechnical problems that may require the services of a professional engineering geologist or geotechnical engineer.

Classification of Landslides

"Landslide" is a general term that describes the movement of rock, debris, or soil down a slope under the influence of gravity. Landslides are classified by the type of material (rock, debris, earth) and how it moves (falls and topples, slides, and flows). Correct classification is important because triggering mechanisms and management measures may be different.







Assessing Landslide Hazard

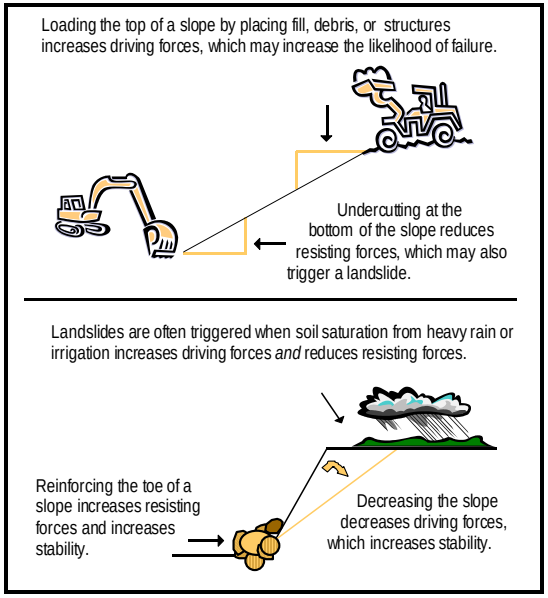
Potential hazards associated with continued or renewed slope failure, and what to do about them, depend on what's at stake; an unstable slope poised to deliver large volumes of mud and rock to a residential area, would represent a high hazard situation that calls for a detailed investigation and quick action to reduce the hazard. Landslides in open areas that do not pose a hazard to life or property may only require a qualitative evaluation, monitoring, and proper land use management.

Geotechnical Site Investigations

Engineering geologists and geotechnical engineers work together to determine what factors contribute to instability and what triggered the landslide. They look at rainfall records and aerial photos; study geology and soil maps; and review other reports that describe historical land use, cover, and slope conditions. Reports may also be available that evaluate slope stability at or in the area around the site. In the field, they characterize the rock or soil material in terms of its composition, texture, and strength; they identify discontinuities such as bedding planes, faults, and fracture zones; they evaluate surface drainage and subsurface groundwater; and they work to define the shape and size of the failure including the location of the failure plane. In order to adequately characterize the site, the study area should always extend beyond the bounds of the existing slide. Some failures may actually be a part of a larger, compound slide. A subsurface investigation is often conducted as a part of a detailed geotechnical investigation, but may not be required in low or moderate hazard situations.

Landslide Forces

Slopes are considered stable when the resisting forces (defined by the strength of the material) exceeds those forces that drive a slope towards failure. Failure occurs when a triggering mechanism, such as intense rainfall, shifts the balance by rapidly increasing the driving forces and/or decreasing the resisting forces. Other potential triggering mechanisms include earthquakes, rapid water level changes, streambank erosion, irrigation, and excavation for roadcuts or building pads. Natural events or land use activities may not be identified as a triggering mechanism, but may contribute to failure by lowering the slope's threshold for failure, making it more likely that failure will occur in response to some triggering event.



Reducing Landslide Hazards

Landslide hazard reduction may be accomplished by:

1. Relocating structures and moving property out of harm's way;
2. Deflecting or intercepting flow material and either storing it in debris basins, or conveying it through adequately sized channels or floodways;
3. Decreasing driving forces that trigger failure; and
4. Increasing those forces that resist failure.

The first two approaches consider land uses in the vicinity of the landslide and may require easements, acquisition, and/or condemnation. In addition, adequate storage or conveyance capacity must be available.

The second two approaches address slope stability directly. The following methods are commonly used, often in combination, to reduce the probability that slope failure will occur during dry to normal rainfall years:

Drainage

Intercepting and removing surface and/or subsurface water is one of the most common approaches to landslide management. Removing excess water from the soil increases resisting forces by increasing internal strength, *and* reduces driving forces by reducing loading. Drainage methods include surface diversions, roof runoff management, subsurface drains, grading to reduce infiltration through cracks, and others. Covering the slide with plastic to reduce infiltration is discouraged; installation and maintenance can be difficult, soil moisture is retained, and the plastic may obscure incipient failure.