Swiss Virtual Campus

"Dealing with Natural Hazards"

Module 3

Topic group: **Landslide process types and principles**

Learning unit: **Landslide terminology and classification**

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Introduction

Why do we study landslides?
Despite improvements in recognition, prediction and mitigative measures, landslides still extract a heavy social, economic and environmental toll in mountainous regions around the world.

What is this course about?
This course will examine the processes and mechanisms responsible for landslides in soil and rock, the procedures available for investigating them and the means to analyze and mitigate such phenomenon.

Significance of landslides

The significance and importance of understanding landslides
Throughout the world, mountain valleys have experienced accelerated economic development in response to population growth and associated demands for increased mining, forestry and agricultural activities. Economic growth has also demanded the expansion of transportation and communication infrastructure.

Human expansion happens so quickly....
The short history of extensive human development in many regions, however, makes the evaluation of potential landslide hazards and appropriate countermeasures very difficult.

Socioeconomic examples

Slope failures have caused untold numbers of casualties and huge economic losses.

In addition to killing people and animals (both livestock and wildlife), landslides destroy or damage residential and industrial developments as well as agricultural and forest lands and negatively affect water quality in rivers and streams.

The world's most devastating landslide disasters typically involve numerous fatalities due to indirect consequences.



Aquarell by D. A. Schmid (1791-1861).

Rockslide engulfing the village of Goldau causing disturbance to the Lauerzer See. Debris from the Goldau slide partly filled the Lauerzer See and produced a 20 m high wave that surged over lakeside villages.

Albert Heim, 12.04.1849 – 31.08.1937



In 1932 the first monogragh about Swiss landslides was published by Albert Heim. The famous title "Bergsturz und Menschenleben" (Translated "Landslides and Human Lives" by Skermer 1989) proves Heim to be the first person to think about the mechanisms of geological mass movements and their socioeconomic impact. The monograph includes data from all known minor and major landslides in Switzerland. Heim's geological and mechanical observations, his detailed sketches and sections of landslides are still unsurpassed.

Assistant of A. Escher von der Linth, 1872-1912 Professor at the ETH in Zurich, 1894-1925 President of the Swiss Geological Commission. Heim was one of the most famous alpine geologists and published leading papers on orogeny and glaciology. He supported the nappe theory by attributing folding and overthrusting to horizontal forces. As a consultant he worked on many minor and major landslides in and around Switzerland.

Definition of a landslide

Landslides can be defined as:

"the movement of a mass of rock, debris or earth down a slope" (Cruden 1991)

Note: The above definition reflects the international practice. In Switzerland landslide terms are also connected with the Swiss laws on landscape and the environment given by the BUWAL - *Bundesamt für Umwelt, Wald und Landschaft*

Landslides can be classified using several different criteria such as....

- the type of material.
- the type and rate of movement.
- the mechanism or process.
- and the landslide‘s dimensions.

Landslide Features

***Crown**:* Virtually undisplaced material still in place and adjacent to the highest parts of the main scarp.

***Main scarp**:* A steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the displaced material away from-the undisturbed ground. It is the visible part of the surface of rupture.

***Top**:* The highest point of contact between the displaced material and the main scarp.

***Head**:* The upper parts of the landslide along the contact between the displaced, material and the main scarp

***Minor scarp**:* A steep surface on the displaced material of the landslide produced by differential movements within the displaced material.

***Main body**:* The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp and the toe of the surface of rupture.

***Foot**:* The portion of the landslide that has moved beyond the toe of the surface of rupture and overlies the original ground surface.

***Tip**:* The point on the toe farthest from the top of the landslide.

***Toe**:* The lower, usually curved margin of the displaced material of a landslide, it is the most distant from the min scarp.

***Surface of rupture**:* The surface which forms (or which has formed) the lower boundary of the displaced material below the original ground surface.

***Toe of surface of rupture**:* The intersection (usually buried) between the lower part of the surface of rupture of a landslide and the original ground surface.

***Surface of separation**:* The part of the original ground surface overlain by the foot of the landslide.

***Displaced material**:* Material displaced from its original position on the slope by movernent in the landslide. It forms both the depleted mass and the accumulafion.

***Zone of depletion**:* The area of the landslide within which the displaced material lies below the original ground surface.

***Zone of accumulation**:* The area of the landslide within which the displaced, material lies above the original ground surface.

***Depletion**:* The volume bounded by the main scarp, the depleted mass and the original ground surface.

***Depleted mass**:* The volurne of the displaced material which overlies the rupture surface but underlies the original ground surface.

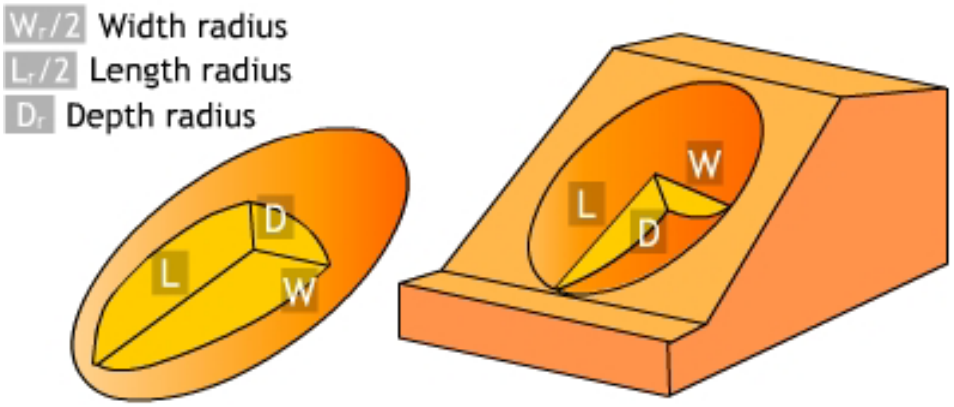
***Accumulation**:* The volume of the displaced material which lies above the original ground surface.

***Flank**:* The undisplaced material adjacent to the sides of the rupture surface. Compass directions are preferable in describing the flanks, but if left and right are used, they refer to the flanks as viewed from the crown.

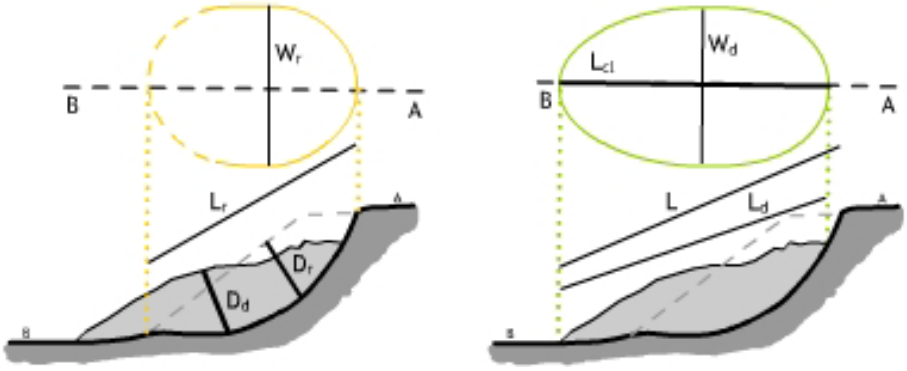
***Original ground surface**:* The surface of the slope that existed before the landslide took place.

Landslide Dimensions

Landslide volume



Landslide dimension



Wd Maximum breadth of displaced mass perpendicular to length Ld.

Wr Maximum width between flanks of landslide perpendicular to length Lr.

Ld Minimum distance from tip to toe.

Lr Minimum distance from toe of surface of rupture to crown.

Dd Maximum depth of displaced mass measured perpendicular to plane containing Wr & Lr.

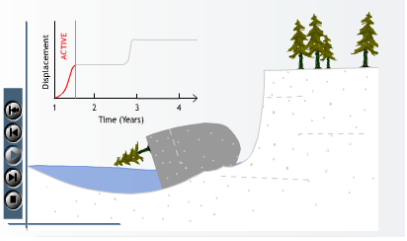
Dr Maximum depth of surface of rupture below original grounf surface measured perpendicular to plane containing Wr and Lr.

L Minimum distance from tip to landslide crown.

Lcl Distance from crown to landslide tip through points on original ground surface, equidistant from lateral margins of rupture surface and displaced material.

Landslide activity

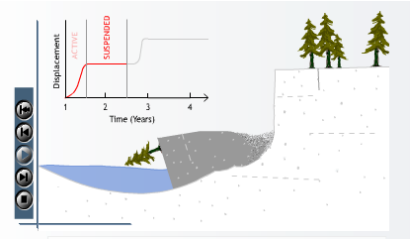
Active



Erosion at the base of slope causes a block to topple.

Definition: An **active** landslide is currently moving.

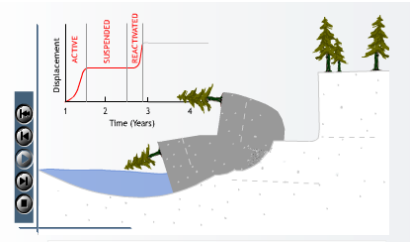
Suspended



Localized cracking develops in the crown of the slope.

Definition: A **suspended** landslide has moved within the last 12 months but is not presently active.

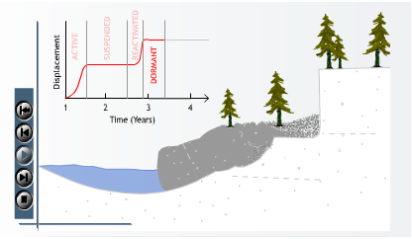
Reactivated



Another block topples.

Definition: A **reactivated** landslide is an active landslide which was previously inactive.

Dormant

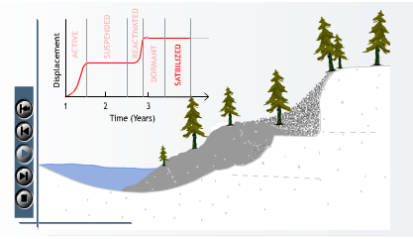


Displaced mass begins to regain its tree cover and scarps are modified by weathering.

Definition: An **inactive** landslide has not moved within the last 12 months. Inactive landslides can be subdivided into the following states: dormant - stabilized – relict

A **dormant** landslide is an inactive landslide which can be reactivated by its original causes or by other causes.

Stabilized

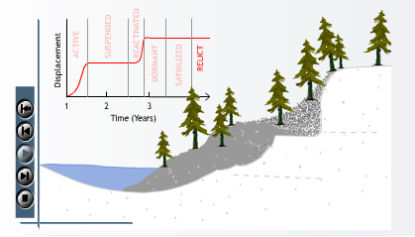


Fluvial erosion/deposition stabilizes the slopes toe and begins or further develops vegetation cover.

Definition: A **stabilized** landslide is an inactive landslide which is no longer affected by its original causes.

The term is also used for an inactive landslide which has been protected from its original causes by artificial remedial measures.

Relict



Modified develops further vegetation cover.

Definition: A **relict** landslide is an inactive landslide which developed under climatic or geomorphological conditions different to those at present.

Distribution of landslide activity

***Advancing**:* In an advancing landslide the rupture surface is extending in the direction of movernent.

***Retrogressing**:* In a retrogressive landslide the rupture surface is extending in the direction opposite to the movernent of the displaced material.

***Enlarging**:* In an enlarging landslide the rupture surface of the landslide is extending in two or more directions.

***Diminshing**:* In a diminishing landslide the volume of the displacing material is decreasing.

***Confined**:* In a confined landslide there is a scarp but no rupture surface visible at the foot of the displaced mass.

Style of landslide activity

Complex: A complex landslide exhibits at least two types of movement. (falling, toppling, sliding, spreading, flowing) in sequence.

***Composite**:* A composite landslide exhibits at least two types of movement simultaneously in different parts of the displacing mass.

***Successive**:* A successive landslide is the same type as a nearby, earlier landslide but does not share displaced material or a rupture surface with it.

***Single**:* A single landslide is a single movement of displaced material.

***Multiple**:* A multiple landslide shows repeated development of the same type of movement.

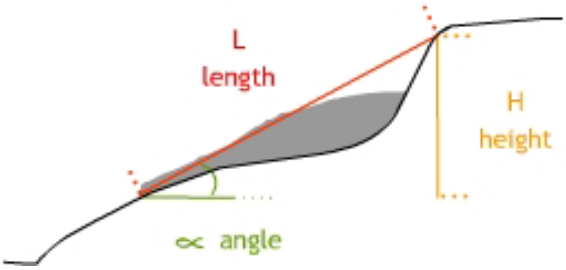
Single and Multiple toppling

***Single topple**:* A single block rotates forward, out of the slope, about the axis below the centre of gravity of the displaced block.

***Multiple topple**:* After a single block has toppled, other blocks can topple and hence, follow the first block.

Travel angle and mobility of landslides

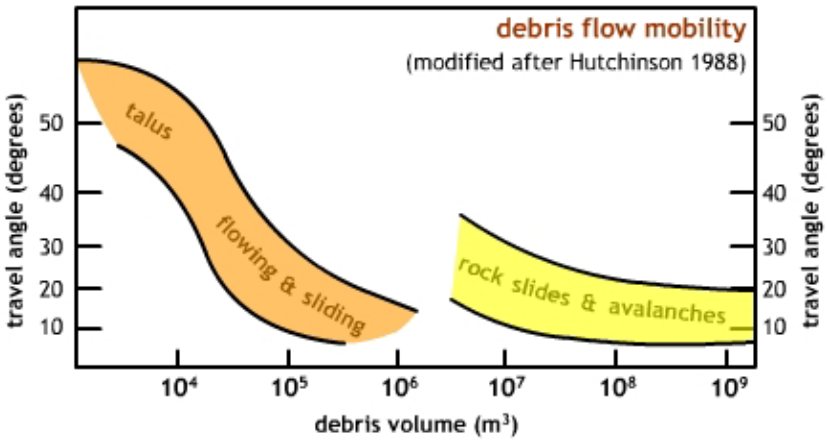
Travel angle



The travel angle is derived as the arcsin of the height of the landslide **H** versus the total landslide length **L**.

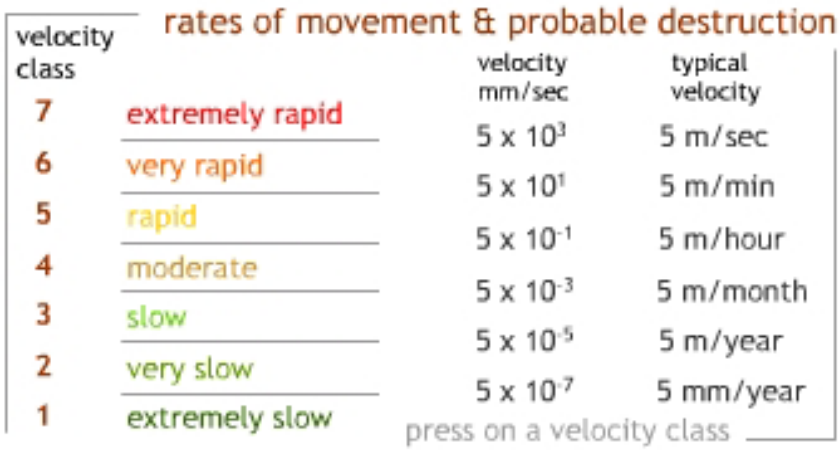
The height is measured from the crown to the toe of the landslide or from the crown to the end of the runout area.

Mobility



The debris flow mobility diagram shows the connection between travel angle and debris flow volume (modified after Hutchinson 1988). In general it can be stated that the lower the travel angle is, the more volume can be mobilized. E.g. the largest landslide in the alps (10-12 cubic kilometres) at Flims only has a travel angle of 5.5 degrees !

Rate of landslide movement



7 - Catastrophe of major proportion, buildings destroyed by impact of displaced material, many deaths, escape unlikely.

6 - Some lives lost, velocity too great for all persons to escape.

5 - Evacuation possible, structures, possessions and equipment destroyed.

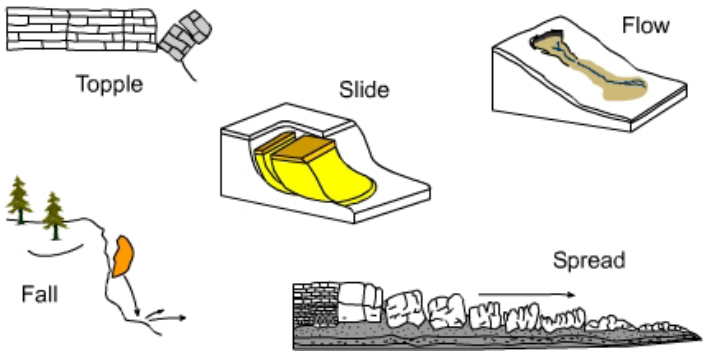
4 - Some temporary and insensitive structures can be temporarily maintained.

3 - Remedial construction can be undertaken during movement, insensitive structures can be maintained with frequent maintenance work if total movement is not large during an acceleration phase.

2 - Some permanent structures undamaged by movement.

1 - Impercetible without instruments, construction possible with precautions.

Types of landslide movement



Summary of objectives

In this learning unit we have learned....

- To define the term landslide

> ***"The movement of a mass of rock, debris or earth down a slope"*** (Cruden 1991).

- To learn different landslide features, phenomena and dimensions.
- To estimate the state of landslide activity, distribution and style using geomorphological observations.
- To define landslide runouts and to realize the connection between velocity and damage.
- To distinguish the 5 major types of movement.

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Technical Realisation: Dr Andrew Kos

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