SRC International Cooperation

Hazard Analysis of debris flow processes

Description of working steps for debris flow hazard assessment

Minimal standard

Swiss Red Cross

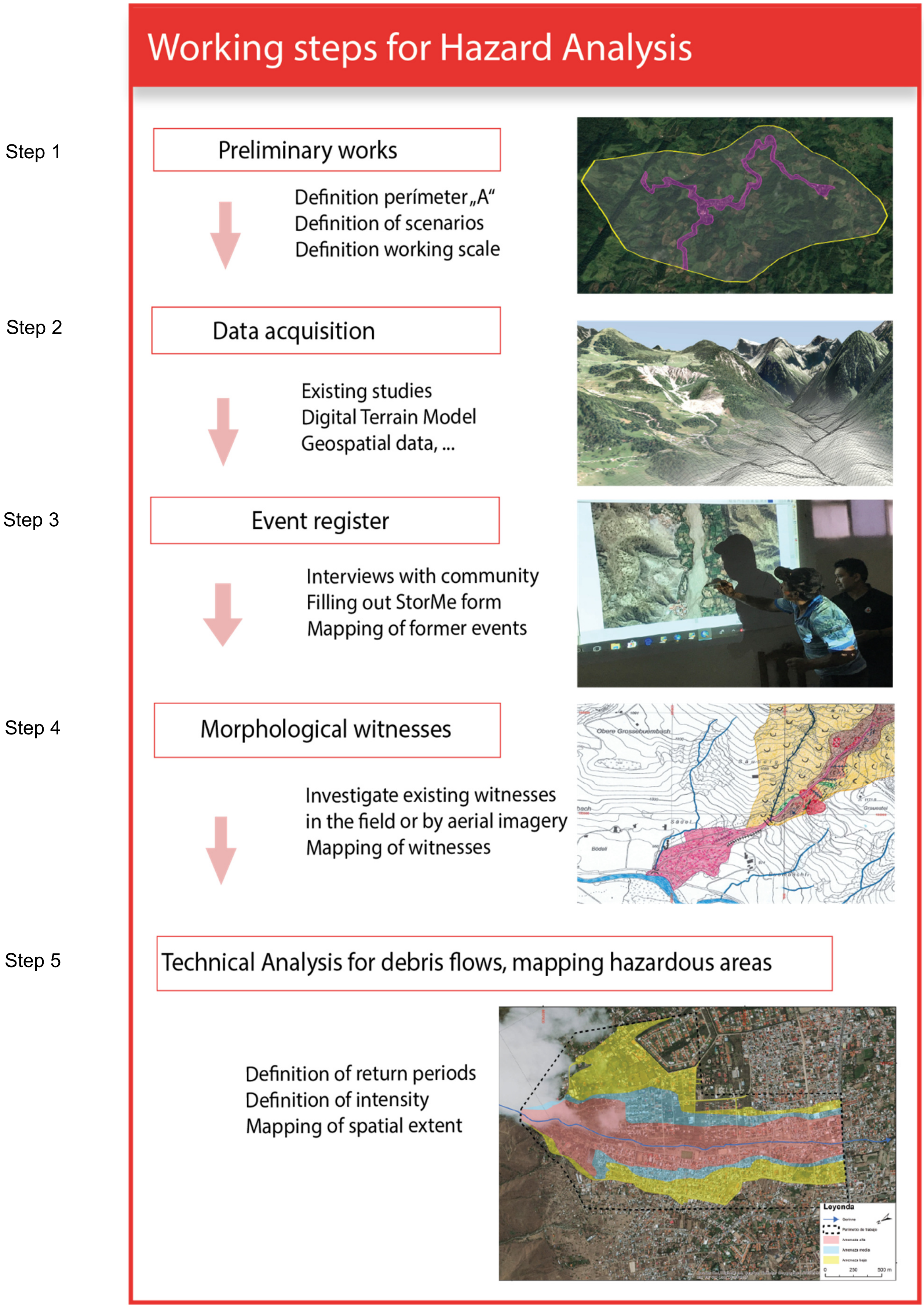

Illustration 1: Working steps for the analysis of debris flows, minimum standard. Source: SRC.

Step 1 – Preparatory Work

Definition of the perimeter and the level of detail of the analysis

Before starting a hazard analysis, the study area should be spatially defined and captured on a map. As a general rule, the perimeter of a hazard map is smaller than the project area and includes areas for settlements, infrastructure facilities and important livelihoods. Therefore, the perimeter of the hazard mapping must be limited to these existing or designated areas (perimeter "A"). By limiting the perimeter to relevant areas, it is possible to save time and costs. Areas outside this borderline should also be explored if they affect this perimeter. Illustration 2 shows the project area (in yellow) and perimeter "A" of a hazard mapping (in purple). Perimeter "A" is defined jointly by the communities and competent authorities. In tenders for hazard mapping, perimeter "A" must be defined in the terms of reference. The detail level of the analysis must also be determined. Scale accuracy between 1:5,000 and 1:10,000 is appropriate for landuse and mitigation measure planning at the municipal level.

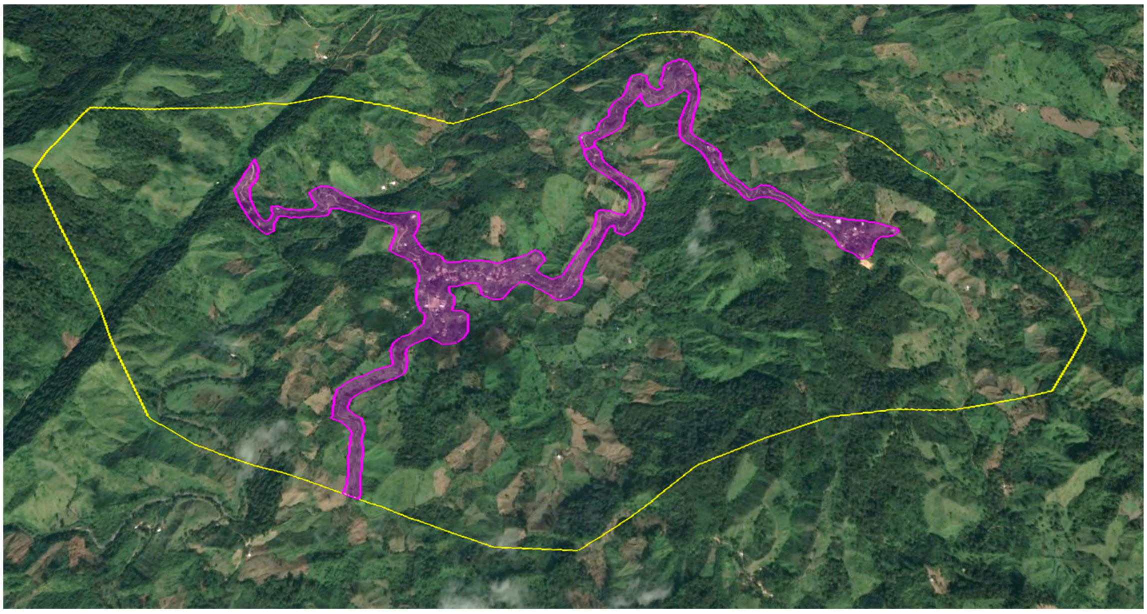

Illustration 2: Drawing of a project perimeter (yellow area) and perimeter "A" of a hazard map (purple area).

Definition of scenarios

The scenarios for the study (return periods to research) are usually specified by the authorities. If no specifications exist, it is recommended to consider three research scenarios, which are often applied with return periods of 10, 30 and 100 years, equivalent to a very frequent event, a generational event and an extreme event, respectively (see table 1). Typically, hazards from frequent and, sometimes, generational events can be reliably determined with the minimum standard. To determine an extreme event hazard, it is advisable to apply the advanced standard, as in a normal situation there is lack of information on events that have occurred within this scenario.

Table 1: Scenarios and their return periods. Source: SRC.

Type of event	Frequent event	Generational event	Extreme event
Name of scenario	„10-year“	„30-year“	„100-year“
Return period	≤ 10 years	10 – 30 years	30 – 100 years
Frequency of occurrence within 30 years	> 3 times	1 – 3 times	< 1 time

Step 2 – Baseline Data Collection

Baseline data provide valuable information on past events with their extent, return period and intensity. The quality of a hazard analysis relies primarily on the availability of baseline data, such as:

- Topographic map or satellite photos as a cartographic base
- Local reports from previous events (VCA, etc.)
- Photos of events and damage occurred
- Articles in newspapers
- Georeferenced aerial photos from different dates
- Geometry of watercourses (longitudinal and transverse profile measurement)
- Studies of mitigation measures
- Previous hazard studies

Step 3 – Event Register

The analysis of past events is a core component of a hazard analysis. Particularly for very short return periods, the information obtained may be sufficient to describe a hazard in the relevant scenario. For scenarios with long return periods (extreme events), data serve to verify the results of technical analyses. The documentation process of these events allows for taking into account the local population's knowledge on natural hazards. It also serves to raise awareness and help the population to take ownership of the hazard map.

The IFRC's VCA methodology describes methods and tools to collect information from past events in a participatory manner. Particularly interesting is the frequency and spatial extent of the debris flows occurred. In addition, the observed flow height of debris flows [m] should be mapped at as many locations as possible and recorded using the StorMe form (Annex 1). Two pragmatic approaches are presented below:

Aerial Photo-based Approach

- A facilitator projects an aerial photography of the perimeter of interest (GoogleEarth) on a white paper (Illustration 3).
- Through an exercise with the plenary, the facilitator ensures that all participants can orient themselves using aerial photography.
- In a participatory procedure, the spatial extent of previous events is marked on the white paper. Each event area is assigned with the date of the related event and the type of hazard process (event index). This is linked to the StorMe forms (Annex 1) attached to each documented event.
- In the plenary, known damage and event information are compiled into the StorMe form. For this, the facilitator appoints someone who has previously become familiar with the form so that he/she can be responsible of the protocol. The StorMe form is referenced with the event index on the photo displayed.

Illustration 3: Mapping carried out by the population on areas affected by previous events (Poco Poco, Bolivia). Source: SRC.

"Field Tour" Approach

After meeting with the community or when participants cannot orient themselves with aerial photos, they are invited to tour the area of interest. The information collected in the field is entered into the StorMe form. For the debris flow process, points will be mapped where there is information about the flow height and velocity of the overflows occurred.

Illustration 4: Photo of a debris flow event in Lima, Peru. Spatial extension and flow height will be documented in the StorMe form.

Step 4 – Morphological Silent Witnesses

In areas with insufficient data, as well as for quality control of the technical analysis results, it is needed to map the geomorphological silent witnesses of previous debris flows. Documenting and interpreting these silent witnesses in the field will lead to similar conclusions about future events in terms of their possible spread, intensity and frequency of occurrence. For debris flows, in particular, traces of past events can usually be found. A mapping is mainly carried out through on-site inspections, but it can also be complemented with information from aerial photographs or geological maps. A scale of 1:10,000 is recommended for mapping, using the symbolism as shown in Annex 2.

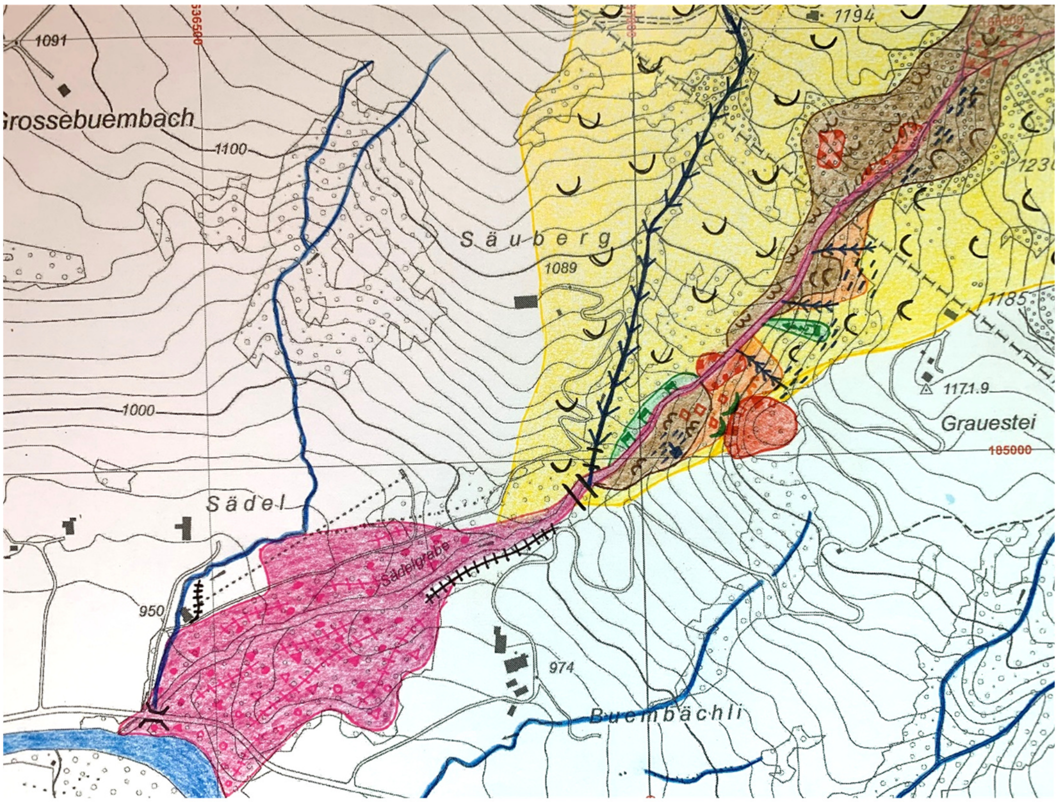

Illustration 5: Detail of a morphological silent witnesses map of a basin in Schangnau, Switzerland. The corresponding key is presented in Annex 2. Source: SRC.

Here are examples of morphological silent witnesses of debris flows:

Illustration 6: Steep cone with sharp morphology (Vallecito, Chile).

Source: Geotest Chile SpA.

Illustration 7: The blocks deposited on the riverbed or in the cone area have rounded edges. The size of particles in the deposits is very variable (Macul, Chile).

Source: Geotest Chile SpA.

Illustration 8: Along the riverbed or on the cone there are Levées, whose axes point in the direction of the flow (Cochabamba).

Source: COSUDE Bolivia.

Illustration 9: As a result of the blocks transported, the tree vegetation may have bark lesions (red arrows).

Source: COSUDE Bolivia.

Illustration 10: Historical images showing the spatial extent of previous debris flow events.

Source: Helvetas Intercooperation.

Step 5 – Technical Analysis of Debris Flows

Debris flow hazards are determined on the basis of morphological silent witnesses (deposits) and the event register. Topographical maps or aerial photos are essential for site inspections. As a general rule, the basin should be explored from the lower parts to the upper ends. For analyzing extreme event scenarios or if the traces of morphological silent witnesses are blurred, it is recommended to apply the advanced standard.

Step 5.1: Assessment of debris flow propensity

This step clarifies if the torrent under study has the characteristics for generating debris flows. If the following criteria are met, propensity can be assumed:

- The overall slope between the upper end of the area of possible debris flows and the lower end of its deposits on the cone is > 15 %.

- Slope of the watercourse cone is > 8 %.
- Extensive sediment sources on the slopes and in the torrent riverbed.
- Morphological footprints of historical flows along the watercourse and on the cone (morphological silent witnesses).

If these criteria are not met, the watercourse should be assessed according to the "flood" methodology.

Step 5.2: Definition of the maximum extent of debris flows

An area is likely to be safe from debris flows if the slope of the cone is less than 8 % over an area of several hundred meters and no corresponding morphological phenomenon are detected. Information from the event register also helps to determine the extent of debris flows. Surrounding areas may be affected by floods if there are free flow trajectories. The hazard assessment in these areas should be conducted using the "flood" methodology.

Step 5.3: Definition of the intensity

The intensity of the process is determined based on the expected flow height and its velocity as shown in Table 2. Under international guidelines, no low intensity is defined for debris flows. Within the framework of the minimum standard, the intensity classification of areas threatened by debris flows is based on the deposit thickness of the observed morphological phenomena (Levées).

Table 2: Differentiation of debris flow intensities and the degree of impact on people and material assets. Source: SRC.

	Intensity		
	Low	**Medium**	**High**
Flow height h [m]	-	< 1.0	> 1.0
Flow velocity v [m/s]	-	< 1.0	> 1.0
People affected	-	Fatal outside buildings	Fatal inside and outside buildings
Assets affected	-	Significant damage	Structural destruction to be expected

Examples of debris flow intensities

Illustration 11:

Medium intensity: The area outside the torrent is covered by debris. It is possible that medium damage may occur in reinforced concrete buildings, but their stability is still ensured. Adobe and wooden houses can be destroyed.

Illustration 12:

High intensity: Reinforced concrete buildings can be destroyed by the high flow energy and large amounts of deposits. Source: Geotest AG.

Step 5.4: Definition of the return period

The return period allocation of the flows is uncertain, especially for the minimum standard. Table 4 provides guidance on the estimation of return periods, based on morphological evidence, event register and vegetation succession. When at least 3 criteria are applied, the corresponding return period is designated.

Area	Subject	Return period < 10 years	 10 – 30 years	 30 – 100 years
Basin	Susceptibility to slope-type mud flows	High in large areas	Medium in large areas	Low in large areas
	Permanent landslides	Large areas with permanent high intensity landslides flow into the torrent	Medium intensity permanent landslides flow into the torrent	Permanent landslides of low intensity with reactivation potential flow into the torrent
	Material in watercourse and alluvial terraces	Loose material easy to be transported on slopes > 8 %	Torrent riverbed made of thick blocks, easily erodable alluvial terraces	
	Cloggings	Existing cloggings in the watercourse, poorly consolidated in erosion sections with slopes > 8 %	Existing cloggings in the riverbed with slopes > 8 %, without much erosion potential but with forested slopes	
Cone	Vegetation	Recent visible damage/injury to the cone vegetation due to debris flows	Vegetation of young trees in the bed and on the slopes of the watercourse (the succession depends on climate conditions)	
	Age of deposits	Morphology of well-defined deposits without vegetation cover	Morphology of welldefined deposits with young vegetation cover	Blurred or worn traces in the cone, lots of vegetation in the deposits
	Event documentation	Several events documented in the last 10 - 20 years	At least one event documented in the last 10 - 20 years	No events or only extreme events documented

Table 3: Assessment matrix to determine the return period of debris flows using the minimum standard. Source: SRC.