SRC International Cooperation

Definition and Description of landslide, debris flow and flood processes

Swiss Red Cross

1. Definitions

Natural hazard

A condition of meteorological or geological origin that may result in an event harmful to people, the environment or property. A hazard is characterized by its frequency of occurrence (return period) and intensity (kinetic energy).

Disaster risk

It describes the potential direct and indirect dammage to people, animals and livelihoods caused by existing hazards over a certain time period. A risk quantification is based on a hazard analysis and a potential harm assessment. The Swiss Red Cross (SRC) has developed a methodological guide to quantify disaster risks and to calculate the cost-effectiveness of mitigation measures.

2. General Description of Hazard Processes

This guide presents the working steps for the analysis of landslide hazards and water processes. Illustration 1 shows the various existing subprocesses, which differ in water content and motion velocity.

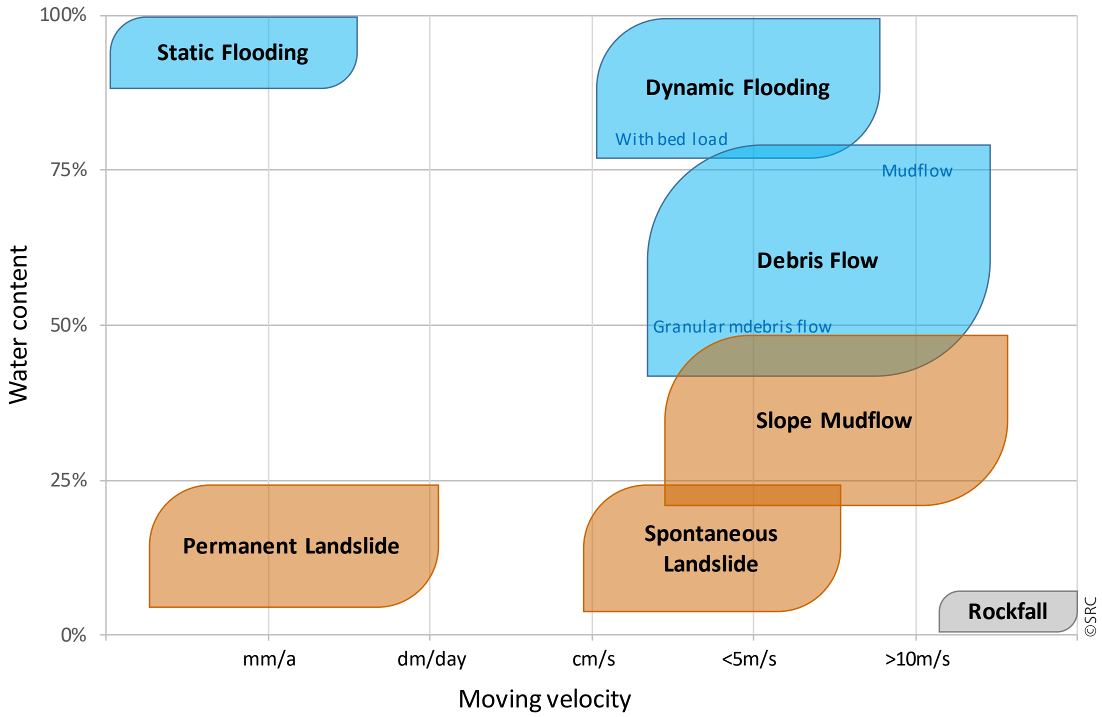

Illustration 1: Landslide processes are shown in brown; water processes in blue. Transitions between these processes are smooth.

3. Description of Landslide Processes

3.1 Permanent Landslide

Definition

Permanent landslides are continued motions of loose rock and soil material on one or more sliding surfaces. Two motion mechanisms can be identified. In rotational landslides (Illustration 2, left), the mass slides along a concave cracked surface. Ditches and cracks can be seen in the landslide's rupture area. The pressure of the sliding body causes a bulge in the front. If single layers or entire bundles of layers slide down on a sloping planar surface, this is known as "translational landslide" (Illustration 2, right). Often, mixed forms of translational and rotational landslides occur.

Characterization

The motion distance is often less than the size of the landslide, which area can be up to several square kilometers. The thickness of the sliding masses can be up to several tens of meters. Motion rates vary from just a few millimeters per year to several decimeters per day. They depend mainly on precipitation, rock properties and soil type and moisture. The hazard degree is determined by the average annual mass displacement and the potential for motion intensification (reactivation potential). If permanent landslides have a steep surface, deep spontaneous landslides (section 3.2) and slopetype mud flows (section 3.2) may occur.

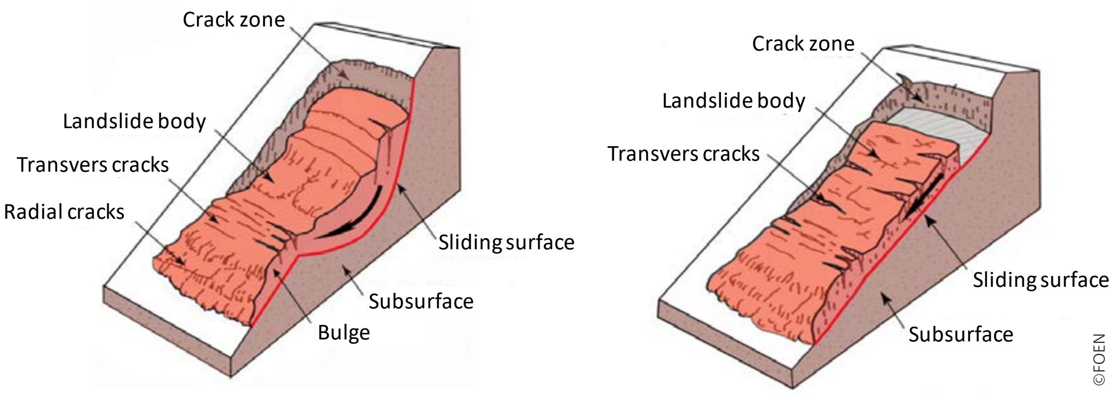

Illustration 2: A circular sliding surface is typical for rotational landslides (left). Sliding planar surfaces form the basis for translational slides (right).

Illustration 3: Permanent landslide (rotational landslide) on Guarin Hill, Honduras.

3.2 Deep Spontaneous Landslide

Definition

Deep spontaneous landslides include rotational or translational landslides, which occur spontaneously, mostly with signs of previous motion. Their volume can be as large as several million cubic meters. Sites with deep spontaneous landslide potential are rare.

Characterization

Deep spontaneous landslides often occur on the steep slopes of permanent landslides (e.g. caused by stream erosion at the front of the landslide). Long-term precipitation and earthquakes often triggers deep spontaneous landslides. The probability of occurrence depends on the underground material, the velocity of the landslide, the hydrogeological conditions and the degree of erosion at the front of the landslide. In particular cases, the potential for a deep spontaneous landslide can be determined on the basis of morphological silent witnesses. But as a general rule, detailed expert studies are required to assess the hazards in these cases. For this reason, this guide does not provide guidance on the assessment of this process.

Illustration 4: Deep spontaneous landslide.

3.3 Slope-type Mud Flow

Definition

Slope-type mud flows are a very frequent type of landslides involving a mixture of loose material and water. Most of them are superficial processes that flow spontaneously and quickly due to underground water oversaturation or seismic activity. They often lack the formation of a clear cracked base surface.

Characterization

Due to the high water content of the moving mass, the length of the flow range largely exceeds the length of the crack area. The thickness of the sliding masses ranges from decimeters ro a few meters. Flow velocities can reach more than 10 m/s (36 km/h); therefore, they often have a destructive effect on buildings and infrastructure. A hazard assessment is based on the expected thickness of the landslide masses in the initiation and deposition areas, as well as on the frequency of occurrence.

Illustration 5: Mid-depth slope flow.

4. Description of Water Processes

4.1 Debris Flow

Definition

Debris flows are a rapidly flowing mixture of loose material, vegetation and water. They only occur in steep torrents. Debris flows can be triggered by the rupture of temporary water course clogging (torrent blockages by rocks and floating trees), by lateral landslides, or by riverbed erosion. There is often no linear relationship between the amount or intensity of precipitation and the occurrence or volume of flows (see chapter 6). Debris flows are often discharged in several surges with strongly varying discharge. The material composition is highly variable. Fine materials and water prevail in mud flows, while thick blocks are only sporadically moved. In granular debris flows the proportion of large particles predominates.

Characterization

The main characteristics of debris flows and their footprints on the ground are listed below and presented in Illustration 6:

- Different sized blocks and stones are transported without grain size sorting
- The proportion of solids (stones, blocks) is often 30 to 50%
- Strongly variable flow rate during the event
- Sediments are especially deposited after the watercourse has been widened or when the riverbed abruptly reduces its slope
- Typical forms of deposits: lateral „snakes“ (Levées, Illustration 7)

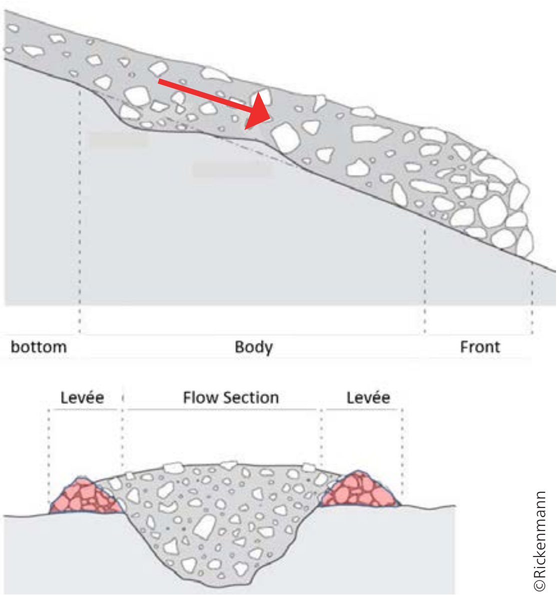

Illustration 6: Longitudinal and cross sections of a debris flow. In the cross-section, it is possible to see the adjacent lateral levées left by a flow as morphological silent witnesses.

Illustration 7: Deposits of a debris flow in Bondo, Switzerland (left). Debris flow in Illgraben, Switzerland (right).

Debris flows can reach velocities up to 60 km/h. In major events, several 100,000 m3 of blocks, stones and fine particles can be pushed through. The distance travelled by the flow depends on the amount of solids transported, the water content, the torrent slope and the riverbed roughness.

4.2 Flood

Definition

A flood is defined as an overflow of water from a natural or artificial water course, or an accumulation of water outside a channel due to ground oversaturation. There are two types of floods: dynamic and static.

Characterization

Dynamic floods can cause high-velocity runoff and flow energy. The erosion of embankments or riverbeds can lead to the transport of sediments that are deposited in the surrounding area during flooding. Usually a flood is of short duration. A hazard is characterized by the maximal flow hight and flow velocity, and by the frequency of floods.

Static floods occur in morphologic depressions when the soil is oversaturated after prolonged precipitation. A hazard is characterized by the water depth and the frequency of floods.

Illustration 8: Static flood (left) and medium intensity dynamic flood (right).

5. Interaction between processes

When different processes occur in the same place or at the same time, they can mutually affect and reinforce each other. For example, riverbed erosion can destabilize adjacent slopes and trigger landslides. This in turn can lead to temporary clogging of the watercourse. A debris flow can occur when this clogging is bursting. Another example is water infiltration into a steep slope due to inundation, causing landslides. These interactions must be taken into account in both hazard assessment and design of mitigation measures.

6. Event Triggers

For a natural hazard to occur, there must exist a general susceptibility to the formation of such an event. Also, there must be a triggering factor that will activate the event. General susceptibility is described by a basic disposition and a variable disposition, according to Illustration 9. The trigger is mostly precipitation, but it can also be an earthquake. The basic disposition (the „character") remains consistent over a long period of time; it includes aspects of relief, geology and climate. The variable disposition (the "mood") is understood as the fluctuating predisposition. Season, weather conditions, groundwater balance or vegetation status are aspects of variable disposition. An event is therefore not only dependent on the trigger (e.g. precipitation), but also on the simultaneous occurrence of a larger variable disposition. This interaction between disposition and trigger must be taken into account in the hazard assessment. It explains why there is often no mathematical relationship between the precipitation amount or intensity and the event occurrence or intensity, especially in the case of landslides and debris flows. These correlations justify the geomorphological approach to the hazard analysis followed in this guide.

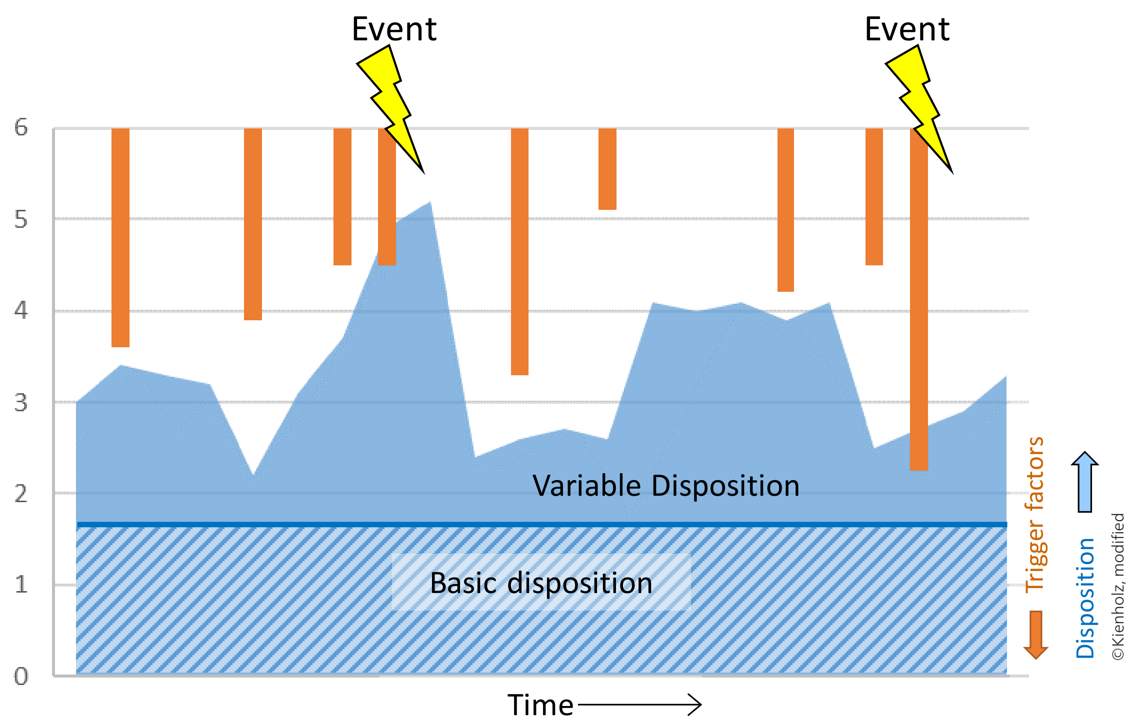

Illustration 9: Disposition and event triggering (e.g. precipitation as a trigger for a debris flow with a specific disposition).