

# > Protection against Mass Movement Hazards

*Guideline for the integrated hazard management of landslides,  
rockfall and hillslope debris flows*



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Federal Office for the Environment FOEN



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**Legal status of this publication**

This publication is a guideline issued by the FOEN as a supervisory authority and is primarily aimed at the implementing authorities. It substantiates indeterminate legal concepts from legal acts and ordinances and is intended to promote uniform and consistent enforcement. If the implementing authorities comply with this guideline, they can assume that their implementation activities are compliant with federal law; however, other solutions are also admissible as long as they comply with the legislation in force. The FOEN publishes guidelines of this kind (previously also known as guidelines, recommendations, handbooks, guides to practice etc.) in its "The Environment in Practice" series.

This guideline replaces the recommendations "Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten" (BRP, BWV, BUWAL 1997).

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## > Abstracts

This guideline explains the management of landslides, hillslope debris flows and rockfall processes. These natural hazards are identified and evaluated using state-of-the-art methods. The criteria of probability of occurrence and intensity are determined for the compilation of hazard maps. The evaluation of risks, definition of protection objectives and target measures and the determination of the action requirement is necessary for planning. The process to be implemented for the optimisation of measures incorporates the examination of all options for action. These include spatial planning, biological, structural and organisational measures. The evaluation of measures takes technical, economic, ecological and social criteria into account.

**Keywords:**

landslides, hillslope debris flows,  
rockfall, hazard evaluation,  
hazard map, protective measures

Die Vollzugshilfe erläutert den Umgang mit Rutschungen, Hangmuren und Sturzprozessen. Diese Naturgefahren werden mit modernen Methoden lokalisiert und beurteilt. Bei der Erstellung der Gefahrenkarte werden die Kriterien der Eintretenswahrscheinlichkeit und der Intensität bestimmt. Die Beurteilung von Risiken, die Festlegung von Schutzziele und von Massnahmenzielen sowie die Ermittlung des Handlungsbedarfs sind bei der Planung notwendig. Das Vorgehen bei der Optimierung von Massnahmen umfasst die Überprüfung aller Handlungsoptionen. Dazu gehören raumplanerische, biologische, bauliche und organisatorische Massnahmen. Die Bewertung der Massnahmen berücksichtigt technische, ökonomische, ökologische und soziale Kriterien.

**Keywords:**

Rutschungen,  
Hangmuren, Steinschlag,  
Gefahrenbeurteilung,  
Gefahrenkarte,  
Schutzmassnahmen

Cette aide à l'exécution indique comment traiter les glissements de terrain, les coulées de boue et les processus de chute. Ces dangers naturels sont localisés et évalués en appliquant des méthodes modernes. La carte des dangers est élaborée en tenant compte de la probabilité d'occurrence et de l'intensité des processus dangereux. La planification des mesures à prendre demande d'évaluer les risques, de fixer des objectifs de protection, d'assigner des objectifs aux mesures envisagées et de déterminer les travaux à entreprendre. La méthode préconisée pour optimiser les mesures inclut un examen de toutes les options concevables – mesures d'aménagement du territoire, biologiques, constructives ou d'organisation. Les mesures considérées sont évaluées en tenant compte de critères techniques, économiques, écologiques et sociaux.

**Mots-clés:**

glissement de terrain,  
coulée de boue, chute de pierres,  
évaluation des dangers,  
carte des dangers,  
mesure de protection

L'aiuto all'esecuzione spiega come gestire i scivolamenti, le colate detritiche di versante e i processi di crollo. Questi pericoli naturali vengono localizzati e valutati applicando metodi moderni. Nell'allestimento delle carte dei pericoli si determinano i parametri «probabilità di accadimento» e «intensità». Per la pianificazione delle misure occorre valutare i rischi, definire sia gli obiettivi di protezione che gli obiettivi delle misure e stabilire la necessità d'intervento. L'ottimizzazione delle misure richiede una verifica di tutte le opzioni d'intervento: dai provvedimenti di pianificazione del territorio a quelli edili, biologici e organizzativi. La valutazione delle misure considera criteri tecnici, economici, ecologici e sociali

**Parole chiave:**

scivolamenti,  
colate detritiche di versante,  
caduta sassi,  
valutazione dei pericoli,  
carta dei pericoli,  
misure di protezione





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## > Foreword

The Federal Act on Forest is intended to contribute to the protection of human life and important material assets against avalanches, landslides, erosion and rockfall. This guideline “Protection against Mass Movement Hazards” explains the legally compliant implementation of the provisions of this act. The starting point for the development of this new guideline was the 1997 recommendations *Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten* (“Consideration of mass movement hazards in activities with a spatial impact”), which have become established in expert circles. The basic principles of these recommendations have been retained in this publication. The new elements include the consideration of current research findings in relation to the evaluation of landslides and the provision of more detailed quantitative guidelines. Hence the temporal variation of velocity is now also incorporated into the evaluation process. The reactivation and acceleration of existing landslides are common causes of damage and destruction, hence greater significance is now attached to the hazard register. Measures for the management of mass movement hazards, for example monitoring and the operation of early warning services, are also presented in detail. Another new element is the evaluation of the probability of hillslope debris flows in five operational stages.

The FOEN submitted this guideline for consultation in autumn 2009 and in the year 2015 a working group comprised of federal and cantonal representatives took over the task of revising this guide. The maximum possible number of the numerous comments and suggestions made were taken into account in this final version. This guideline should be considered in the context of other FOEN publications on the topics of integrated risk management and flood protection. It also refers to the PLANAT publication *Sicherheitsniveau für Naturgefahren* (“Safety against Natural Hazards”) and the protection objectives contained in it (PLANAT 2013).

This guideline contributes to the establishment of the appropriate preventive management of mass movement hazards. It highlights the need for objective and comprehensible hazard documentation and risk evaluations. The sustainable and holistic management of mass movement hazards – that is integrated risk management – is only guaranteed if all measures are combined in an optimum way and economic and social criteria are taken into account. For this reason, action planning should aim to coordinate the associated spatial planning, biological, structural and organisational measures in an optimum way.

Josef Hess  
Vice Director  
Federal Office for the Environment (FOEN)

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## > Summary

The guideline “Protection against Mass Movement Hazards” explains how landslides, hillslope debris flows and rockfall processes are managed in accordance with the Forest Act (ForA). The second chapter describes the approach to be adopted in the production of hazard documentation. The reliability and effectiveness of existing hazard protection measures are taken into account in the hazard evaluation process. The requirements for hazard evaluation are determined on the basis of the specified objectives and can now be subdivided into three levels. Very stringent requirements apply for construction projects, reports and detailed studies (scale 1:1,000 to 1:5,000). A higher standard is also required for hazard maps, for which a mandatory level of spatial accuracy of around ten metres applies (scale 1:2,000 to 1:10,000).

The degrees of hazard for mass movements are determined using the intensity-probability diagram (chapter 2). Possible scenarios are used here as a basis for evaluation. The aim is to determine annual probabilities of occurrence corresponding to those used for flood and avalanche processes. The following intensity categories apply for rockfall processes: low <30 kJ, medium 30–300 kJ, high >300 kJ. A method is used for the evaluation of shallow landslides and hillslope debris flows which primarily improves the disposition analysis and determination of probability. Three average velocity intensity levels are applicable for permanent landslides (0–2 cm/year, 2–10 cm/year and  $v > 10$  cm/year). Possible accelerations and differential movements are incorporated based on the insights gained from event analyses. For this reason, additional criteria have been introduced for the determination of intensities: a) accelerations of landslides corresponding to the maximum speed; b) differential shifts; and c) depth of the sliding surface. The criteria applicable for hillslope debris flows are depth and depositional height. Collapses and subsidence (e.g. in sinkholes) are evaluated when clear indicators of spatial expansion are detected in the field.

The third chapter explains the determination of risks and definition of protection objectives. The federal authorities aim to attain a comparable level of safety against all natural hazards throughout Switzerland that is ecologically justifiable, economically proportionate and socially acceptable. With the help of protection objectives, the public authorities establish the areas in which they need to take action. In the event of a protection deficit, they examine whether the risk can be reduced with the help of suitable measures. The responsible actors define specific objectives when planning such measures.

The fourth chapter provides explanations of the planning and implementation of protective measures. During the planning and optimisation of measures, all possible action alternatives are examined. The extent of the possible damage arising from a hazard event is reduced using passive protection measures. The cantons take the hazard maps into account in all activities with a spatial relevance or impact, in particular in the cantonal structural and land-use planning. The damage potential should be minimised primarily by means of spatial-planning measures. The course of a hazard process is

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influenced using active protection measures. These include extensive measures like protective forest maintenance and afforestation and individual structural measures like rockfall nets. Structural protective measures may be adopted in areas, in which a land use or function worth protecting already exists, or in which a change in use or function is essential following the evaluation of all associated interests. For technical or economic reasons, however, it is not possible to provide structural protection against mass movements in all cases, in particular in cases involving large volumes and high energy levels. If it is not possible to provide complete protection for a hazard zone for such reasons, monitoring, alerting and warning systems can nonetheless provide a cost-efficient way of protecting human life. Four different levels with different requirements have been defined here. High safety requirements for early warning systems apply when people have to be evacuated and transport routes closed.

Technical explanations and the information necessary for the implementation of the processes described in the preceding chapters are provided in the Appendix. Following the presentation of the basic legal documents, definitions and explanations of the different types of mass movements, information on the spatial-planning application and the risk-appropriate definition of protection objectives are summarised in the other appendices.

# 1 > Legal Documents and Concept

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## 1.1 Introduction

Areas with known mass movements account for 6–8% of the territory of Switzerland; this includes slide processes that are both currently active and were active in the past. The regions most affected by these processes include the Alps, the Pre-Alps, and some parts of the Jura region. The importance of mass movements prompted the federal authorities to formulate recommendations for the consideration of mass movement hazards in 1997 (BRP et al. 1997). The cantons subsequently embarked on the hazard evaluation of mass movements. Based on the experience gained in these cantonal processes, proposals for additions to the recommendations have been submitted to the federal authorities in recent years. The *Arbeitsgruppe Geologie und Naturgefahren* (Working Group on Geology and Natural Hazards) compiled a report in 2004 (AGN 2004) which proposed additions to the existing method based on practical experience. The analysis of the storms of 2005 and 2007 showed that, in some cases, the reactivation and acceleration of slide processes had been underestimated in the past. Moreover, slopes, which had not previously been recorded or evaluated, had also become unstable in the storms. These events, which involved movements of large volumes of mud and debris, caused direct damage and the flow of material into torrent channels, in which debris flows then formed. The analysis of shallow landslides and hillslope debris flows also led to the improved evaluation of the disposition of these spontaneous processes.

The federal recommendations *Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten* (“Consideration of mass movement hazards in activities with a spatial impact”) were jointly published by three federal authorities (the then Federal Office for Spatial Development [BRP], Federal Office for Water [BWV] and the Swiss Agency for the Environment, Forests and Landscape [BUWAL]) in 1997 and provided the basis for the development of this guideline. The basic principles of this publication are retained, however more detailed quantitative data are provided for the approach to be adopted. It is aimed to achieve a ‘*unité de doctrine*’ and uniform hazard evaluation of rockfall, landslides, hillslope debris flows and erosion processes. The federal authorities also provide information about possible hazard protection strategies in this guideline document.

## 1.2 Legal bases

With regard to the area of hazard documentation, this guideline is based on Article 15 of the Federal Ordinance on Forest of 30 November 1992 (ForO). According to this article, the cantons are responsible for compiling the basic documentation for protection against natural hazards, in particular hazard registers, measure registers, hazard maps and organisational measures (para. 1). When developing this documentation, they consider the work and technical guidelines carried out and defined by the specialist

federal agencies (para. 2). This guideline provides instructions on how the hazard documentation, in particular, the hazard maps, are developed by the cantons and is intended to ensure that the geological mass movement hazards throughout Switzerland are recorded on the basis of uniform criteria and standards. The generally valid criteria can be applied analogously in the management of flood hazards and avalanches. Hence, identical principles are applied to the management of natural hazards and this ensures the consistent implementation of the provisions of the Forest Act and Hydraulic Engineering Act in relation to the compilation of hazard documentation. The cantons take the documentation into account in all activities with a spatial relevance or impact, in particular structural and land-use planning (para. 3). They make the documentation available to the Federal Office for the Environment (FOEN) on request and to the public in a suitable form (para. 4).

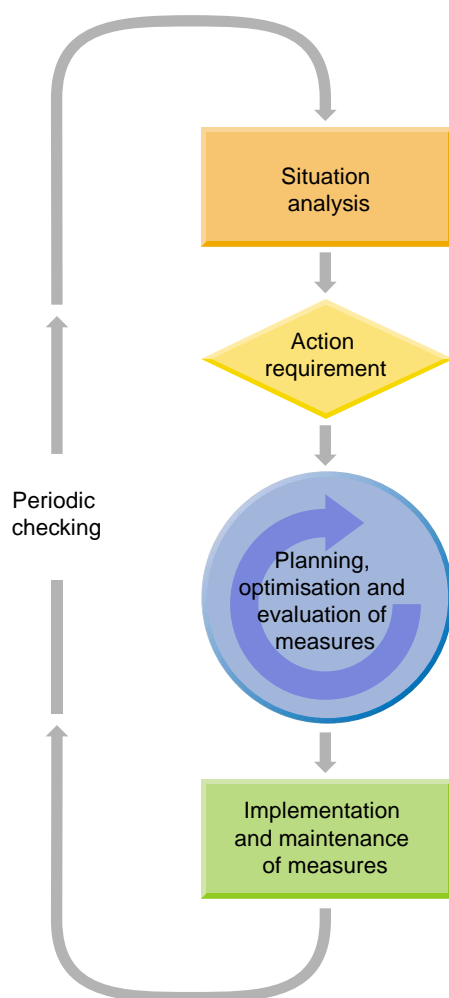
With regard to topics that go beyond the area of hazard documentation (see chapters 3 and 4), this guideline is based on the general supervisory powers of the FOEN in relation to protection against mass movement hazards, which authorise the FOEN to substantiate legal concepts that are not precisely defined, and in this way promote consistency of practice in the enforcement of the legislation.

Extracts from the relevant legislative articles and ordinances are provided in Appendix A1.

### 1.3 Concept of the new guideline

In terms of its concept, this guideline adopts the principles applicable to the management of natural hazards and explains the process to be followed in the production of hazard documentation (Fig. 1). The associated requirements and methods are presented in chapter 2 “Situation Analysis”. The action requirement is examined and the protection objectives are defined before the planning of measures (chapter 3). The mandate for the protection of human life and important material assets can be fulfilled if the planning and implementation of measures follow the requirements specified in chapter 4. Chapters 2 to 4 constitute the main part of the guideline and substantiate the legal concepts specified in the legislative acts and decrees. Technical explanations and additional information that does not qualify as legal guidelines are provided in the Appendix.

Fig. 1 > Procedure to be followed in the management of natural hazards



As far as possible, the new guideline adopts the recognised principles and specifies the details of certain requirements (see Fig. 1 for the general procedure to be followed). Apart from the details specific to the hazard processes, the hazard evaluation, action planning and evaluation processes are basically comparable to the practices implemented for flood protection.

The main innovations presented in the guideline are:

- > Improved definition of the hazard processes in Appendix A2: rockfall, landslides and hillslope debris flows are common events in Switzerland. Detailed definitions and hazard evaluation criteria are provided and explained for these processes. The process combinations and transitions are defined by means of the differentiation between initial and secondary processes ('first move', 'second move').
- > The requirements in relation to hazard evaluation are determined by the objectives set and the legal status of the results. Accordingly, the requirements presented in chapter 2 are differentiated on the basis of three levels of processing. Very high re-

quirements apply for construction projects, reports and detailed studies. In this case, uncertainties should be minimised as much as possible in the evaluation and possible structures should be correctly dimensioned. Binding hazard documentation must be compiled for the authorities in the context of the hazard maps. In this case also, a higher standard is required with a spatial accuracy of around ten metres.

- > The evaluation of mass movement events should be carried out using possible scenarios. Annual probabilities of occurrence (0.033, 0.01, 0.003, <0.003) should be determined which correspond to the return periods for flood and avalanche processes (30, 100, 300, >300 years).
- > The degrees of hazard for mass movements are determined using the intensity-probability diagram. Three intensity levels based on average velocity apply for permanent landslides. Based on the insights gained from event analyses, possible accelerations and differential movements are given stronger weightings. New additional criteria have, therefore, been introduced for the determination of intensities:
  - Acceleration or reactivation of landslides corresponding to the maximum velocity during a crisis ( $v_{\max}$ ).
  - Differential shifts (D). The greatest damage usually arises in differential shift zones because the rock slides downhill at varying velocities (shearing process).
  - Depth of the sliding surface (T). From a depth of around 30 metres, intensity can be downgraded if all of the following conditions are fulfilled simultaneously: large cohesive sliding masses, phenomenologically homogenous areas and geotectonically substantiated uniform movement.
- > A new method for the evaluation of shallow landslides and hillslope debris flows is introduced in this guideline. Geological and geomorphological analysis of past events provide statistical data which can be used in the determination of the probability of occurrence.
- > Detailed information about the evaluation of collapses and sinkholes is provided in this guideline, however red hazard zones for sinkholes should only be designated in the case of a demonstrated risk.
- > Icefall is evaluated analogously to rockfall hazards.
- > Generally valid principles are defined for the consideration of measures in hazard evaluation.
- > Protection objectives are defined on the basis of a risk-based approach. It should be aimed to achieve a high level of protection against major risks. No protection or minor expenditure are planned for minor risks (chapter 3).
- > The possible measures for protection against mass movements are presented in chapter 4 (spatial planning, biological, structural, organisational measures). Greater emphasis is now also being placed on organisational measures, particularly because these options often take priority in the case of rock avalanche and deep landslide hazards.

## 2 > Situation Analysis

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The cantons develop the necessary documentation for protection against natural hazard events (Art. 15 ForO). To enable the avoidance or reduction of risks, these hazards must be identified and evaluated. In the context of the situation analysis, the existing hazards are evaluated (chapters 2.2 to 2.10) and the existing and planned land uses and structures are surveyed (chapter 2.1). The areas in which people, material assets, infrastructure and other structures are potentially at risk from natural hazards can be identified from the combination of the hazard and land-use documentation.

The degree of detail in the analysis can vary considerably, i.e. due to the spatial perimeter (Switzerland, canton, region, commune, project) or as a result of the available documentation (nature, scale, content, etc.).

### 2.1 Land use

Land uses and object classes involve different levels of detail and are divided according to their function. For overviews of large spatial systems, a summary, e.g. based on the following main categories (objects of protection), is sufficient:

- > Persons
- > Buildings
- > Infrastructure (e.g. roads, railways) and Lifelines (e.g. power lines)
- > Cultural assets
- > Special objects

In the context of action planning, it is usually necessary to carry out a detailed survey as applied, for example, in EconoMe. This is obtained by coding the uses and structures on a more detailed level and, possibly also, supplementing additional information.

Irrespective of the degree of detail, when establishing the overview of the damage potential, in addition to existing uses, planned or future uses should be taken into account so that a picture is obtained of possible changes in the damage potential or risks. Information about future development is provided by the land use plans and communal structure plans. Other sources of information about planned developments include the federal sectoral plans, and if available the cantonal structure plans and the cantonal and regional development programmes.



## 2.2 Processes dealt with

The Federal Act on Forest is intended to contribute to the protection of human life and important material assets against landslides, erosion and rockfall (natural events) (Art. 1 para. 2 ForA). The following mass movement hazards are dealt with in this guideline:

- > Fall processes: rockfall (*Steinschlag*, *Blockschlag*), rock avalanche (*Felssturz*, *Bergsturz*) ice fall and collapses
- > Slide processes: landslides, rock slides and Sackungen
- > Flow processes: hillslope debris flows

Hillslope debris flows (*Hangmuren*) are evaluated according to this guideline. Channel-type debris flows (*Murgänge*) are dealt with in the recommendations on flood protection (BWW et al. 1997). The consideration of process sequences (e.g. landslides, hillslope debris flows, debris flows) is particularly important because the mass movements are often located at large distances from the damage potential.

The definitions of the processes associated with the mass movements taken into account are explained in Appendix A2. Snow avalanches are not dealt with in this guideline.

## 2.3 Basic information and documentation

The first phase in the management of mass movement hazards requires the judgement-free documentation of all of the available information, observations and measurements that point to an existing hazard. As part of hazard recognition, objective observations should be recorded that should be as free as possible from interpretation. It is essential that information be provided about the quality of the observations – i.e. whether they are based on estimates, calculations or measurements. Hazard recognition is based on a series of sources and methods. In particular, previous events and ‘silent witnesses’ are important indicators, even if protective measures have been implemented in the meantime.

### 2.3.1 Basic information and methods

The principles and methods for the evaluation of mass movement hazards are presented in brief. The natural hazard register and the map of phenomena will be presented in sections 2.3.2–2.3.4.

Topographical analysis is part of a holistic strategy that also includes orthophotos, elevation models, remote sensing data and thematic maps. Among others, slope-angle maps and relief images (‘hillshading’ or ‘hillshades’) can be generated from the elevation models, which serve the purpose of geomorphological mapping at a higher resolution.

Remote sensing includes all methods that are used from space, the air or terrestrially remote locations. It incorporates different physical methods:

- > optical images
- > radar images (microwaves)
- > laser images (LIDAR)

Satellite-, aerial- (e.g. small aeroplanes, helicopters, drones) or ground-based data collection are possible with optical, radar or laser images.

The term ‘surveying’ covers very different traditional and modern methods which are used to record displacements (e.g. GPS, Tachymeter). In the area of slope instabilities, the aim of all of these methods is to measure the displacement and determine the velocities involved.

The geological map forms an important basis for the mapping of mass movements, in which varying forms of movements like landslides and Sackungen are differentiated.

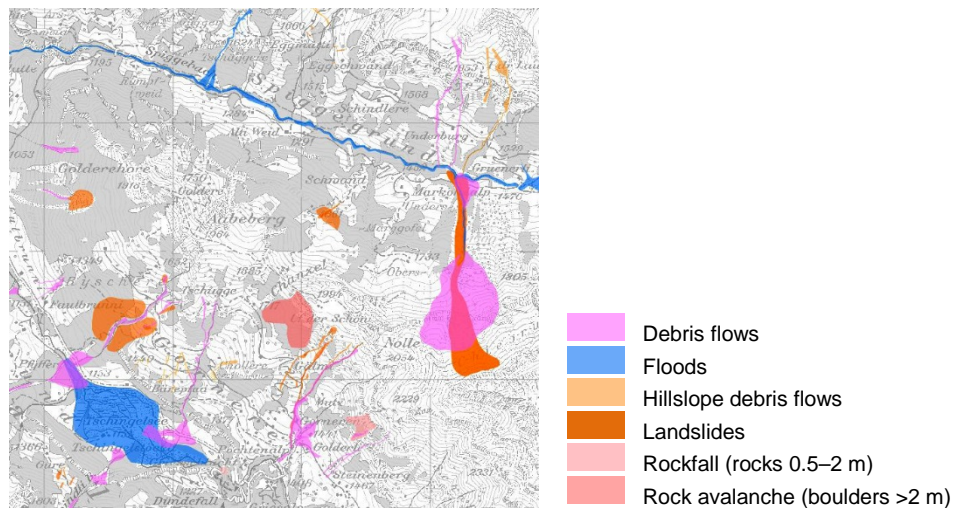
Water plays an important role in gravitational mass movements. For this reason, information about hydrogeological and hydrological conditions in the catchment area are required.

Boreholes can be drilled with an extracted core or with the destructive method using compressed air or water. Core drilling is the only certain method of determining the nature of the rock with depth and its geotechnical characteristics. Inclinoimeters, extensometers and piezometers, for example, can be installed in the borehole. An inclinometer can be used to identify an active deep sliding surface with certainty and quantify the associated movement.

### 2.3.2 Natural hazard register

To be able to forecast future events, it is necessary to look back at the past. The process areas and testimonies documented in natural hazard registers provide valuable indicators for the designation of potential hazard areas and help with the estimation of the return period, the definition of scenarios and in calibration of damage overviews.

The natural hazard register is operated by specialists at the cantonal departments and is regularly updated. The federal authorities provide standardised survey forms for the documentation of the hazard process type's avalanche, fall, slide, water and subsidence. The recorded information is managed centrally in a web database (StorMe). The events are represented spatially. At a minimum, the crucial processes, their sphere of action, the time at which they arose and the extent of the damage caused are documented. The meteorological environment may also be recorded as an option. The recording can involve different degrees of detail (see also “Data modelling” box, 2.3.4).

**Fig. 2 > Natural hazard register**

Geoportal des Kantons Bern, [www.apps.be.ch/geo](http://www.apps.be.ch/geo)

### 2.3.3 Register of protection works

In recent decades, it has been possible to safeguard a lot of settlements and transport infrastructure with the help of structures in the hazard release areas or using protective measures in the transit or run-out areas. To be able to guarantee the long-term protective effect of the numerous protective structures, regular controls and maintenance must be organised (monitoring of structural safety and fitness for purpose).

The register of protection works is an important instrument for this effective management of protective structures. This register contains, in particular, information about the nature, location, state, age and size of the structure or barrier in question. Information about the protected assets, the client, the construction costs, the maintenance plan, responsibilities etc. can also be recorded in the system. The federal authorities have specified principles and minimum requirements regarding the content, structure and management of a register of protection works. The specialist cantonal departments survey the necessary data and regularly update their registers (see also “Data modelling” box, 2.3.4).

**Fig. 3 > Rockfall protection net**



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#### 2.3.4 Map of phenomena

The map of phenomena records the geological-geomorphological features and indicators observed in the field in cartographic form. Terrain analysis is an important addition to the event documentation. It primarily presents facts in a cartographic form but should also incorporate the necessary judgement-free interpretations. It serves the identification and estimation of possible hazard types (disposition, release mechanisms, mode of action). The map of phenomena is produced independently of the degree of hazard which is determined at a later stage.

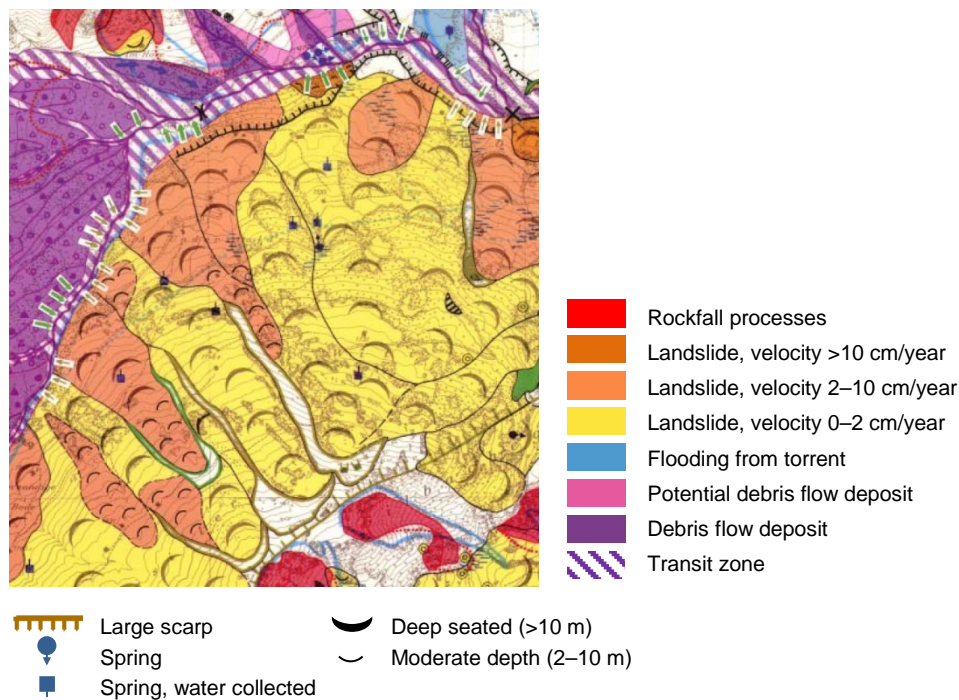
The terrain analysis is based on the observation and interpretation of site forms, vegetation, water conditions and 'silent witnesses' from past or current hazardous processes (e.g. fallen boulders). This often enables the establishment of the causes, probabilities of occurrence and other important factors in relation to hazard events (e.g. definition of the scenarios).

Hazardous processes and their manifestations are recorded and presented using a special standardised legend (Symbolbaukasten zur Kartierung der Phänomene, BWL und BUWAL 1995).

- > Scale: 1:2,000 to 1:25,000 depending on the intended use
- > Updating or verification: in the event of a new hazard situation or revision of the hazard map

**Fig. 4 > Map of phenomena**

Example produced using the symbol toolbox. A selection of the symbols relating to landslides is shown in the key to the map.



BWW et. al. 1995

### Data modelling and publication of the hazard documentation

*For those directly affected by natural hazards and the population in general to be as well informed as possible about the situation with respect to the danger posed by such hazards, the cantons make the hazard documentation available to the public in a suitable form (Art. 15 para. 4 ForO).*

*The careful and comprehensible description of the geodata or geodata sets is necessary to facilitate the further-processing and exchange of the recorded information. The data structure and content must comply with minimum requirements. Moreover, the Geoinformation Act (GeoIA, SR 510.62) and the associated Geoinformation Ordinance (GeoIO, SR 510.620) oblige the responsible federal authorities and the cantons to produce minimum geodata models (Art. 66a ForO). In accordance with Appendix I GeoIO a collection of geobasis data sets under federal law was compiled. In this context, the following geobasis data sets, which are published at [www.bafu.admin.ch/geodatenmodelle](http://www.bafu.admin.ch/geodatenmodelle) (German, French), must be published:*

- > “Hazard register” with the identifier 167.1 (corresponds to the natural hazard register, chapter 2.3.2)
- > “Register of flood protection works” with the identifier 81.2 (corresponds to the register of protection works, chapter 2.3.3)



*The data models developed by the federal authorities must be taken into account in the development of the aforementioned products by the cantons. These data models consist of two parts: the so-called “minimum data model” in accordance with the geoinformation legislation, which is mandatory in nature, and the “extended data model” which is recommended in nature.*

#### **Further information**

- > *Symbolbaukasten zur Kartierung der Phänomene, BWW und BUWAL 1995*
- > *Data models: [www.bafu.admin.ch/geodatenmodelle](http://www.bafu.admin.ch/geodatenmodelle) (German, French)*

## **2.4 Effect of existing protective measures**

The existing protection measures consist of protection forests, constructed protection works, and organisational measures. The influence of the protection forest should be considered for the hazard evaluation and documented in technical reports (e.g. after the method of Protect Bio).

Protective structures are built to provide protection against hazardous processes that is to reduce their intensity or probability. A sustained reduction in the risks to human life and material assets is only guaranteed, however, if the protective structures and measures fulfil the intended effect in the case of a hazard event. The functioning of the structure must be guaranteed now and in the future for the expected lifespan. In the evaluation of the functionality, the performance during conditions of overloading should be presented. Accordingly, the maintenance of protective structures is a top priority and requires long-term organisation.

Protective structures are subject to constant wear and tear and their condition must be examined regularly, particularly after hazard events. Many structures from the 19th and early 20th centuries are now reaching the end of their lifespan and must be replaced. In addition, the dimensioning of many existing structures is based on knowledge and experience from periods in which extraordinary hazard events were relatively rare (for example, the period between 1927 and 1977).

### **2.4.1 Taking the effect of protective structures into account in hazard evaluation**

Protective structures can only be taken into account in hazard evaluations if they are demonstrably reliable as this can have consequences for both the spatial planning and dimensioning of new protective structures. The evaluation of the effectiveness of protective structures against natural hazards involves three stages:

- > The first stage involves the implementation of a general evaluation. It includes an estimate of the relevance of the protective measures and makes it possible to decide whether further detailed consideration is necessary.
- > The reliability of the measure is evaluated in the second stage: this is based on the structural safety, fitness for purpose and durability of the structure (see box, 2.4.2).
- > The effect evaluation then quantifies the influence of the protective structure on the course of the hazard process. Different scenarios with corresponding intensities and probabilities are evaluated.

The effect of protective measures must be quantifiable and permanently available with a suitable degree of certainty (50 years). The consideration of protective structures necessitates the maintenance of the system as a whole and of the protective structures in particular. The condition of protective structures and the hazard situation must be verified periodically. They can also be monitored (see chapter 4.10). In the event of faults, the protective effect is no longer provided or additional hazards may arise. The protective effect can already be reduced by the failure of a single component to fulfil its fitness-for-purpose requirements. The situation is critical when the failure of an individual part can render the entire protective system dysfunctional.

The following principles also apply:

- > If the uncertainties in the process evaluation exceed the impacts of the measures, the measures cannot be taken into account.
- > Generally four scenarios are taken into consideration: scenarios with greater, medium and lower probability of occurrence and an extreme scenario with very low probability. Process chains and combinations must also be taken into account.
- > The measure should be viewed as an individual system and also in relation to the overall system.

#### 2.4.2 Taking organisational measures into account in hazard evaluation

In contrast to the permanent structural measures, precautionary organisational measures are not taken into account in hazard evaluation. Although the systems for monitoring, alerting and warning reduce the risks to human life (e.g. through closure) and material assets, they do not usually have any impact on the hazard process. In other words, temporary measures, the reliability and availability of which are not guaranteed in all situations, do not have any effect on the hazard map.

##### **Structural safety**

*Tests are carried out to ensure that the structure has sufficient load-bearing capacity to absorb the impacts resulting from the scenarios. If the structural safety/capacity is insufficient, the measure displays a low degree of reliability.*

**Fitness for purpose**

*Fitness for purpose is the capacity of a structure to guarantee functionality in terms of the defined use requirement (e.g. net height) during its use.*

**Durability**

*The requirements relating to the structural safety and fitness for purpose of a measure should remain fulfilled in the context of the predictable impacts.*

**Reliability**

*For a high degree of reliability, structural safety, fitness for purpose and durability must be fulfilled (measure completely effective). Limited reliability is characterised by the reduced effectiveness of the measure. In the case of low reliability (no or negative effect), the failure of the measure must be expected.*

**Evaluation of effectiveness**

*The evaluation of effectiveness is based on the reliability and quantifies the influence of the measure on the course of the process.*

**Further information**

- > Norm SIA 260: Grundlagen der Projektierung von Tragwerken (Principles of the design of load-bearing structures)
- > Norm SIA 261: Einwirkungen auf Tragwerke (Impacts on load-bearing structures)
- > Norm SIA 269: Grundlagen der Erhaltung von Tragwerken (Principles of the maintenance of load-bearing structures)
- > Norm SIA 269/1: Erhaltung von Tragwerken – Einwirkungen (Maintenance of load-bearing structures – impacts)
- > Romang H. (Ed.) 2008: Wirkung von Schutzmassnahmen (Strategie Naturgefahren Schweiz), Einzelprojekt A 3 (2008). Nationale Plattform Naturgefahren PLANAT, Bern.

## 2.5

**Requirements for hazard evaluation**

The requirements for hazard evaluation increase with the level of detail. A distinction is made between three levels based on different scales M1–3:

Level 1: hazard index map (approximate scale, M1)

Level 2: hazard map (medium scale, M2)

Level 3: studies for construction projects or detailed studies (detailed scale, M3)



### **M1: Requirements for hazard index maps**

The hazard index map provides an overview of the spatial manifestation of hazard processes and hence indicates where something can happen. It should indicate all areas that are affected by mass movements. The hazard index map does not contain any degrees of hazard defined on the basis of intensity and probability. They only show whether a potential hazard is present or not (yes/no classification).

**M1; scale 1**

### **M2: Requirements for the process involved in the production of hazard maps**

The hazard map is intended for use by the communes and cantons in the application of spatial planning (land-use plan). Hence it should divide the area being used according to the degrees of hazard as accurately as possible. Hazard maps are usually created on a scale of 1:5,000 or 1:10,000. The scale can also be more detailed in individual and special cases (e.g. 1:2,000). In terms of content and spatial resolution, the detail contained in a hazard map with five degrees of hazard is greater than that of the hazard index map.

**M2; scale 2**

Hazard maps, intensity maps and the associated technical reports contain detailed information about the causes, course, spatial extent, intensity and probability of occurrence of possible mass movement processes. The evaluation of mass movement hazards is based, first, on documentation that presents the existing hazards. Indications about the process and its spatial extent can be deduced for the hazard evaluation from previous events. These include observations, visual documents and measurements. The results are recorded in a natural event register and presented in cartographic form.

List of documents necessary for the dossier of the hazard map:

- > Natural hazard register, event documentation (StorMe)
- > Map of phenomena on a scale of 1:10,000 or more detailed
- > Register of protection works and evaluation of the effectiveness of the protective structures
- > Intensity maps for the scenarios with return periods of 30, 100, 300 years and as required for the extreme event
- > Technical report with all necessary calculations, models and explanations
- > Cross-sections or trajectories should be annexed to the map in the case of fall and major slide processes
- > Hazard maps with the five hazard levels and the perimeters of the evaluated areas

### **M3: Requirements for the process involved in the drafting of construction plans or detailed studies**

Construction projects and complex processes require in-depth processing that exceeds the standard level of detail provided in the compilation of the hazard maps. Such detailed studies can be used for the design of a protective measure, whose dimensions present a major risk or which is being planned for a particularly hazardous slope. Level M3 is also applied for sophisticated evaluations that may be controversial in the context of a report. A scale of 1:5,000 or bigger is usually used for a detailed map. Con-

**M3; scale 3**

struction projects, in particular structural measures, are represented at scales of 1: 2,000 or bigger.

On the level of construction projects (M3) that are subsidised by the federal authorities, all products of the hazard map (M2) must be available. Additional products will also be required and the ratio of costs to the consideration of the risk involved should be evaluated on a case-by-case basis:

- > Geological model including determination of material properties
- > Hydrogeological model if the influence of water is crucial
- > Quantitative information about displacements, velocities and shear deformation
- > Boreholes for high-risk deep landslides
- > Results of the modelling of fall processes, including energies and bounce heights at the location of the structural measures (for the dimensioning of the protective structures)
- > Modelling of slide and flow processes
- > Quantitative evaluation of the effectiveness of the protective structures
- > Intensity and hazard map prior to and following the implementation of measures

## 2.6

### **Cartographic hazard products**

To be able to manage risks, the associated hazards must first be described and evaluated. The main products of hazard evaluation are intensity maps and hazard maps. These provide a basis for the ensuing examination of the action requirement, the risk analysis (chapter 3) and the action planning (chapter 4).

The hazard maps present the mass movement hazards and the resulting danger to human life and material assets, environmental and other values in spatial form. Together with intensity maps and other documents, they form the basic prerequisite for making the hazards understandable for the authorities and affected persons. This is the only way that they will be able to check the action requirement and take suitable measures (implementation of preventive measures, management of extraordinary events etc.).

The hazard analysis must be carried out by recognised experts. The cantonal natural hazard offices are responsible for the development of the content. A lot of basic documentation has to be evaluated and surveyed. These concern not only the demonstrated processes in a given area, but also the suspected and conceivable ones (see chapter 2.10 for scenario definitions):

- > events that are documented;
- > events that cannot be demonstrated as having arisen in the location in question, but have arisen in comparable areas or situations;
- > events that, following the evaluation of all of the criteria, could arise in the process area in question.

The important products of the hazard evaluation processes are described in brief below.

#### 2.6.1 Hazard index maps

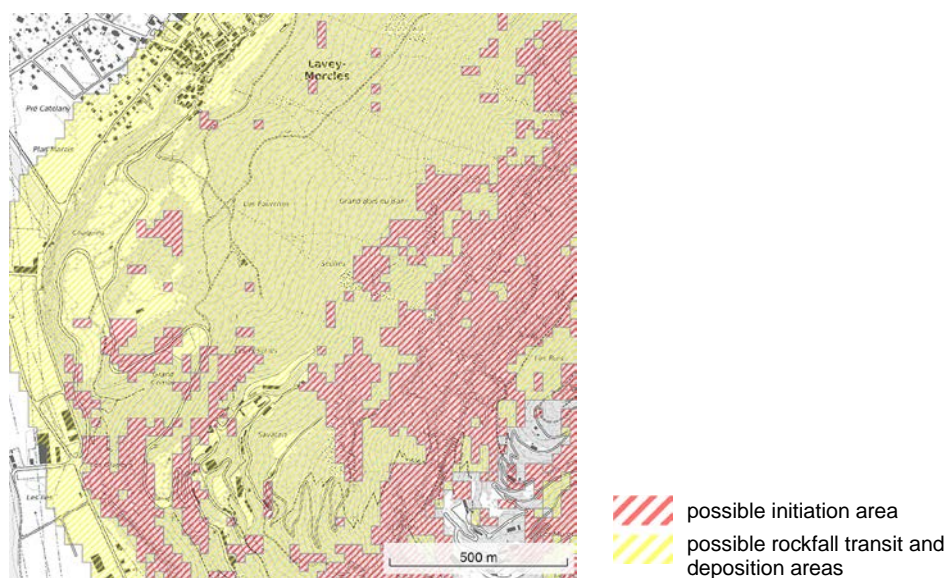
The hazard index map provides a rough overview of the hazard susceptibility situation. It covers large areas where potential threats exist but does not provide any information about the degree of hazard (Fig. 5). These index maps are produced individually for each type of hazard process. They can be based on geoscientific documents and model calculations and are substantiated using the natural hazard register. They may contain inaccuracies in relation to spatial demarcation, and the presence of a threat may not be precisely indicated in all cases. These maps only contain indications of hazard susceptibility and not verified facts. The hazard index maps are only used in locations for which there is no binding hazard map available (e.g. outside of settlement areas) or for specific overviews.

Possible points of conflict between hazard susceptibility and land use can be identified from the hazard index maps with relatively little expenditure.

- > Function: basis for cantonal structural planning, identification of areas of conflict, basis for the evaluation of planning applications outside the perimeter of the hazard maps, priority-setting in the development of the hazard maps
- > Depth of processing: low, can contain inaccuracies, not verified locally
- > Scale: 1:10,000 to 1:50,000
- > Perimeter: usually for a canton (or region/community)
- > Updating: periodically in the context of structural planning

**Fig. 5 > Hazard index map for rockfall hazards**

*The presentation of the hazard index map may vary (e.g. with a distinction in documented or suspected events or e.g. with modelled mass movement processes).*



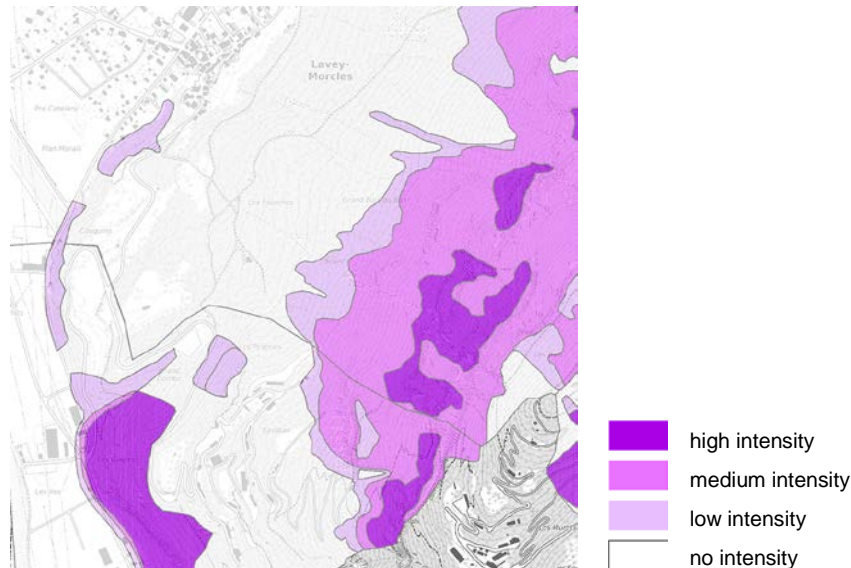
Canton of Waadt, project CDN-VD, GEODE-DN

## 2.6.2 Intensity maps

Intensity maps indicate the intensities of the hazard processes to be expected per probability class (high, medium, low, very low). Limit values are defined for the differentiation of the intensities for each hazard process. Depending on the process different parameters are used for the estimation of the intensity (e.g. the energies for the rockfall process, see chapter 2.9).

Accordingly, the intensity maps form the basis for the development of hazard maps, however they have many other possible applications. For example, information for the dimensioning of protective structures (energy absorption capacity, suitable location etc.) can be deduced from the energies and their spatial distribution.

- > Function: basis for the development of hazard maps and for risk analyses (EconoMe); instrument for use in emergency planning, local protection, design of protective measures
- > Content: intensities in four classes (low, medium, high and none) for each scenario
- > Depth of processing: high (similar to hazard maps)
- > Scale: 1:2,000 to 1:10,000 (similar to hazard maps)
- > Perimeter: region, community (not extensive; similar to hazard maps)
- > Updating: similar to hazard maps

**Fig. 6 > Intensity map for rockfall***Return period 100 years.*

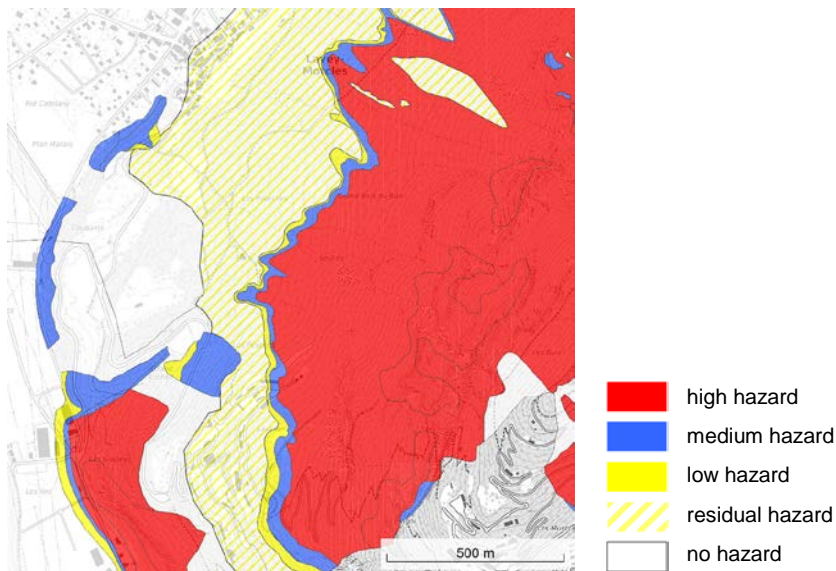
Canton of Waadt, project CDN-VD, GEODE-DN

### 2.6.3 Hazard maps

Hazard maps and the associated technical reports contain detailed information about the causes, course, spatial extent, intensity and probability of occurrence of natural hazards (Fig. 7). They are binding on the authorities. Hazard maps primarily constitute the expert basis for the consideration of natural hazards in the development of communal land-use plans (local plans). They are also important for the planning and mandating of measures in relation to local protection and for emergency planning. Hazard maps do not, however, indicate which risks are associated with the depicted processes.

- > Function: basis for adapted land use, the designation of hazard zones in land-use planning, the formulation of building regulations, action planning
- > Content: precise information about hazard types, the spatial extent of the hazard areas and degrees of hazard (5 degrees graded according to intensity and probability); detailed documentation
- > Depth of processing: high, high level of accuracy in relation to delimitation (plot-level)
- > Scale: 1:2,000 to 1:10,000
- > Perimeter: region, community, or subarea (not necessarily continuous coverage, i.e. in terms of the specified perimeter, the basis of which should be as broad and future-oriented as possible in the spirit of prevention)
- > Updating: period, e.g. in the context of the revision of land-use plans; in the case of a considerable change in the hazard situation (for example, following the implementation of protective measures or altered natural preconditions); if new evaluation methods and documentation enable substantially better evaluation; following hazard events (deviations from the scenarios or in the impact evaluation).

**Fig. 7 > Hazard map for rockfall hazards**



Canton of Waadt, project CDN-VD, GEODE-DN

### Data modelling and publication of the hazard documentation

*For those directly affected by natural hazards and the population in general to be as well informed as possible about the situation with respect to the danger posed by such hazards, the cantons make the hazard documentation available to the public in a suitable form (Art. 15 para. 4 ForO).*

*Geodatamodel:*

- > “Hazard map” with the identifier 166.1 (corresponds to the products hazard index map, intensity map and hazard map, chapters 2.6.1–2.6.3)

### Further Information

- > Hazard maps: [www.bafu.admin.ch/naturgefahren](http://www.bafu.admin.ch/naturgefahren) > Fachinformationen Wasser, Rutschungen, Sturz, Lawinen > Gefahrensituation und Raumnutzung > Gefahrengrundlagen > Gefahrenkarten, Intensitätskarten und Gefahrenhinweiskarten (German, French, Italian)
- > Data models: [www.bafu.admin.ch/geodatenmodelle](http://www.bafu.admin.ch/geodatenmodelle) (incl. model for hazard maps, German, French, BAFU 2015)

## 2.7 Hazard evaluation using the intensity-probability diagram

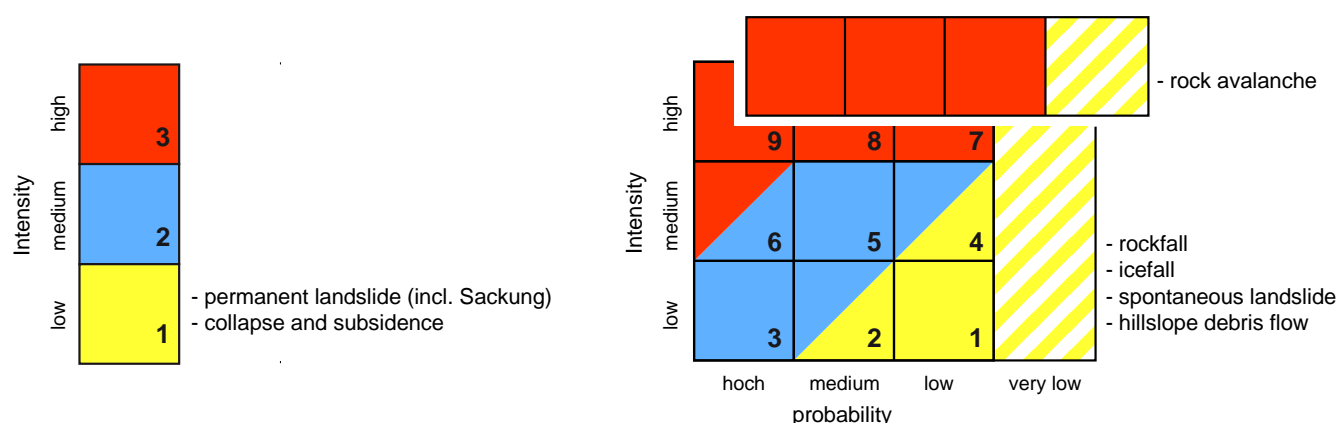
The compilation of the hazard maps was largely shaped by spatial planning objectives and thus incorporates only three degrees of hazard and a residual hazard zone for very low probabilities of occurrence. If no hazard or threat was identified in evaluated areas, these are left white on the map. The classification is carried out on the basis of uniform criteria in relation to the possible impacts on human life and material assets. The aim here is to assess all natural hazard processes on an equal basis. Comparability is urgently required for spatial planning measures and also in general and in the context of the erection of protective structures. These general criteria are uniformly evaluated for snow avalanches, flooding and mass movement hazards (see BWV et al. 1997, BFF and EISLF 1984).

The two parameters intensity and probability (or return period) are defining the degree of hazard for the various processes. These parameters are summarised in a magnitude-probability diagram (Fig. 8), which is also referred to as the 'intensity-probability diagram'. The diagram containing nine fields is used for spontaneous mass movements. A diagram with three fields (excluding probability) is used for permanent landslides and collapses. With regard to the differentiation of permanent and spontaneous slide processes:

Spontaneous processes are phenomena that arise suddenly, i.e. there was no movement previously or no indications of such high velocities. Examples of spontaneous movements include primary processes (occurring for the first time), reactivated processes and partial break-offs, which come loose in the crown or frontal zone and present an elevated level of activity. It is possible to assign a probability of occurrence to these processes. With permanent (continuous) processes, there is no subdivision in columns representing different probabilities of occurrence, or the probability is 100%. Variations in velocity can also arise in permanent landslides (acceleration, deceleration). These are incorporated into the evaluation on the basis of the intensity criteria (Fig. 11).

**Fig. 8 > Intensity-probability diagrams for permanent processes (left) and spontaneous mass movement processes (right)**

The icefall process is treated analogously to rockfall and is evaluated using the diagram on the right. Sackungen as defined in Appendix A2 are treated analogously to permanent landslides (i.e. with the diagram on the left). For collapses and subsidence (including sinkholes), the disposition is grouped into three classes, low, medium and high. The degree of hazard is determined by analogy to the intensity classes for permanent landslides into red, blue, and yellow categories. Further explanations are provided in the text and in the following chapters.



The classification indicates the degree of hazard to human beings, animals, buildings, infrastructure and major material assets. The fact that people are generally safer in buildings than in the open is taken into account here.

**Tab. 1 > Meaning of the degrees of hazard**

For the application to land-use planning, see Appendix 4 (Table 6) and the publication "Raumplanung und Naturgefahren" (ARE et al. 2005).

	Degree of hazard	Meaning
	Red: high	<ul style="list-style-type: none"> <li>Persons are at risk both inside and outside buildings.</li> <li>The rapid destruction of buildings may be expected.</li> </ul> <p>or:</p> <ul style="list-style-type: none"> <li>The scope of the events may be lower, however, there is a higher probability of their occurrence. In this case, either persons are at risk, particularly outside buildings, buildings suffer considerable damage or are rendered uninhabitable.</li> </ul>
	Blue: medium	<ul style="list-style-type: none"> <li>Persons are at little or no risk inside buildings but are at risk outside.</li> <li>Damage to buildings may be expected, however the rapid destruction of buildings may not be expected in this area as long as certain requirements in relation to construction methods are met.</li> </ul>
	Yellow: low	<ul style="list-style-type: none"> <li>Persons are at little or no risk.</li> <li>Minor damage to buildings and obstructions may be expected.</li> </ul>
	Yellow-white hatching: residual hazard	<ul style="list-style-type: none"> <li>Threats with a very low probability of occurrence can be indicated using yellow-white hatching. The yellow-white hatched zone is a reference area that presents a residual risk.</li> <li>A restrictive approach should be adopted to the designation of reference areas. It should be carried out on a process-specific and damage-potential-oriented basis.</li> </ul>
	White	No or negligible threat based on the current knowledge status.



The degrees of hazard are determined separately for each hazard source and each process. These are indicated on the hazard map using an index. The following abbreviations are used for mass movement types:

- > Rockfall: SS
- > Rock avalanche (Felssturz): SF
- > Rock avalanche (Bergsturz): SB
- > Shallow landslide: RF
- > Medium-depth landslide: RM
- > Deep landslide: RT
- > Hillslope debris flow: HM
- > Collapses and subsidence (including sinkholes): D

An additional index can be added for the movement behaviour of landslides: permanent (P) and spontaneous (S).

The field number from the intensity-probability diagram is added (numbers 1–9 in the diagram, or 1–3 for permanent landslides and collapse processes, see Fig. 8) to the process abbreviations. Hence an index of “RT8” means: deep landslide with high intensity and medium probability (field 8).

If an area is at risk from several hazards, the highest risk level is applicable for the hazard map. However, the hazard levels are not added together to give a higher level. For example: blue for hillslope debris flows and blue for landslides give a blue zone (not red). The reason for this is that the threat per process does not usually increase, and protective measures can be implemented for each process. As opposed to this, the probability of damage may be greater in the event of the accumulation of hazards and the risk increases accordingly. In addition, the interaction between the processes must be examined in relation to its intensity.

## 2.8

### Criteria for the evaluation of probability

A probability is assigned to each process using the available method. The term ‘recurrence period’ is very established in the areas of flood and avalanche protection. For mass movements, the term ‘annual probability of occurrence’ is used. Mathematically, the two terms are reciprocal:

$$P_y = 1/T$$

$P_y$  = annual probability of occurrence

$T$  = return period

The annual probability of occurrence is a statistical value for the advent of an event. A  $P_y$  of 0.033 means that such an event will arise with a probability of 3.3% over the course of one year, or once over a period of 30 years. In the area of mass movements the annual probabilities of occurrence (0.033, 0.01, 0.003, <0.003) are used analogously to the return periods in flood and avalanche protection (30-, 100-, 300-year, and >300). With climate scenarios in mind, a change in precipitation volumes and intensities and a rise in temperature is expected. These changes and the melting of ice in glacial and paraglacial areas (e.g. permafrost) should be considered where possible.

The probability of occurrence for a certain period of time (e.g. lifespan of a building) can be calculated from the annual probability of occurrence:

$$P_n = 1 - (1 - P_y)^n$$

where:  $n$  = period of time  
 $P_y$  = annual probability of occurrence  
 $P$  = probability of occurrence

The evaluation of mass movement processes can be improved under certain circumstances through observation and monitoring (see chapter 4). Based on their dynamics, large and deep masses of rock, in particular, can provide important information about probability and development.

**Tab. 2 > Correspondence between probability of occurrence and return period**

Probability of occurrence	
Probability of occurrence in 50 years	Probability of occurrence linguistic
100 to 82%	high
82 to 40%	medium
40 to 15%	low
<15%	very low
Return period	
Return period in years	Return period linguistic
<30	frequent
30 to 100	average
100 to 300	rare
>300	very rare

### 2.8.1 The probability of occurrence of fall processes

In the case of mass movements, the analysis of historical events can only provide a limited basis for the determination of the annual probability of occurrence: for smaller fall events like rockfalls, the analysis of the debris production in the depositional area is a good way of empirically determining the probability. In contrast, in the case of events of a greater magnitude like rock avalanches, the probability of occurrence must be estimated on the basis of the characteristics of potential release areas. Hence, for the evaluation of probabilities, geologists identify processes that unfold similarly and determine the fracture mechanisms. The evaluation of changing conditions (glacier retreat, drainage, temperature increase etc.) also assumes a central significance here.

In the context of hazard mapping practice, probability of rockfall processes can be deduced from different sources of information:

- > The evaluation of the probability of a rupture or acceleration of the rock mass is based on geological rock analysis in the area of origin or release area, which is also referred to as the supply area. A microstructural analysis and the recording of faults or fractures form part of this phase of work.
- > Observation of the 'silent witnesses' on the debris cone or in the depositional area. The fallen stones and rocks are assigned to a probability category with the help of the natural hazard register.

All observations and information are incorporated into the definition of the scenarios.

### 2.8.2 The probability of occurrence of slide processes

In the case of permanent landslides the probability of occurrence is 1 (or 100%), i.e. the event has already occurred. For this reason it is recommended that, as a first step, the average long-term velocity ( $v$ ) be determined to evaluate the hazard. The second step involves the consideration of the raised velocity ( $v_{\max}$ ). The variations in velocity are dependent on different factors: precipitation, slope water levels, depth and volume assume an important role. Analysis costs increase and the possibility of making a comprehensive evaluation declines with increasing volume, deep processes and subterranean water circulation.

With active landslides, rare ( $P_y = 0.01$ ) and very rare ( $P_y = 0.003$ ) increased sliding velocities ( $v_{\max}$ ) may be expected. Unfavourable developments or scenarios must be taken into consideration here (spontaneous release, first move, second move, simultaneous flooding and landslide etc.). During acceleration, a landslide can expand and mobilise previously unstable or inactive masses of rock. The acceleration and reactivation of landslides is possible particularly when the water pressure increases strongly in the pores or discontinuities. With a detailed map of phenomena, such hazards can usually be localised (Raetzo and Rickli 2007). Unconsolidated material that has not yet slid but is in a critical state can be evaluated in relation to the probability of instability (potential landslides) using calculations and modelling. In the case of solid rock the evaluation must be based on geomechanical assumptions.

A special case of active landslides arises when a secondary sliding surface causes a 'spontaneous' rupture at the front. This corresponds to the massive acceleration of a partial mass. These rapid processes are dealt with in the next section. The expansion of the landslide, the formation of secondary sliding surfaces and the increase in differential movements should be taken into account in the evaluation of acceleration scenarios.

Spontaneous landslides can:

- > be shallow to deep rotational or translational landslides which arise rapidly and spontaneously without any preliminary signs and previous movements. In the storms of recent years, such spontaneous processes frequently arose after precipitation peaks. The volume of the sliding masses involved can reach up to 100,000 m<sup>3</sup>. The method presented in Fig. 9 is applicable for the determination of the probability of occurrence of shallow landslides (first move), which develop into hillslope debris flows (second move).
- > affect part of the deep sliding mass which spontaneous slide or break off from steep landslide faces due to high velocities or fluvial erosion. The probability of such ruptures is dependent on the geotechnical solidity, velocity of the main landslide, the hydrogeological conditions and the rate of erosion in the underlying channel. In the case of spontaneous sliding, a (new) secondary sliding surface generally becomes active. In rare cases, the volume of these processes can encompass a few million cubic metres. The energy associated with such events and the impact on buildings are comparable with those of rock avalanches.

The concept of probability expresses whether a change in state can lead to an active landslide. The probability of occurrence of the reactivation of such landslides is strongly dependent on weather conditions. For example, long periods of precipitation, possibly in combination with snow melt, can reactivate an inactive landslide.

The slide processes in places in which no movement previously existed involve a special case of inactive landslides. During storms, landslides can arise surprisingly or 'spontaneously' in previously inactive slopes (first move). The potential for shallow landslides can be evaluated through the mapping of phenomena, the slope gradient, unconsolidated material analysis and the slope water conditions (see also chapter 2.3.4).

### 2.8.3 The probability of occurrence of flow processes

Hillslope debris flows can arise as initial (first move) or secondary (second move) processes. Accordingly, the probability of occurrence and the disposition in the release area are similar to those of shallow to medium-depth spontaneous landslides (chapter 2.8.2). The thicknesses of the masses which can be mobilized are generally 0.5–3 m and rarely up to 10 m.

The disposition and affected process space are determined for hillslope debris slopes with the help of site surveys and modelling. This analysis should be carried out in a geologically uniform test area, i.e. in conditions that are geologically homogenous or characterised by comparable unconsolidated material. The geotechnical characteristics should be taken into account primarily – less so the stratigraphic ones. The methodology presented below (Fig. 9) is based on the work of the geology and natural hazards working group AGN (study commissioned by the FOWG in 2004) and provides starting points for the evaluation of the probability of a rupture in a potential release area. In the case of hazard analysis, the surveying of previous hillslope debris flows in the study area is important. If there are no natural hazard register data available, data from neighbouring regions or other can be used as approximate values for comparative geological units.

For hillslope debris flows a procedure with five stages leads to the assessment of the probability:

#### Determination of the study area

Stage 1

The study area is defined on the basis of geological criteria. The aim is to define zones of a uniform basic disposition. For this purpose zones with a consistently uniform homogenous geological nature are segregated. A fundamental distinction should be made between unconsolidated material and bedrock because usually unconsolidated sediment is mobilized on top of the bedrock. Geotechnical rock characteristics should also be taken into account here (e.g. granulometry, friction angle, cohesion, plasticity).

#### Natural hazard register and map of phenomena

Stage 2

The hazard event register provides information about the recorded hillslope debris flows and shallow landslides. The Possible previous events in the study area are recorded and evaluated ('silent witnesses' on the terrain, indications of slope instability, surveys of the local population).

Event analyses showed that traces of previous events could be established in over 70% of the event locations. Hence detailed field observations are indispensable for the assessment of hillslope debris flow events.

#### Determination of the slope gradients in the initiation zones

Stage 3

The results from Stage 2 are statistically analysed to determine the frequency of hillslope debris flows as a function of the slope angle of their geologically homogenous

release areas (Fig. 10). The average slope angle  $\alpha_m$  and its standard deviation ( $\sigma$ ) for all release zones of a hillslope debris flow are deduced. If the statistical determination of the average slope gradient is based on an insufficient number of surveys, then comparable geological units from neighbouring regions can be used as an approximation.

In general, a basic disposition for hillslope debris flows exists when unfavourable geological characteristics exist in a test area with slope gradients steeper than  $20^\circ$ . In unusual geological situations the slope gradient can also be smaller than  $20^\circ$  (exceptional cases).

#### Determination of the facilitating factors

Stage 4

Different factors facilitate the emergence of hillslope debris flows. The influence of these facilitating factors should be examined on a case-by-case basis. A purely qualitative distinction is made here between strong, weak and no influence. The evaluation and the weighting of the factors taken into account should be explained in the report accompanying the hazard map. The presence of active or old mass movements and the potential water influences (saturation, pressure, flow force).

Possible facilitating factors:

- > Location in a permanent landslide area. Changes in the slope gradient and water circulation conditions due to sustained movements.
- > Terrain forms: e.g. transitions from flat to steep terrain (alternating slope gradients) or location in hollows.
- > Existence of permeability discontinuities close to the surface: aquitard below (e.g. rock surface) or layers with poor permeability embedded in more porous material.
- > Hydrogeological conditions: slope water and mountain water outlets, source outlets, water logging, flows of water from the rock to the unconsolidated material (in particular through crevasse water circulation).
- > Hydrological conditions: water logging, flows of water into the unconsolidated material, mountainside area, from which surface drainage water and/or slope water can flow.
- > Surface characteristics and land use: differentiation between open land and forest, open erosion areas, pastureland with trampling damage, cattle tracks, forest damage (storms, bark beetle), unsuitable forest stand composition (e.g. overaged forests) etc.
- > Anthropogenic influences: flow of water from impermeable surfaces (e.g. roads, residential areas, compacted soils etc.), overflows from drinking fountains or spring vaults, defective drainage systems, very steep slope sections etc.

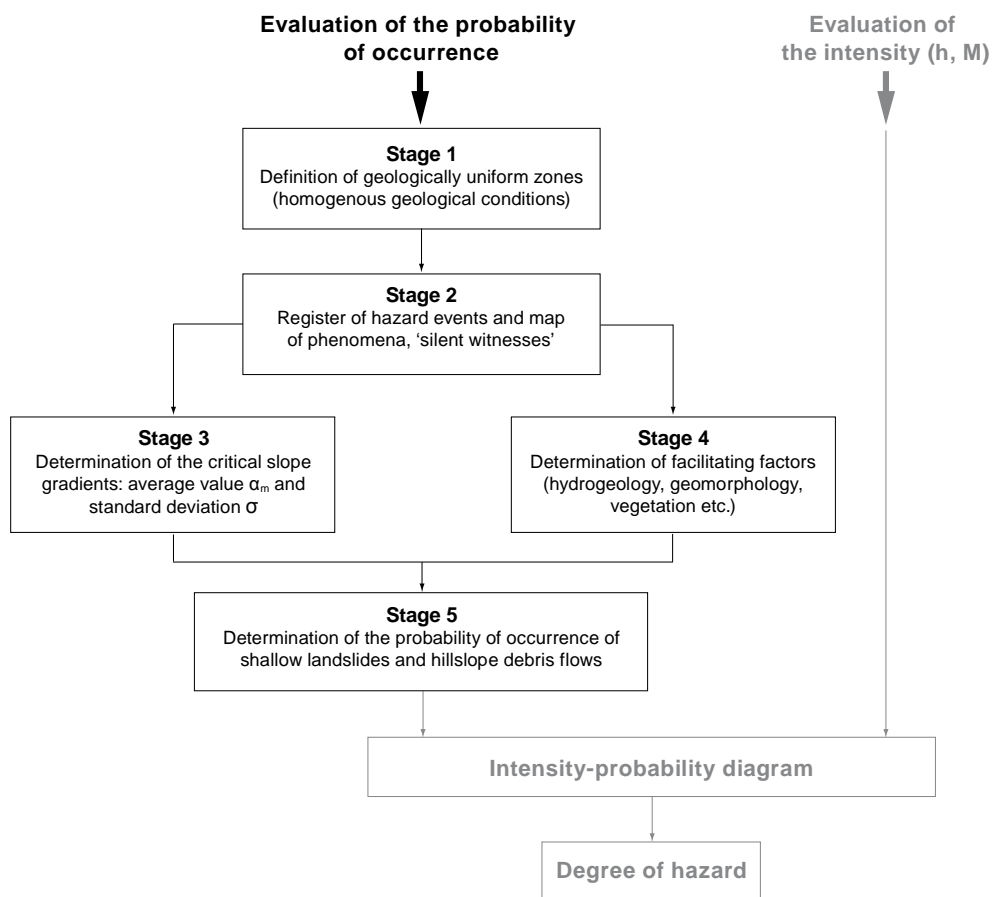
#### Determination of the probability in the initiation area

Stage 5

The probability of initiation of hillslope debris flows is determined with the slope gradient and the influence of the facilitating factors. Various methods can be used for this purpose (see Appendix A3).

**Fig. 9 > Stages in the procedure to determine the probability of occurrence of hillslope debris flows**

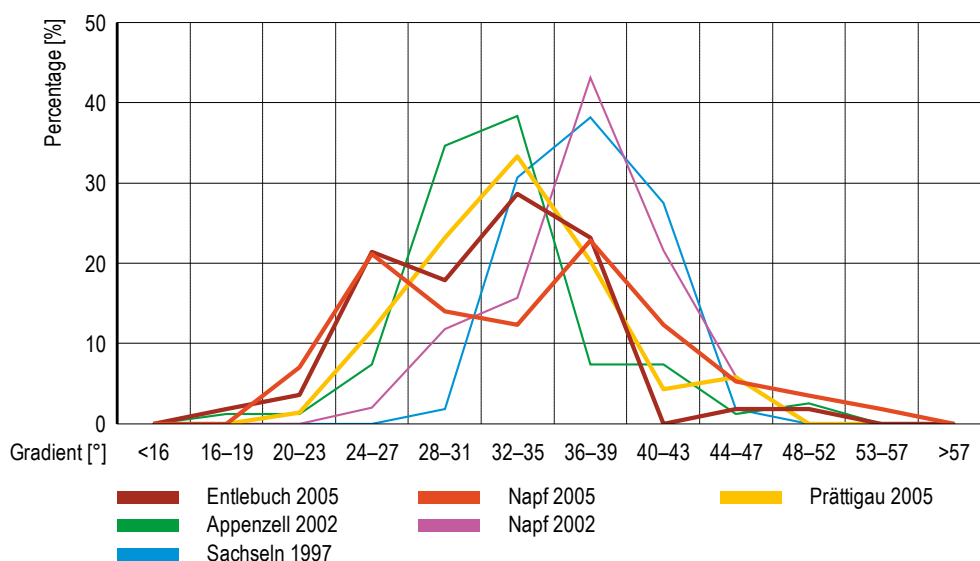
*For the determination of the degree of hazard an additional criteria of intensity is required (see chapter 2.9).*



Other methods are used for the runout and the comparison with well documented events is suitable for determining the runout zones. Modelling is used for the runout phase and especially for the evaluation at certain objects.

**Fig. 10 > Percentage of shallow landslides per gradient class in the release zone**

The data originate from the areas of Appenzell, Napf, Sachseln, Entlebuch and Prättigau (Raetzo and Rickli 2007). In each case, the gradient data were surveyed after storms. The average value for all landslides is approximately 32°; the dispersion covers slopes from 16° to 57°. In molasse rock, for example, a threat may be expected at a critical gradient exceeding 22° and with the crucial impact of facilitating factor. In some areas, individual events arise at slopes of less than 20°.



## 2.9

**Criteria for the evaluation of intensity**

Based on the mechanism of action of various processes, intensity values are determined to define high, medium and low intensity classes. The corresponding quantitative criteria refer generally to the area where the process is active or the area at risk (with the potential for damage). High intensity arises from an energy level of 300 kJ, which corresponds approximately to the resistance limit of solid and reinforced walls. However, this quantitative information is not available in every case, or the spatial resolution is not ideal. In these cases, it is the responsibility of the authorities and specialists to make adequate assumptions and simplifications.



**Fig. 11 > Criteria for the determination of intensity**

Abbreviations, explanations and notes in the following text boxes:

$E$  = Kinetic energy [kJ]

$v$  = Average (long-term) sliding velocity [cm/year]

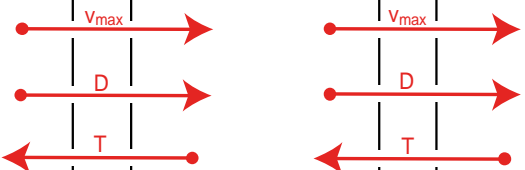
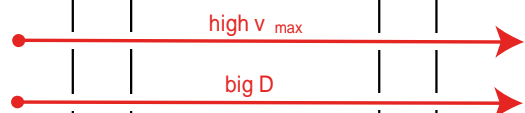
$v_{max}$  = Maximum sliding velocity [cm/year]

$D$  = Differential movements within the lifespan of a building [cm/10 m]

$T$  = Depth of the sliding surface, landslide depth [m]

$M$  = Thickness of the mobilisable mass (potential) [m]

$h$  = Height of deposit by hillslope debris flows or landslides (debris flow height) [m]

Process	low intensity	medium intensity	high intensity
<b>1. Fall processes</b> - Rockfall - Rock avalanche	$E < 30 \text{ kJ}$ --	$30 \text{ kJ} < E < 300 \text{ kJ}$ --	$E > 300 \text{ kJ}$ $E > 300 \text{ kJ}$
<b>2. Slide processes</b>  2.1 Active, continuous, permanent landslide (also sliding processes in the permafrost)	$v \leq 2 \text{ cm/year}$	$2 \text{ cm/year} < v < 10 \text{ cm/year}$	$v > 10 \text{ cm/year}$
			
2.2 Spontaneous landslide	$M < 0.5 \text{ m}$	$0.5 \text{ m} < M < 2 \text{ m}$ $h < 1 \text{ m}$	$M > 2 \text{ m}$ $h > 1 \text{ m}$
			
<b>3. Flow processes</b> Hillslope debris flow	$M < 0.5 \text{ m};$ Overbank sedimentation in the decimetre range	$0.5 \text{ m} < M < 2 \text{ m}$ $h < 1 \text{ m}$	$M > 2 \text{ m}$ $h > 1 \text{ m}$
<b>4. Collapses and subsidence</b> (e.g. sinkholes)	Sinkholes potentially present or rocks prone to dissolution	Sinkholes present, detected	Sinkholes and topple hazard are proved

**E = Kinetic energy [kJ]**

- > 30 kJ can be absorbed by an oak railway sleeper.
- > 300 kJ can be absorbed by a concrete wall with extensive iron reinforcement.
- >  $E > 300$  kJ cannot be absorbed by concrete walls without special reinforcement.

 **$v_{\max}$  = Maximum sliding velocity [cm/year]**

The acceleration of landslides results in greater hazard and, accordingly, a higher degree of hazard.  $v_{\max}$  is defined through the maximum speed reached during an acceleration phase or following reactivation. Definition:  $v_{\max 30}$  refers to an event with a 30-year return period;  $v_{\max 100}$  refers to a 100-year event or a return period of 100 years;  $v_{\max 300}$  refers to an event with a return period of 300 years.

- > Change in sliding velocity ( $v_{\max}$ ) for the change from one intensity level (short arrow):  
 $v_{\max 30} > \text{approx. } 20 \text{ cm/year}$  or  $v_{\max 100} > \text{ca. } 40 \text{ cm/year}$  or  $v_{\max 300} > \text{ca. } 50 \text{ cm/year}$ .
- > Change in sliding velocity ( $v_{\max}$ ) for the change from two intensity levels, i.e. from low to high intensity (long arrow, “high  $v_{\max}$ ”):  $v_{\max 30} > \text{approx. } 50 \text{ cm/year}$  or  $v_{\max 100} > \text{approx. } 70 \text{ cm/year}$  or  $v_{\max 300} > \text{ca. } 80 \text{ cm/year}$ .

If acceleration is measured within a quarter-year period, the corresponding annual velocity should be calculated: the multiplication of the measured quarterly movement by four gives the equivalent annual velocity. This method can be applied analogously for a semester or three quarters.

The exact surveyed values for  $v$  and  $v_{\max}$  are often not available in the case of area-wide hazard mapping (M2). Moreover, geodetic measurement data and corresponding information are not necessarily available with detailed studies (level M3) or for known landslides. The cantonal and federal authorities and surveyors may be able to provide geodetic data and velocities (see also the FOEN's INSAR data). In view of possible developments and the influence of climate change, potential accelerations can also be defined as corresponding scenarios without the availability of measurement data. Potential reactivations and accelerations can be influenced by processes including precipitation, snowmelt, groundwater inflow and erosion processes (e.g. torrential erosion of the toe of a landslide). Explanations and justification are required for the establishment of the scenarios.

**D = Differential movements**

Differential movements are measured on the basis of the absolute differential movement in centimetres related to a uniform width of 10 metres [cm/10 m]. The differential value is related to the duration of use of the affected building due to shear forces and is related to the building's structural safety and fitness for purpose (e.g. over approximately 50 years).

- > Differential movement for a change in intensity level (short arrow):  $D = 2\text{--}10 \text{ cm}/10 \text{ m}$
- > Differential movement for a change in two intensity levels (long arrow, 'big D' or 'DD'):  $D > 10 \text{ cm}/10 \text{ m}$ .

### **T = Depth of the sliding surface, deepness of the landslide**

*The relevant (uppermost) sliding surface must be at least 30 m below ground for downgrading. Downgrading (by one intensity level) can only arise if the following three conditions are fulfilled simultaneously:*

1. *Large, very deep cohesive sliding mass.*
2. *Phenomenologically homogenous areas without higher secondary sliding areas.*
3. *Temporally uniform movement dynamics backed up by geodetic measurements.*

*Intensity with the depth of the sliding surface can only be downgraded for velocities of a maximum of 20 cm/year if conditions 1–3 are fulfilled.*

### **Collapses and subsidence**

- > *In the case of the diffuse distribution of sinkholes, the dissolution-prone formation can be entered on the hazard map over a wide area. Potential sinkhole hazard → low hazard zone (yellow).*
- > *Collapses and subsidence (e.g. in sinkholes) are medium intensity if clear indicators for the spatial extent are detected in the field. The dissolution processes in the Karst rock cause subsidence which can unfold quickly or very slowly. In this case, the area is classified as having a medium degree of hazard (blue).*
- > *If a demonstrated collapse hazard exists, a high intensity and areas under considerable threat can be designated (red). Gypsum formations are, for example, very susceptible to dissolution or the formation of sinkholes.*

*The collapse hazard declines with the thickness of a Quaternary cover if it presents a different lithology and good load-bearing capacity (e.g. thick moraine cover).*

*The hazard evaluation should cover the demonstrated perimeter of the sinkhole and an additional hazard area can be designated to provide preventive protection against secondary instabilities on the edge of the sinkhole. Zones where sinkholes frequently occur are, as a rule, generously aggregated.*

### 2.9.1 Intensities and damage profiles for fall processes

The bouncing of rocks and boulders causes considerable damage. Large cracks in structural elements of buildings and holes in the masonry or roof can result in their partial or total collapse. Human beings and animals are under severe threat, even inside buildings. The collapse of buildings poses a risk to human life. Repairs can only be carried out at a very high cost. The structural damage is often so extensive that the evacuation and destruction of the building are unavoidable. The deposition of falling material can result in the backing up of watercourses. If a lake forms behind the new 'dam', the stability conditions change. In the case of dam instability or erosion processes, flooding and large-scale channel-type debris flows can result in downstream areas. Overground infrastructure (e.g. roads, power lines) can also be directly damaged and blocked by fall processes.

High intensity

Depending on their structural quality, the bouncing of rocks causes extensive damage without affecting the stability of buildings (if the buildings were designed to withstand such stress). Doors are severely damaged or destroyed. There is little risk to humans and animals inside buildings. The damage affects residential quality. Repairs are generally feasible at a proportionate cost. The deposition of falling material can result in the blocking of small streams. Roads and overhead power lines can be damaged and temporarily disrupted.

Medium intensity

Fall processes can cause holes in masonry. Humans and animals are not generally at risk inside buildings. However, they are at risk outside buildings during weak-intensity fall processes. A bang on the head can have fatal consequences.

Low intensity

### 2.9.2 Intensities and damage profiles for slide processes

Strong changes in the terrain lead to considerable differential movements of the substrate and to a substantial impairment of building stability. Partial or total collapse is possible due to cracks in structural components of buildings, subsidence and tilting. Doors and windows are not usable. Humans and animals in buildings are at risk. Collapse poses a fatal risk. Repairs can only be carried out at a considerable cost. The structural damage is usually so extensive that the evacuation and demolition of the building is unavoidable. Infrastructure is severely impaired (e.g. blocked roads). Breaks in power cables arise. The damming of watercourses is possible.

High intensity

Terrain movements cause cracks in walls but not in structural elements that ensure the stability of buildings. The sealing of joints and connections between different structural components is impaired. Doors and windows become jammed. There is no direct risk to humans and animals in buildings. The damage impairs their residential quality. Impairment to infrastructure arises (e.g. deformation of roads and overground and underground power lines). Drainage channels can be blocked or cracked.

Medium intensity

Minor terrain movements can cause slight damage. The stability of buildings is not impaired. Larger stable structures are not generally affected. Buildings can tilt due to changes in the terrain. There is no risk to humans and animals.

Low intensity

### 2.9.3 Intensities and damage profile for flow processes

The current practice, which is based on many years of experience, evaluates the intensities of flow processes using the parameters thickness of mobilisable masses (M) and thickness of the deposit (h). As in the case of avalanches, it is conceivable that other parameters like impact pressure will be taken into account in future.

The intensity classes can be described as follows:

The bouncing of large masses of debris, mud and wood mixed with water onto structural parts of buildings can result in major structural damage or their sudden destruction. Humans and animals are at considerable risk due to the hazard of building collapse and flooding. Hillslope debris flows can penetrate into buildings (through doors, windows, glass façades and structural weak points) and pose a hazard to humans. Repairs often involve very high costs. Considerable terrain changes with large areas of erosion, debris deposits and floods result in the interruption, damaging or destruction of infrastructure (roads, power lines).

**High intensity**

Despite being relatively shallow, moving hillslope debris flows are hazardous due to the debris they carry with them. The bouncing of rocks and boulders and penetrating water can cause damage to building envelopes and interiors without, however, impairing overall stability. Hillslope debris flows can penetrate buildings and pose a risk to humans (through doors, windows, glass facades or structural weaknesses). Humans and animals are also at risk outdoors. Residential quality can be severely impaired. Repairs can generally be carried out at a proportionate cost. The deposition of debris, mud and wood can cause damage and blockages, in particular to overground infrastructure (e.g. roads). Passages, pipelines and drainage channels can be blocked.

**Medium intensity**

Almost only in the runout area of hillslope debris flows due to narrow and halting debris masses or penetrating water. Minor damage to building envelope or interior. Stability not impaired in any way.

**Low intensity**

### 2.10 Definition of scenarios

Scenarios represent possible future events and sequences of events. The ways in which mass movements actually affects particular areas constantly presents surprises, however. During an event, very different outcomes are conceivable which can intensify spasmodically, change abruptly or develop differently to expectation.

Due to the enormous variety and complexity of the courses taken by such processes, hazard evaluation must be carried out using scenarios. A probability is assigned to each scenario.

Scenarios also present combinations of processes and spatial extents in stable or unaffected areas. For example, lateral erosion in torrents results in the mobilisation of a landslide, it forms a dam and the water is backed up, the dam breaks suddenly and large volumes of solid material are transported downstream as bedload or debris. The

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Brienzi debris flows during the storm of 2005 were crucially influenced by mass movement processes.

#### 2.10.1 Scenario development

An open perspective is important for scenario development; even unlikely processes cannot be excluded without reason from the broader consideration. As demonstrated by the flood events of August 2005, the threshold processes, process changes and process sequences beyond locally available experience ('thinking the unthinkable') should be taken into account. Hence very unlikely scenarios or processes should be considered.

The scenarios must be representative enough to openly address and demonstrate all possible developments. They should adequately take account of the possible impacts on the hazard potential. The temporal course of an event can also be crucial in terms of its significance.

#### 2.10.2 Selecting scenarios

Despite solid scientific documentation, good estimation and calculation models, and technical tools, clear ideas about the potential course of processes are ultimately crucial for the quality of hazard evaluations. The question arises in practice as to which scenarios are representative enough in terms of the impacts in the area affected so that they can be used as a solid basis for the hazard evaluation and planning of measures.

The argumentation and motives for the selection or omission of a scenario must be recorded in such a way that they can be understood later. For this reason, the determination of probabilities of occurrence and the intensity of landslides, rockfall and hillslope debris flows requires good quality and in-depth documentation (see previous section).

Qualitative considerations are just as important for the hazard evaluation as calculations. Hence, technical reports must be detailed and all considerations which it would otherwise be impossible to understand at a later stage must be recorded.

The determination of scenarios is accompanied by uncertainties. The approach to be adopted for dealing with uncertainties is explained in the next section.

#### 2.11 Dealing with uncertainties

With natural processes, the determination of intensities and probabilities of occurrence is basically associated with uncertainties. In addition, these uncertainties increase as soon as events lie outside the previous range of experience. The existing uncertainties result in corresponding inaccuracies in hazard evaluation and action planning. They give rise to discretionary scope that poses a challenge for all actors.

It is not possible to depict the course of all events comprehensively. In the process of hazard evaluation and action and emergency planning, surprises always arise in terms of how processes actually unfold in a particular area. Very different processes are conceivable during an event which can intensify spontaneously, alter suddenly or develop differently to expected.

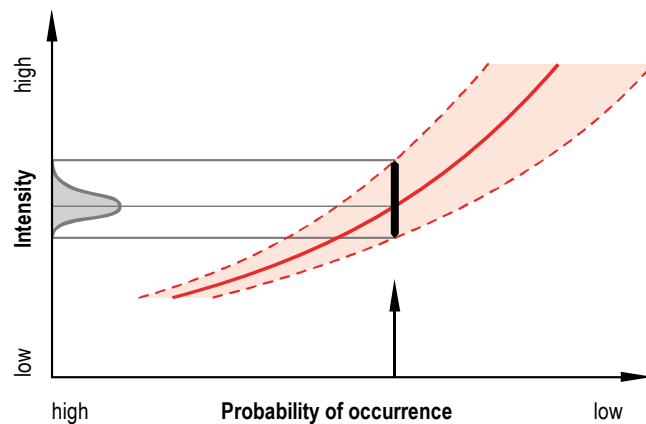
#### Diversity of events

If extensive and continuous observations are available for a process, the associated uncertainties can be quantified using statistical methods or confidence intervals. This situation is most likely to apply to the most common processes. In this case, intensity with corresponding uncertainty can be determined for a probability of occurrence using statistical analyses (Fig. 12).

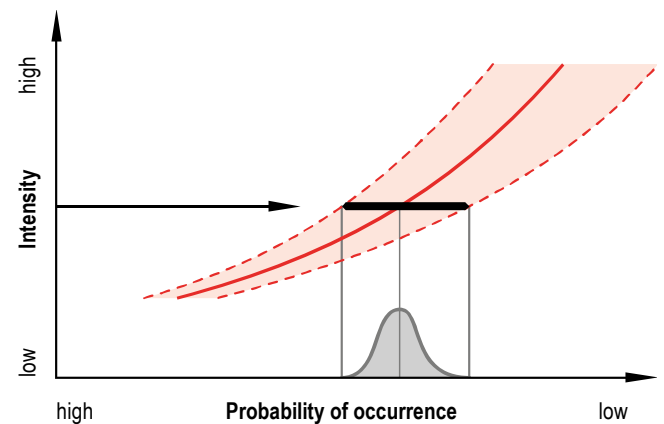
For mass movements, the possible range should be estimated and presented, if possible, even if few event data are available. Extrapolations with increasing volume or higher velocity are required if the hazard register only records more frequent events with a lower intensity and the field evaluation shows that larger events are possible.

Particular caution is advised for the extrapolation of very rare events, in which threshold processes, process changes and process sequences arise that are not reported in the available data set (Fig. 13). The existing uncertainties must be estimated accordingly. The corresponding scenarios should be well-founded and well documented.

**Fig. 12** > Range of intensity with specified probability of occurrence



**Fig. 13** > Range of probability of occurrence with specified intensity



## 3 > Action Requirement

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The Federal Act on Forest is intended to contribute to the protection of human life and significant material assets against landslides, erosion and rockfall (Art. 1 para. 2 ForA). This chapter explains the process involved in the determination of the action requirement.

If a threat exists in the area subject to land-use, the risk situation must be evaluated. To begin, the risks are identified. The current situation is then compared with the protection objectives. The action requirement is then deduced from this and priorities defined. The approach to be adopted in the subsequent action planning is explained in chapter 4.

### 3.1 Risk identification

The first step involves the implementation of the exposition analysis for all hazard processes. The risk in a particular area is dependent on the sum of all possible impacts on the damage potential arising from one or more hazards. The consequences for people and material assets are analysed in the second step. The third step involves the identification of the risks.

Risk identification can be carried out at different levels:

- a) Qualitative risk definition: which structures/areas are affected at which intensities for certain return periods? Number?
- b) Quantitative risk analysis: Identification of the possible extent of damage for the individual structures with the incorporation of the spatial probability of occurrence, lethality and vulnerability. The personal risks are calculated on the basis of average occupancy rates, average transport rates and the effective presence period. A distinction is made between individual risk and collective risk. The material risks can be calculated on the basis of the effective values (direct damage). Among the material risks, the following objects of protection are considered: buildings, infrastructure, objects of considerable national economic importance, resources that sustain human life, cultural goods. The calculation of indirect damage is not carried out in a standard way for all elements, however this parameter may be of interest in the case of major disruptions and subsequent damage (e.g. in the case of the closure of transport routes).

In principle, the evaluation of personal risks must be based on parameters related to individual and collective risk. The individual risk describes the scope of the risk, i.e. that a person loses his or her life due to a threat. Even if the individual risks of all endangered persons are low, the collective risk can be high (e.g. high number of victims).



### 3.2 Safety level and protection objectives

Once the risks have been evaluated, the action requirement is examined: Can the risks be borne by society or must they be reduced? What is essentially involved here is the limit of acceptable and unacceptable risks. The targeted safety level describes the targeted safety status. Through the protection objectives, the different actors describe the level of safety that they aim to achieve within their area of responsibility or their basic contribution to the targeted safety level. The area of responsibility of the different actors varies considerably. In this guideline, the main focus is on the institutional sphere of responsibility (e.g. the public authorities, those responsible for the implementation of the forest legislation). The area of individual responsibility is not covered here. Those affected by risks are responsible for their own protection in this area (e.g. mountain climbers outside of institutional contexts).

Once an action requirement has been identified, it is necessary to plan the associated actions. Action planning demonstrates whether the risks can be reduced at a reasonable cost. During this phase, the actors define the objectives of the risk-reduction measures. Irrespective of structural protective measures, the application of the hazard map in spatial planning is a permanent task in hazardous areas (action requirement in the broad sense). This means that a certain status can be maintained and the increase in risk avoided in the best case scenario.

#### Targeted safety level

The federal authorities aim to attain a comparable level of safety against all natural hazards throughout Switzerland that is ecologically justifiable, economically proportionate and socially acceptable.

The targeted safety level relates to the direct impact of natural hazards on protected objects:

The average individual risk of mortality for persons is not considerably increased by natural hazards. The annual risk of mortality for persons as a result of a natural hazard is considerably lower than the average probability of mortality for the age class with the lowest mortality rate in Switzerland.

**Persons**

#### Buildings

Buildings provide considerable protection to persons and material contents. They are resistant and do not pose a hazard to persons and other material assets. The remaining personal and material risks are acceptable for the bearers of risk.

**Important material assets**

#### Infrastructure, objects of considerable national economic importance or scope, life-sustaining resources

The risk to infrastructure, objects of national economic importance and resources that sustain human life is so low that, today, the survival of the community is ensured for generations to come. The supply of vital goods and services should only be interrupted for a short time in large parts of Switzerland.

### Cultural goods

Cultural goods are protected against natural hazards so that their cultural value is conserved in the long term.

Other values exist, for which no targeted safety level was formulated. This applies to livestock, in particular. The latter have a high priority in Swiss legislation and are treated differently to material assets. Their protection falls within the scope of responsibility of their owners.

### **Protection objectives**

Protection objectives describe a responsible actor's contribution to the targeted safety level in quantitative terms. With the help of protection objectives, the public authorities clarify the areas in which an action requirement exists for them. If the protection objectives are not fulfilled, reference is made to a 'protection deficit'. In the case of a protection deficit, the public authorities examine whether suitable measures could reduce the risk. Hence, in practice, protection objectives also act as criteria for the evaluation of the action requirement. The protection objectives of the public authorities can only be defined by the responsible political authorities. Switzerland's federalist structure with the considerable autonomy of the communes and cantons and the circumstances of direct democracy should be taken into consideration when defining protection objectives.

Accordingly, many cantons have developed matrices of protection objectives. An example of such a diagram is included in Appendix A5 (ARE et al. 2005). In accordance with the NFA (new fiscal equalisation) manual (BAFU 2011), the Federal Office for the Environment formulated the following test criterion for personal risks: a project with an individual risk of mortality greater than  $10^{-4}$  to  $10^{-5}$  per year. Accordingly, the Federal Roads Office (FEDRO) has also defined test criteria for the national roads: an individual risk of mortality exceeding  $10^{-5}$  per year, a risk per 100-metre-stretch of road exceeding CHF 10,000 per year, and a risk per process source exceeding CHF 10,000 per year.

### **Action objectives**

An existing protection deficit is supposed to be reduced or eliminated through the implementation of suitable measures. The total effect of all (planning, technical, organisational) measures corresponds to the level of safety attained. When developing action plans for the protection against natural hazards, the responsible actors define action objectives. These are based on the protection objectives but can be explored in the context of the optimisation that takes place during integrated action planning and be adopted both upstream or downstream on the basis of a comprehensible justification. During this phase, the authorities define the priorities for the institutional area. All aspects of sustainability play a central role here. In some cantons, for example, the availability of cantonal and municipal roads are taken into account as a criterion.

It is admissible for a higher level of safety to be attained than the targeted safety level as long as the greater safety can be justified from the perspective of sustainability. As usual, the federal authorities verify here whether the cost of the planned measures is acceptable. The residual accepted risk can be borne by different actors.

In well justified cases, the level of safety attained can also be lower than that targeted: in some cases, the protection deficit cannot be eliminated at an acceptable cost. In other cases, sustainability is not provided. Hence, for example, the protection of nature and the landscape can be given greater weighting than risk reduction. In such situations, it is necessary to examine alternatives and find an optimal solution. Project-related action objectives can deviate from the protection objectives in these cases. These must be defined in the context of the action planning based on the careful balancing of interests. Accordingly, the objectives should also be graded or differentiated within a project. In addition to land use, the hazard type should be taken into account here: for example in relation to the intensity, advance warning period, and seasonality.

### 3.3 Residual risk

Risks can never be fully eliminated; a certain level of risk always remains ('residual risk'). This must be made clear to the stakeholders so that false expectations are not created in relation to the level of safety provided. Stakeholders should also be made aware of their own responsibility.

Figure 14 provides a schematic presentation of risk before and after the implementation of measures. Prior to the implementation of measures, the risk is too high and exceeds the protection goal. The protection objective is not attained. The risk is reduced through the implementation of all public and private protective measures. These include spatial-planning, structural and organisational measures, which are tailored to each other in a strategy (see chapter 4.4 ff). Following the implementation of measures, the risk is lower. In this example, the risk reduction is based on one part involving the attainment of the protection objective (①) and a second part that involves the attainment of the objective of the measure (②). These parts vary and should be adapted for each situation. The risk after the implementation of the measures is now below the targeted safety level. Hence the level of safety attained is now in the acceptable or green area. The residual risk must be borne by different actors (insurance companies, property owners etc.). In addition, the attained safety level should be maintained in the medium and long term (ensuring spatial planning and maintenance, guaranteeing emergency organisation etc.).



## 4 > Measures

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Measures for the protection of human life and important material assets are necessary if the action requirement has been identified in advance. The selection of such measures must be optimised on the basis of social, economic and ecological criteria (Art. 1 and 19 ForA, Art. 15 to 17). The Confederation grants payments to the cantons for measures that provide protection against natural hazards (Art. 36 ForA).

### 4.1 Optimisation of protective measures

Action planning is based on the results of the hazard evaluation and risk evaluation. It can have the aim of conserving the current status in the absence of protection deficits or aim to improve the current status if protection deficits exist. All possible types of measures must be taken into consideration here: i.e. passive, active and organisational (Fig. 15).

As part of the action planning process a distinction is made between whether the measures influence the process or the extent of the damage it causes. Passive and active protection measures are then explained in order of priority.

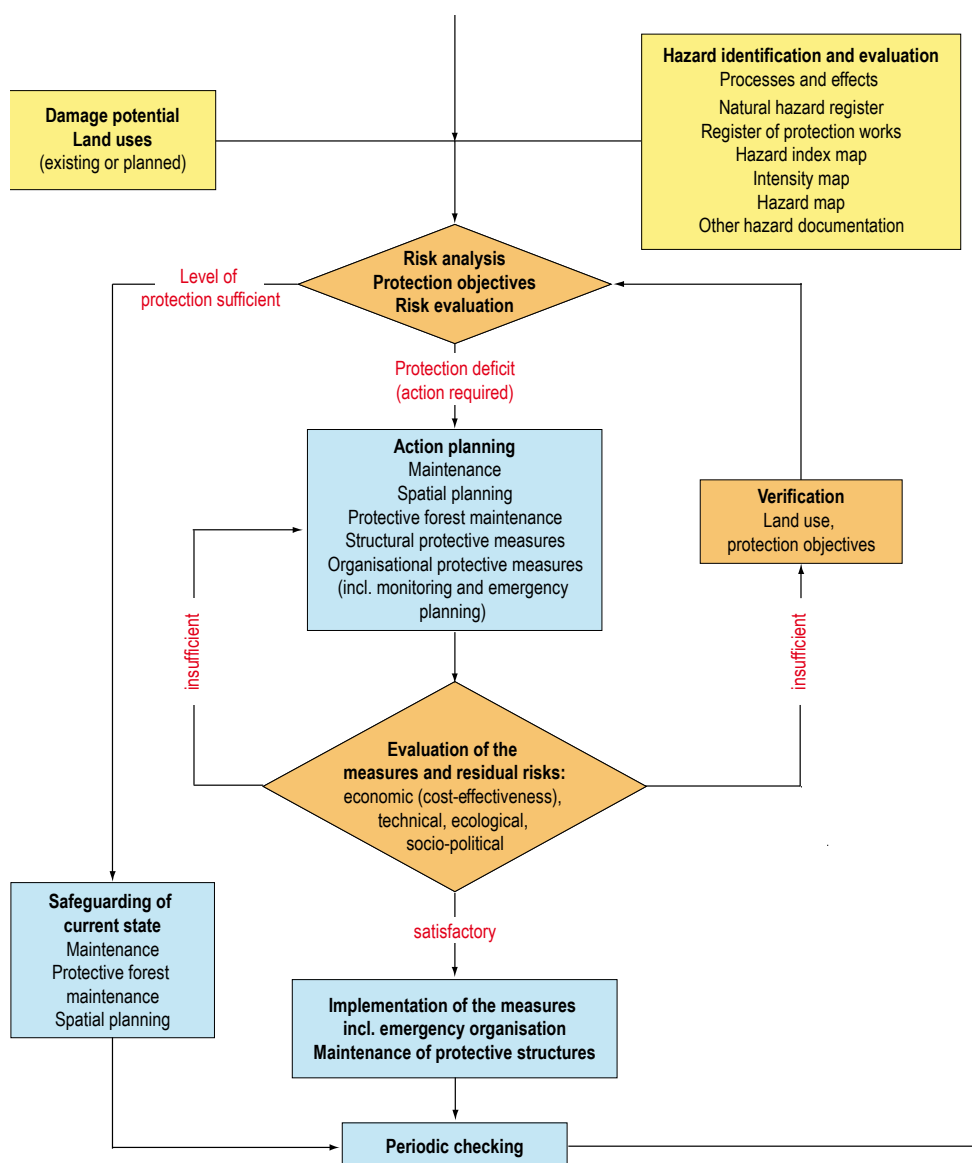
With passive protection measures, the extent of possible damage is limited without influencing the course of the event (ARE et al. 2005). The cantons take the hazard documentation (hazard maps) into account in all activities with a spatial impact, in particular structural and land-use planning (Art. 15 para. 3 and Art. 17 para. 1 ForO). The damage potential should be reduced primarily with the help of spatial planning (i.e. passive) measures. The spatial-planning measures should ensure that land use is adapted to the existing threat. This also includes construction methods adapted to hazard prevention. Local protection can be ensured through the specification of an appropriate construction method in the planning permission process (see, for example, Egli 2005). The corresponding regulations are defined in the land-use planning.

The course of hazard processes is influenced using active protection measures. The safeguarding of hazard areas includes structural measures, barriers in landslide areas, drainage projects and measures to counteract fall processes (Art. 17 Abs. 1–2 ForO). The active protection measures include individual structural protective measures like rockfall nets and also area-wide measures like protective forest maintenance, afforestation and drainage. Structural protective measures can be used in locations in which a land use worth protecting already exists or is deemed essential following the weighing up of all interests. If large dams or collectors need to be built for retention to protect against gravitational natural hazards, it must be verified whether these structures are subject to the Water Retaining Facilities Act (WRFA) (see Appendix A1).

This act applies to retaining facilities which must fulfil one of the following preconditions: the retention water level above the ground elevation (or above the low water level) is at least 10 m, or the facility has a retention area in excess of 50,000 m<sup>3</sup> at a retention water level of at least 5 m. The federal supervisory authority (Art. 22 WRFA) can also subject water retaining facilities with smaller dimensions to this act if they present a particular risk potential. A particular risk potential arises if human life is endangered or major material damage could be caused in the event of the breaching of the dam (Art. 2 DamO).

**Fig. 15 > Action planning procedure**

*A planned sequence of individual steps – from the understanding of the process to emergency planning – is required to provide optimal and sustainable protection against mass movements.*



As part of the selection of suitable protective measures, their proportionality must be taken into account. The development of several different variants should start at an early stage in the process so that advantages and disadvantages can be compared on an ongoing basis. Each measure must basically fulfil the following conditions: first, the proposed measure must fulfil the targeted objective and, second, it should involve minimal intervention. Moreover, it must be socially acceptable.

The cost of the protective measures must be compared with the expected damage potential. The federal authorities have provided the calculation program EconoMe for this purpose. The cost-efficiency of all individual projects approved by the federal authorities must be demonstrated in accordance with EconoMe. If the evaluation of the measure is positive, the decision can be taken to implement the measure. Hazard protection projects that are not cost-effective or fit for purpose do not qualify for subsidies or financial support.

The cantons ensure that planning is integrated; this takes into account, in particular, the interests of forest management, hydraulic engineering, agriculture and nature and landscape conservation (Art. 17 para. 3 ForO). Accordingly, the protective measures should also be evaluated from an ecological perspective. In accordance with the relevant legal provisions and the specific protection objectives for nature and landscape protection, protected landscapes or landscapes worthy of protection may not be impaired or, at most, slightly impaired through structural alterations. The national, cantonal and regional inventories and requirements must be taken into account here (e.g. Federal Inventory of Landscapes and Natural Monuments of National Importance). In principle, the existing status cannot be impaired and should be improved as sustainably as possible if the opportunity arises. Consequently, the objectives for the protection of human life and material assets can be modified for both financial and technical reasons. The eventual balancing of interests must take the framework provided for in the applicable legislation into account.

Organisational measures are used to limit the residual risk. This category includes emergency organisations, measurement stations, early warning services (Art. 16 ForO), evacuations, disaster aid, and temporary measures. Organisational measures form part of the holistic planning of measures.

#### Further information

- > *EconoMe* [www.econome.admin.ch](http://www.econome.admin.ch)
- > *Norm SIA 261/1*
- > *Wegleitung Objektschutz gegen gravitative Naturgefahren* (Egli 2005)
- > *Romang H. (Ed.) 2008: Wirkung von Schutzmassnahmen (Strategie Naturgefahren Schweiz), Einzelprojekt A 3 (2008). Nationale Plattform Naturgefahren PLANAT, Bern.*

## 4.2 Planning stages

The Swiss Society of Engineers and Architects' (SIA) performance model describes the entire life cycle of a built structure from the formulation of requirements to its management. The sequence of services provided by the engineer/architect and client and the client's decisions, which are divided into stages, is intended to provide a model and will need to be adapted for practical application. At the very least, the sequence will change in the main stages:

- > Strategic planning
- > Preliminary studies
- > Design, formulation of the construction project
- > Tender process
- > Construction
- > Management

Previous experience has shown that punctual and cost-effective projects can be developed using the following planning principles:

- > A holistic perspective is adopted during the planning and implementation of projects. This also applies in relation to eventual conflicts of interest.
- > Transparent solution delivery involving all stakeholders and interested parties promotes acceptance (participatory processes).
- > Responsibility must be assumed vis-à-vis neighbouring areas (across communal, cantonal and national borders).

The processing of a project follows the corresponding stages and sub-stages of the SIA service model. Depending on the complexity and scale of the project or the urgency of the measures involved (keyword immediate action), the project stages are developed in varying degrees of detail.

### Further information

- > *SIA 103 Regulation governing services and fees of civil engineers*
- > *SIA 112 Service Model*
- > *Handbuch Programmvereinbarungen im Umweltbereich, BAFU 2011*

## 4.3 Maintenance of existing measures

The maintenance of protective structures is just as important as their construction. If they are not maintained or if they become inefficient, the re-emergence of the threat that existed prior to their construction may be expected. In fact, the threat may be even greater due to the failure of retaining protective structures than it was prior to their construction. Weaknesses and faults can be identified through regular maintenance work. After events retention capacities must be restored in the aftermath of hazard events.



Hence maintenance is a permanent task. It is carried out, financed or monitored by the cantons, communes and owners in accordance with the legislation in force.

The nature, scope and frequency of maintenance must be tailored to the local conditions. All maintenance work shall be carried out with the agreement of the landowners and relevant cantonal agencies.

The planning of appropriate maintenance must be integrated into a protection project as it can influence the selection of measures. The repeated emptying of bedload traps or rockfall nets are two examples of processes that generate significant costs in the case of frequent hazard events and should, therefore, influence the selection of measures from both an economic and technical perspective.

#### Maintenance strategy

This maintenance planning also facilitates the differentiation between construction and maintenance measures and an expedient realisation. The processes and responsibilities are regulated in the maintenance strategy:

- > Who assumes responsibility for maintenance and the costs?
- > Who checks the protective structures?
- > How often are checks and inspections carried out?
- > When and how is the corresponding maintenance to be carried out?

The maintenance-control is determined by the nature of the construction. The technical demands and financial consequences of routine maintenance work may depend on the type of construction.

#### Maintenance

In landslide areas, drainage systems can be damaged or cut off by residual movements. The periodic checking of drainage systems is necessary to verify their functioning. A decline in effect can be observed in many drainage systems with increasing age, in particular in fine-grained rock formations. Additional problems can be caused by sintering and penetrating roots.

The maintenance and checking of rockfall nets are permanent tasks. If measures to prevent rockfall are implemented, not only must the protective structures themselves be checked periodically, the hazard source and hazard area must also be monitored. The development of potential hazards can be identified and additional measures taken in good time through the preventive monitoring of the area. The checking of the measures also involves the recording of the rockfall activity. If a lot of material accumulates behind the protective structure, individual structural elements may be strained. The rocks that accumulate behind rockfall protection structures must be removed periodically if they increasingly impair the original function of the measure. In the event of major impacts from rockfall, the transition to repair work is fluid; it may be necessary also to replace the posts, brakes, anchors and ground plates.

The function of protective measures on private sites must be explained to new owners in the event of a change in ownership. Other efforts and formal requirements are necessary in this regard. Maintenance must also be guaranteed or tolerated by the new owner. Otherwise, the risk arises that protective structures will be removed for aesthet-

ic reasons. The addition of a corresponding note to the land registry and/or insurance policy can be helpful.

#### 4.4 Application in spatial planning

In accordance with the spatial planning, hydraulic engineering and forest legislation, the cantons and communes must take the hazard documentation into account in all activities with a spatial impact (Art. 15 para. 3 ForO). This applies in particular to structure planning, land use planning and the granting of planning permission. The cantons ensure that planning is integrated; this takes inter alia the interests of spatial planning into account (Art. 17 para. 3 ForO).

Spatial planning is part of integrated risk management and makes a crucial contribution to risk prevention. According to the Hydraulic Engineering Act, spatial planning measures take priority over other measures. Spatial planning ensure the suitable use of endangered areas and contribute to risk reduction in this way. Spatial planning measures should enable the reduction of risk in risk areas (e.g. through the reduction of vulnerability or of the damage potential) or prevent the emergence of new risks (e.g. through the forgoing of new uses or through development bans).

The risk-based application of the hazard documentation takes the nature of the threats, the main hazard processes, existing and planned land use and the other interests of society at large into account. Risk-based spatial planning is a measure for protection against natural hazards that not only makes sense in the long term, it also saves on costs. Spatial planning can make a further contribution by keeping the necessary land free for structural and technical protective measures, drainage corridors, the retention of processes and buffer zones to risk areas. If spatial planning exhausts all possibilities and minimises the damage potential, it makes a major impact in a highly efficient way.

Protective structures are designed to themselves withstand hazardous processes. The effect of protective measures should be quantifiable and permanently available with a suitable degree of certainty (approx. 50 years). The primary aim is greater safety and the secondary aim is the downgrading in the hazard map. Protective structures only be taken into account in hazard evaluations if their acceptance has been signed off; they cannot be taken into account at the planning stage. The application of the hazard maps and the consideration of protective structures on the basis of standard principles is a challenge (*'unité de doctrine'*).

#### 2005 Recommendation (ARE et al. 2005)

In the recommendation "Spatial Planning and Natural Hazards" (ARE et al. 2005), the federal authorities specified principles for the appropriate and sustainable application of the natural hazard documentation. This recommendation forms the basis for the application of the structural planning, land-use planning and zone designation (see Appendix A4) and for the process for granting planning permission. In the case of the designation of zones and planning permission processes, responsibilities and risk-based considerations should also be taken into account.

Experience has shown that major material risks can be reduced using simple and low-cost measures, even in reference zones (yellow, and yellow-white hatched areas). Personal risks in these and other zones can be reduced with the help of organisational measures (see chapter 3.3). These measures generate relatively few costs but they have a significant impact.

The degrees of hazard are primarily tailored to the consequences for the use of land for construction. They should prevent the threat to human life and limit the extent of material damage. If hazard index maps only are available outside of the development zone, the threat or degree of hazard should be determined if required (e.g. in an application for development). The degrees of hazard are not decisive for leisure and recreational activities (e.g. hiking trails, ski runs) and are not directly applicable. In the event of a hazard the action requirement there is primarily determined using risk analyses.

During the planning permission process, the responsible authorities verify whether a construction project complies with the main regulations. These also include provisions regarding the protection against natural hazards. Possible building regulations for damage prevention in the case of mass movement hazards are listed in the Appendix. The publication ARE et al. (2005) should be consulted (see also SIA standard and Egli 2005) for additional information and possible regulations for other hazard processes.

#### Further information

- > *Spatial Planning and Natural Hazards (ARE et al. 2005)*
- > *Norm SIA 261*
- > *Wegleitung Objektschutz gegen gravitative Naturgefahren (Egli 2005)*

## 4.5 Protective forest maintenance and silvicultural measures

The safeguarding of hazard areas includes among others silvicultural measures (Art. 17 para. 1 let. a ForO). The forest protects human life and material assets against natural hazards by preventing hazard processes or reducing their impact. Protective forest maintenance is based on the assumption that there is a direct link between risk reduction and the state of the forest. The targeted forest state is based on the knowledge of natural hazards and of specific site conditions.

The guide “Nachhaltigkeit und Erfolgskontrolle im Schutzwald” (“Sustainability and Success Monitoring in the Protective Forest”) (NaiS, BUWAL 2005) provides information about the possibilities provided by and requirements made of the protective forest in relation to all natural hazards.

### Further information

- > *NaiS / Frehner et al. 2005, Nachhaltigkeit und Erfolgskontrolle im Schutzwald* (NaiS); [www.bafu.admin.ch/naturgefahren](http://www.bafu.admin.ch/naturgefahren) > Fachinformationen Wasser, Rutschungen, Sturz, Lawinen > Umgang mit Naturgefahren > Massnahmen > Schutzwald > NaiS
- > *SilvaProtect CH: Schutzwald in der Schweiz*; [www.bafu.admin.ch/naturgefahren](http://www.bafu.admin.ch/naturgefahren) > Fachinformationen Wasser, Rutschungen, Sturz, Lawinen > Gefahrensituation und Raumnutzung > Gefahrengrundlagen > SilvaProtect-CH

## 4.6

### Structural measures for fall processes

The safeguarding of hazard areas includes rockfall and rock avalanche barriers, retaining structures and the preventive release of material at risk of falling (Art. 17 para. 1 let. e ForO). In general it may be stated that for the three different fall processes (rockfall, rock avalanche, collapse), the number of possible measures declines with the size of the moving mass (Fig. 16). Few really effective structural measures can be implemented for rock avalanches. The same applies to collapse processes in Karst areas.

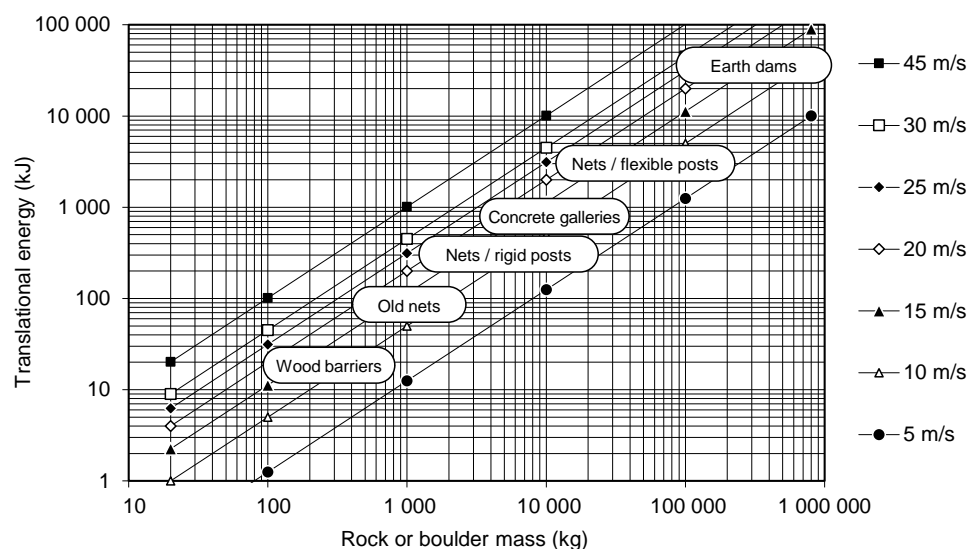
In contrast, when the threat of rock avalanche arises, individual measures can be taken to reduce the expected damage somewhat.

The basis for the planning of measures is formed by the information about the movement forms, bounce heights, masses, rock/boulder sizes, velocities and energy of the fall components. The fall trajectories must also be spatially familiar. The hazard map does not contain sufficient information for the dimensioning of protective structures because it primarily portrays the energies of the falling bodies and the envelope of the possible fall trajectories. Decisions regarding a protective measure cannot be taken on the basis of the maximum kinetic energy alone. In addition to the specified parameters, other factors like accessibility, spatial conditions and maintenance must be taken into account. The construction costs also play a crucial role.

The possibilities offered by the measures are divided on the basis of the process sequence: release area (section A), transit and depositional area (section B), and local protection (section C).

**Fig. 16 > Translational energy in fall processes and the deployment of possible rehabilitation methods**

The kinetic energy is produced by the translational energy and rotational energy combined, which often represents around 20% of the translational energy. The translational energy is presented in the diagram as it can be calculated from the velocities and the mass of the rocks and boulders. The maximum retention forces of protective measures are indicated in the diagram.



The standard rules of architecture and engineering, in particular the SIA norms, are applicable to the dimensioning of protective structures. For some types of structures, the load-bearing capacity and fitness-for-purpose must be demonstrated in all sub-areas, but not for others. For example, protection galleries must be dimensioned in accordance with the guideline of the Federal Roads Office (ASTRA 1998). According to this guideline, a static substitute load must be calculated on the basis of the kinetic energy of the main boulder. All areas of the gallery are then dimensioned based on this static substitute load. The flexible protective nets used must be officially certified for quality. Buyers and users must specify the requirements for the protection of networks, their assembly, fixings and foundations in procurement. The forces in the supporting steel ropes should generally be increased by 30% and these increased forces should be used as static substitute loads in the dimensioning of the foundations and anchorage. Despite the extra loads included in the dimensioning, the consequences of overload must be tested in each case. This is due to the possible heterogeneity of the rock, potentially larger falling masses and the corresponding uncertainties (see chapter 2.11). Recommendations regarding construction in permafrost should be taken into account for the design of protective structures in the high-Alpine process area (Phillips et al. 2003).

### A Measures in the release area

The following measures can be carried out in the release or originating area to reduce the associated hazards:

- > silvicultural and biological methods,
- > rock clearing, blasting,
- > covers, wire mesh nets,
- > soil nailing, anchorage, stanchions, underpinning.

### B Measures in the transit and depositional area

- > Silvicultural and biological measures, placing felled trees in a cross-pattern (“cross-felling”).
- > Protective walls with steel supports, rockfall nets, protective galleries, protective dams.

### C Measures as local protection

Measures are mainly integrated into the existing structure (measures carried out on the object). The reinforcement of building walls is a standard measure, in which the window and door openings must be eliminated simultaneously or reinforced. Depending on definitions, property-related nets, walls and dams are also classified as ‘local protection’.

## 4.7

### **Structural measures for slide processes**

The safeguarding of hazard areas includes landslide and gully control structures, drainage works, retention structures and erosion protection (Art. 17 para. 1 let. d and e ForO). Slide processes are highly varied in terms of their depth, width, length and steepness. The geological, hydrogeological and topographic conditions in landslides are also heterogeneous. For this reason, different remedial options are used when required based on the prevailing conditions. The following list provides an overview of the possible measures implemented for the improvement of stability and tightness (adapted from Reuter et al. 1992):

- > drainage, both surface and underground (gravitational or using pumps), drainage of surface water in the area of contribution, minimisation of infiltration;
- > structural-mechanical measures:
  - support structures (e.g. retaining walls, wood boxes for shallow and medium-depth landslides)
  - anchors, nails, pins, posts, microposts
  - geotextiles
  - nets and suspension
  - surface sealing

- > topographic changes in the release area (discharge) and on the landslide toe (e.g. braking effect);
- > improvement of the rock characteristics through material replacement;
- > silvicultural measures, engineering-biological slope stabilisation, erosion protection (e.g. in watercourses).

Structural measures are often deployed in the case of smaller sliding masses. These methods are common in the fields of engineering and geotechnology and are explained in the relevant literature. The planning of such measures necessitates, therefore, a knowledge of dimensions of the unstable mass, in particular the depth of the sliding surface, the rock lithology and the hydrogeological conditions. This information is not generally available on hazard maps and must be surveyed for the planning of measures at the M3 level. In addition, movements must be differentiated spatially and temporally with great precision. If the information is imprecise or incorrect, the risk arises that the measures will be insufficient or oversized. In the former case, subsequent costs will arise due to damage, and in the second case the cost of construction is already excessive.

Large-scale structural-mechanical measures are implemented in the release area of rock slides if required, if the effect is sufficient and the cost-effectiveness of the measure is good. Anchors and rock nails can be installed individually or across an area. Short nails and pins with steel tubes tend to be used more in the case of shallow to medium-depth instabilities. A distinction is made between prestressed and untensioned anchor types (also referred to as slack anchors). In this case, the forces are absorbed following small movements that arise after installation. Prestressed anchors are used when the intention is to completely prevent movements. Depending on the rock lithology, the anchor heads can be reinforced if required with reinforced concrete plates and bars. The forces that affect the anchors should be checked periodically (Monitoring, see chapter 4.10).

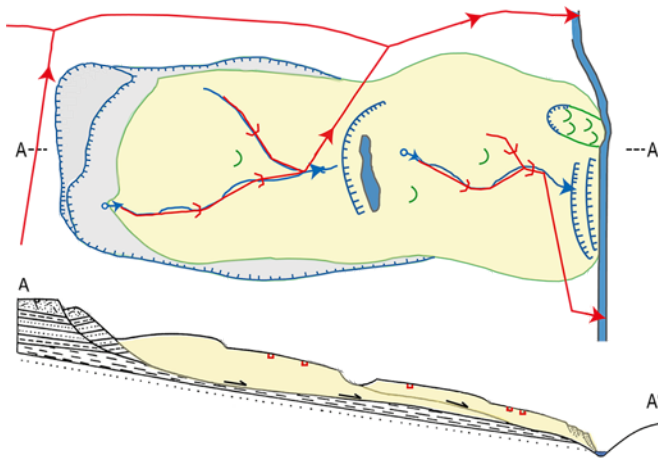
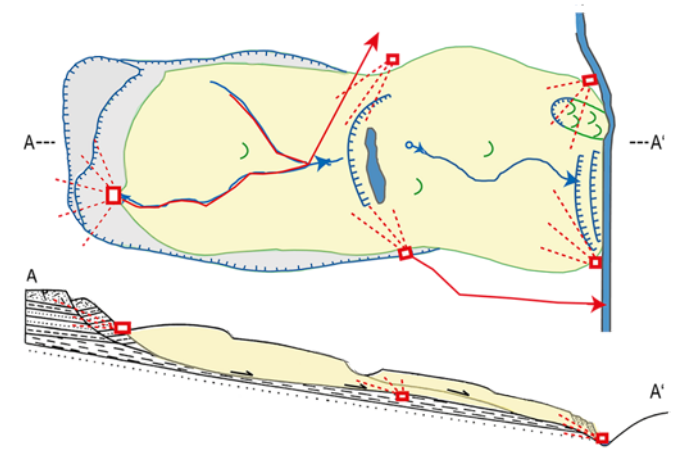
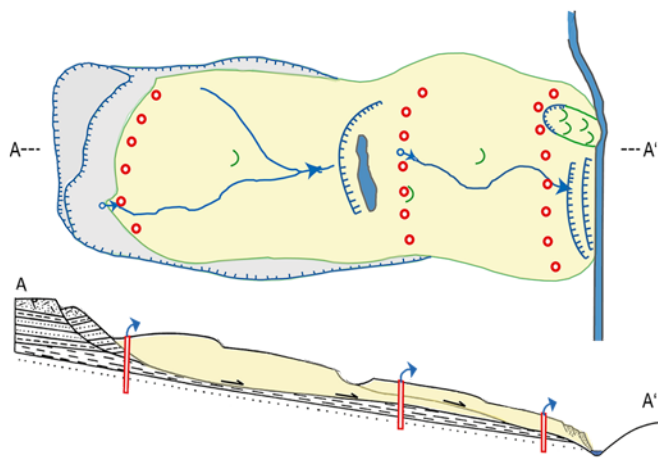
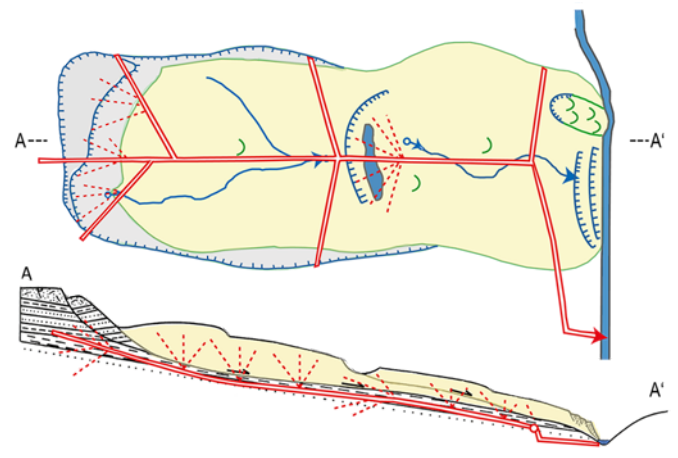
Drainage is frequently considered as an option for action planning in landslide areas of all sizes. Hence, what is intended here are all types of drainage systems used in landslide areas. Numerous wide-ranging methods and technologies make it possible to influence the hydrological and hydrogeological conditions to improve slope stability. They can be classified on the basis of the area in which they take effect: on the surface (e.g. open collection trenches for the surface water), at shallow depths (e.g. drainage trenches) and, finally, at large depths (e.g. tunnels with radial drainage boreholes, screened wells, Fig. 17). The forest also influences the flow conditions and can play an important role in remediation.

#### Drainage systems

Detailed technical explanations of the requirements for and possibilities of drainage system can be found in the FOEN guide “Rutschungen: Hydrogeologie und Sanierungsmethoden durch Drainage” (“Landslides: Hydrogeology and Rehabilitation Methods through Drainage”) (Parriaux et al. 2010). The principles and of typical uses are listed below.

**Fig. 17 > Comparative diagrams of the main hydrogeological remediation measures**

Plan view (top) and longitudinal section (bottom). Partly a schematic representation. Constructions are partly projected along the axis, and in plan view D the tunnel structure is shown schematically on the sliding surface.

**A: Collection trenches for the surface water****B: Subhorizontal drainage boreholes****C: Screen of vertical filter wells****D: Tunnel with radial drainage boreholes**

modified after Parriaux et al. 2010

The principle of hydrogeological remediation (drainage) consist in artificially altering flow conditions to reduce the movement-promoting effects of the water and increase the forces that inhibit movement. This result can be achieved in two ways:

#### Principles

- > by reducing the flow of water to the subsurface by decreasing infiltration on the surface, at the sides or under the sliding mass;
- > by lowering the ground water level using various drainage technologies and the pore water pressure in the unstable mass and/or subsurface

In general, all drainage measures contribute to the stabilisation of a slope. However, drainage can also have less welcome side effects like subsidence, local increases in percolation forces, the sealing of sources, and the drying up of possibly protected



wetlands or streams. The selection of suitable drainage technologies is a complex operation which depends on several factors, in particular:

- > the size and geometry of the sliding body to be stabilised,
- > the geological and hydrogeological conditions,
- > the time needed to implement the measures and for them to take effect,
- > the effectiveness and durability of the method,
- > the access possibilities and location conditions,
- > the impacts on the environment,
- > the risks (damage potential),
- > the maintenance costs (long term),
- > the available financial resources.

#### 4.8 Structural measures for flow processes

The safeguarding of hazard areas includes landslide and gully control structures, drainage systems, retention structures and erosion protection (Art. 17 para. 1 let. d and e ForO). As in the case of fall processes (chapter 4.6) the protection against hillslope debris flows can be divided into measures implemented in the release area, in the transit and depositional areas and local protection. Another distinction is made in relation to the movement of the flow mass: whereas braking measures (or stopping measures for small volumes) alter the flow velocity (impact), diverting measures mainly influence the direction of the flow. The following parameters of hillslope debris flows must be known for the planning of braking and diverting protective structures: flow velocity, flow height, flow direction, volume, material properties (e.g. density, particle size, block size) and the influence of wood. The technical aspects of the different types of measures involved are described at the end of the following list.

##### A Measures in the release area

These measures serve the purpose of stabilisation and are basically comparable with the measures undertaken for shallow landslides.

##### B Measures in the transit and depositional areas as well as local protection

Different types of measures may be assumed for local protection:

- > Protection by retention of the mass above the area with damage potential (e.g. with hillslope debris-flow protection barriers or a dam)
- > Protection against the impact of the hillslope debris flow on buildings (e.g. walls or dams)
- > Deflection of the hillslope debris flow using splitting wedges, deflection walls or dams

Local protection measures includes all structural measures that protect a single building. This category also includes structural measures on buildings.

## 4.9

**Overload**

Overload arises when the pressure or stress generated by the natural hazard process exceeds the protective capacity of the protective structures or the combined protection system. In this case, the hazard event exceeds the dimensioning of the structures or system. In the case of fall processes, for example, this would involve volumes of energy that exceed the dimensioning value of the protective nets or a high bounce. Overload can also arise when a measure does not take effect as expected.

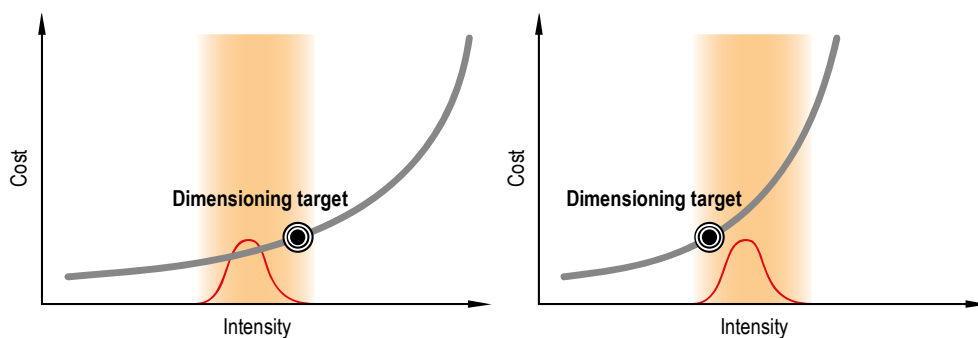
The planning of protective measures must take the existing ambiguities and uncertainties into account: process dynamics, unexpected event trajectories, modelling results, the reaction of the protective system to a load, successive events etc. All of these uncertainties can be taken into account in the optimisation of protective measures. The dimensioning of protective structures is based on the pertinent scenarios (see chapter 2.10) and is carried out for the so-called design event.

Values from the flood statistics are used in the case of water hazards and snow-height statistics are used in case of avalanche hazards. In contrast, in the case of mass movements, the selection of the pertinent scenarios, the protection objectives and the scale of the risk reduction are decisive. The dimensioning and design must also take possible consequences or the damage to be expected into account (risk).

If generous dimensioning does not result in significant extra costs, the measures or strategies implemented should be based on a load that lies on the upper limit of the uncertainty range (Fig. 18, left). If the costs increase dramatically within the area of uncertainty, the dimensioning should be based on a load located on the lower limit of the range (Fig. 18, right). Moreover, it must also be considered that, in addition to the intensity, the probability of occurrence is also associated with uncertainties.

**Fig. 18** > Design of a measure taking the uncertainty range into account

*The frequency distribution and the coloured area indicate the uncertainty range for the dimensioning of the relevant intensity. Left: Design at the upper limit of the uncertainty range with moderate cost development. Right: Design at the lower limit of the uncertainty range with a strong increase in costs.*



If the protection objectives cannot be attained through the implemented protective structures, greater safety is achieved using additional measures in accordance with the integrated hazard management approach: i.e. monitoring, organisation and planning measures (see chapter 3, 4.1, 4.4, 4.10 ff.). The optimum combination should be sought, therefore, during the planning of measures. All measures should also be designed so that they can be adapted to new general conditions using an appropriate level of resources – for example, large-scale events caused by climate change.

In every case it is essential to explain what is expected to happen during the overloading of protection systems. Protective structures must not fail and collapse in the case of events that exceed their dimensioning as this causes uncontrolled processes and the sudden increase in the damage caused. For this reason, existing and planned protective structures must undergo systematic testing in relation to the functioning and failure in the event of overload (see chapter 2.4). However, the condition of overload capacity cannot always be fulfilled for protective measures in the area of mass movements. In these cases, redundancies should be created or robust systems selected, which can withstand greater impacts without failing and provide greater reliability in the case of increased loads (e.g. dam instead of rockfall net).

Robustness is defined as the ability of a structure and its components to withstand damage or failure to within limits that are in reasonable proportion to the cause (SIA 260). Specifically, the failure of a component part should not result in the failure of the entire system. In the planning stage it is therefore essential to ensure that the relevant short-term damage during the action of a natural process cannot occur. On the basis of technical and financial conditions, it may be useful to plan additional measures or redundant systems to minimize the extent of damage.

These systems can complement the other measures with a view to limiting the residual risks and reducing them to an acceptable level. Irrespective of all of these possibilities, the greatest level of safety and sustainability can be achieved through planning-based measures – assuming the areas and corridors affected in the event of overload are kept free or cleared (Art. 17 para. 3 ForO).

#### 4.10 Organisational measures and emergency planning

The cantons establish early warning systems if they are required for the protection of human life and important material assets. They ensure the development and operation of the associated measurement stations and information systems (Art. 16 para. 1 ForO). We will probably never be in a position to fully protect ourselves against mass movement hazards. The hazard potential is neither completely predictable or entirely controllable. Natural events can exceed the intensity provided for in the action planning, arise in locations in which hazards are not expected or affect developed areas that are not safeguarded.

The aim of organisational measures is to limit the extent and duration of a crisis situation. These include monitoring, early warning services, alerting, the timely initiation of prepared intervention measures, rescue services and victim support. Immediate

measures are also required directly before and after an event. The preparation and implementation of response measures are basically part of the area of responsibility of the natural hazard experts and the executive and intervention forces. Civil protection involves the following partner organisations: police, fire brigade, health service, technical operations and civil protection. The smooth functioning of deployment and co-operation is a precondition for the successful response in emergency situations.

For technical and economic reasons, it is not always feasible to provide structural protection against mass movements, particularly in the case of large rock masses. If complete protection is not available for the hazard area, the protection of human life can nonetheless be guaranteed at an acceptable cost through monitoring, alerting and warning systems.

The establishment of monitoring systems for warning and alerting must be adapted and developed on an appropriately phased basis. The individual stages and criteria to be considered are described below.

Before establishing a monitoring system, it is necessary to have good basic information. In the case of lacking basic information, the processes, hazards and risks must be first analysed.

#### **4.10.1 Early warning systems**

The protection requirements and aim of the monitoring must be defined at the outset as they have a crucial influence on the monitoring strategy. Periodic measurements often simultaneously serve the purposes of monitoring and the understanding of a hazard process. The development of slide processes can often be monitored through periodic measurements if it is assumed that sufficient reaction time is available for the implementation of supplementary measures (e.g. evacuation). In the case of rapid and brutal processes, the reaction time (or intervention time) is brief, hence the hazard locations must be monitored using a permanent alerting system.

Four stages can be defined for monitoring based on the associated objectives. The hazard processes must be understood before warning or alerting systems can be established. For this reason, the first stage involving hazard evaluation is compulsory. It can then be decided whether stages 2, 3 or 4 will be carried out. The number of measurements recorded increases with each stage:

**Tab. 3 > Monitoring stages**

Stage	Objective, type	Temporal surveying
1.	Improving the understanding of the process, hazard evaluation	once to several times
2.	Tracking or monitoring process development	periodic*
3.	Early detection, alerting system**	periodic*, frequent
4.	Permanent monitoring for alarm**	permanent***

\* Possible intervals for periodic measurements: days, months, year (years). The intervals can be regular or irregular. A specified measurement interval may be reduced in certain situations (following precipitation, storms etc.).

\*\* Early warning systems include warning and alerting systems. They are part of the safety strategy.

\*\*\* Permanent monitoring and real-time transmission for alerting. Permanent monitoring with rapid transmission is required, in particular, if spontaneous failure is possible. In principle the first process (first move, e.g. rockfall) and/or second process (second move, e.g. debris flow) can be monitored.

Following the determination of the monitoring stage, a measurement strategy is required which evaluates the possibilities for surface and underground measurements. It is possible for stages one to four to be planned and implemented in succession. The selection of possible parameters for integration into the monitoring strategy is carried out as follows:

- > Displacement, deformation. Reference to derived products: velocities, acceleration and differential movements are calculated on the basis of the displacement.
- > Parameters of a meteorological nature (precipitation, temperature etc.)
- > Water measurements (water pressure, water level, flow velocity etc.)
- > Geophysical measurements (micro-seismic, acoustic measurements etc.)
- > Other parameters of the rock or the hazard processes.

The selection of the methods or measurement technology is of central importance. The question arises as to whether the methods are suitable for reliable, detailed, long-term, area-wide or linear monitoring. The advantages and disadvantages must be evaluated in advance on the basis of the defined objectives. In principle, it is possible to differentiate between three spatial types of measurement methods for monitoring:

a) Point measurement:

Examples: extensometers for crack measurement, GPS.

b) Measurement along a line or profile:

Linear and profile measurements can be used above ground or underground, for example in a borehole. Measurements in boreholes are very important because they can provide a reliable record if changes or deformations in the substrate. Example: inclinometer in a borehole.

c) Area measurement:

The advantage of area measurement lies in the spatial resolution (or coverage) it provides. This is very important in areas in which the extent and activity of a hazard are unknown. Example: LIDAR, INSAR, images (satellite, air and ground images are possible)

It can make sense to combine several methods if there is an interest in obtaining point, line and areal information. This is also necessary when spatially different analysis are pending or if stringent requirements exist in relation to the monitoring (redundancy).

### Accuracy of measurements

*The requirements in relation to accuracy must be defined in advance. Accordingly, the technical characteristics of the measurement equipment or the characteristics of the monitoring system with respect to accuracy must be known. The level of accuracy can be in the sub-millimetre to decimetre range for displacement measurements. An accuracy level in the millimetre range is generally required for the threat of rockfall. The measurement equipment must be checked for its accuracy (calibration).*

At the start of a newly installed monitoring system, an evaluation phase is required so that the relevant actors can get to know the system, the measurement variability, the natural changes and their influence (so-called 'calibration phase'). Safety-relevant interpretations should only be carried out and threshold values defined after this phase. The following questions are examined during the evaluation and interpretation process:

Evaluation and interpretation

- > How are the displacements developing? Dynamics, movement behaviour, acceleration and trends?
- > Are external influences like precipitation or temperature relevant?
- > Can indications of failure mechanisms be established?

The interpretation of the data and dynamics of the mass movements forms the basis of the hazard evaluation. It enables the verification of the scenarios and the early warning system.

The monitoring system should be checked if the risk changes or if the uncertainties that remain are excessive. The reliability of the data, limit values and system must be verified. This includes statistical data evaluations and error analyses (standard deviation etc.).

Reliability of the early warning system

The reliability of early-warning systems can be classified in three categories:

1. Technical reliability (devices, components, system structure)
2. Reliability of the data in relation to warning about natural hazard processes (relevance)
3. Reliability of persons (experts, safety officers etc.)

The reliability of persons is primarily relevant in relation to warning systems which constitute a precondition for decisions about intervention. This includes the quality of the interpreting and performance of the experts in the case of a hazard event. These people's propensities for taking or avoiding risks influences safety. In the case of a hazard event, the reliability of other persons with decision-making competencies must be a given (safety officers, communal management body etc.).

During the evaluation of the data and measurement network, the question arises as to whether the number of measurement points and parameters is adequate. The evaluation may reveal that relevant points are lacking while unimportant points are being measured. The measurement frequency also should also be checked.

The fitness for purpose and availability of an early-warning system must be guaranteed. It must also be aimed to establish sufficient durability. Reliability must be tested regularly during the operating phase: reliability of the system (functioning of the measuring devices, data transmission, emergency power supply etc.), impacts of natural hazards (rockfall impacts, lightning etc.) and impacts of human beings or animals (damage etc.). High requirements in relation to reliability necessitate redundancies.

Warning or alerting is associated with a development or process. This includes, for example, warnings against floods, avalanches and rockfall events. These processes have both a temporal and spatial dimension. Accordingly, warnings are also related to a specific area, for example, on a local, regional, national or international level. The processes and their temporal development also vary significantly. In the case of a threatened rockfall event, the temporal development is a matter of seconds or minutes. Several minutes are usually available to raise the alarm when debris flows are triggered in the unstable periglacial unconsolidated material. In the case of the flood risk for cities like Bern, Basel and Budapest, more time is usually available for the warning process (hours to days).

#### Warning

The local authorities are basically responsible for local alerting. In known hazard areas, specially trained teams are responsible for warnings and alerts. These teams obtain their information from their own monitoring systems and from the national institutions. The limit values for mass movements should be defined on a case-by-case basis. For imminent rockfall hazards, threshold values in the millimetre or centimetre range are often defined. In the case of landslides in unconsolidated soil materials, the limit values are usually higher.

The safety strategy serves the public authorities or an institution for the preparation for a natural hazard event. The safety strategy also regulates the responsibilities for warnings and alerts. The people and organisations potentially involved are:

- > Natural hazard experts
- > Safety officers, safety services, natural hazard consultants<sup>1</sup>
- > Hazard commission, warning commission, warning service<sup>1</sup>
- > Communal management committee, communal executive
- > Civil protection action forces (police, fire brigade; health service, civil protection, technical services)
- > Cantonal authority, cantonal management committee
- > Federal authority, third parties

The effect of these protective measures is also dependent on the reaction of the persons at risk. The affected persons must receive and be able to understand the alarm. They must then adapt their behaviour in the case of acute danger. Examples of such behaviours include: stopping at red lights, leaving the area at risk on hearing a siren, seeking the protected area (see also the section on emergency planning).

<sup>1</sup> (possible stages/units: commune, facility, canton)

The limit values for the early-warning system are defined by experts in advance and specifically for the location in question. The procedure for lifting alerts must also be defined (limit value, controls, responsibilities etc.). An example with three limiting or threshold values and the corresponding responsibilities is presented in the following table:

**Tab. 4 > Examples of thresholds**

Limit value	Velocity v [mm/day]	Persons, responsibilities
e.g. Limit value 1:	v > 1 mm/day If displacement > 3 mm	→ geologist, expert etc.
e.g. Limit value 2:	v > 3 mm/day	→ + hazard commission
e.g. Limit value 3:	v > 8 mm/day or total displacement > 10 mm	→ + management committee etc.

Note: Fewer or more than three limit values can be defined.

#### Further information

*The specialist federal agencies are responsible for national warning processes (see Alarm Ordinance and the Federal Council OWARNA Decree). The federal authorities and natural hazards experts jointly present their products for the different natural hazards on the Common Information Platform for Natural Hazards (GIN). These include measurement data, forecasts, warnings, and bulletins.*

#### 4.10.2 Emergency planning

Emergency planning specifies the measures to be taken by the responsible authorities and action forces in the case of a hazard event (Art. 15, ForO). The particular concern here is to save human life and, if applicable also, livestock, to reduce the extent of the material damage and the consequential damage that can be caused by hazardous materials, for example chemicals.

It is crucial that the responsible authorities are aware of the mass movement hazards and the corresponding warning and alerting stages (see previous section). The consequences of hazardous events can be alleviated, at the very least, through the development of evacuation and intervention plans and the corresponding preparation. In addition to logistical preparation, the definition of safe withdrawal areas for evacuated people is important.



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**Further information**

- > Sättele M., Bründl M. 2015: *Praxishilfe für den Einsatz von Frühwarnsystemen für gravitative Naturgefahren*.
- > GIN (not publically available): [www.gin.admin.ch](http://www.gin.admin.ch)
- > Owarna: [www.planat.ch/de/behoerden/im-ereignisfall/owarna](http://www.planat.ch/de/behoerden/im-ereignisfall/owarna)
- > Federal natural hazard warnings: [www.naturgefahren.ch](http://www.naturgefahren.ch)

**4.11 Periodic checking and success monitoring**

Success monitoring reveals, first, whether or not certain measures have attained their objectives. The periodic verification of the measure strategy and the hazard documentation is the task of the authorities and is particularly important in the aftermath of storm events. Second, success monitoring also provides indications of the adaptations and optimisations that could be implemented in the future. Therefore, success monitoring is not an end in itself but part of the project implementation process. Success monitoring also reveals whether the deployed resources have been used in an optimum and target-oriented way.

Maintenance is also associated with the checking of the protection strategy. All measures must be maintained: this applies not only to structural measures but also to planning and organisational measures.

## > Appendix

### A1 Legal bases

The Guideline on Protection against Mass Movement Hazards is based on a series of federal legislative acts and the corresponding ordinances. The relevant acts for the domain of the natural hazards are exposed here.

As English is not an official language of the Swiss Confederation, the legislative acts are normally not translated into English. As a consequence, the German version is reproduced below. Other versions in French or in Italian are also available under [www.admin.ch/gov/de/start/bundesrecht/systematische-sammlung.html](http://www.admin.ch/gov/de/start/bundesrecht/systematische-sammlung.html).

#### **Bundesgesetz vom 22. Juni 1979 über die Raumplanung (RPG, SR 700)**

##### Art. 6: Grundlagen

- <sup>2</sup> Für die Erstellung ihrer Richtpläne erarbeiten die Kantone Grundlagen, in denen sie feststellen, welche Gebiete
- c) durch Naturgefahren oder schädliche Einwirkungen erheblich bedroht sind.

##### Art. 15 Bauzonen

- <sup>4</sup> Land kann neu einer Bauzone zugewiesen werden, wenn:
- a) es sich für die Überbauung eignet.

#### **Bundesgesetz vom 4. Oktober 1991 über den Wald (WaG, SR 921.0)**

##### Art. 1: Zweck

<sup>1</sup> Dieses Gesetz soll:

- a) den Wald in seiner Fläche und in seiner räumlichen Verteilung erhalten;
- b) den Wald als naturnahe Lebensgemeinschaft schützen;
- c) dafür sorgen, dass der Wald seine Funktionen, namentlich seine Schutz-, Wohlfahrts- und Nutzfunktion (Waldfunktionen) erfüllen kann;
- d) die Waldwirtschaft fördern und erhalten.

<sup>2</sup> Es soll ausserdem dazu beitragen, dass Menschen und erhebliche Sachwerte vor Lawinen, Rutschungen, Erosion und Steinschlag (Naturereignisse) geschützt werden.

##### Art. 19: Schutz vor Naturereignissen

Wo es der Schutz von Menschen oder erheblichen Sachwerten erfordert, sichern die Kantone die Anrissgebiete von Lawinen sowie Rutsch-, Erosions- und Steinschlaggebiete und sorgen für den forstlichen Bachverbau. Für die Massnahmen sind möglichst naturnahe Methoden anzuwenden.

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#### Art. 36: Schutz vor Naturereignissen

<sup>1</sup> Der Bund gewährt den Kantonen auf der Grundlage von Programmvereinbarungen globale Abgeltungen an Massnahmen, die Menschen und erhebliche Sachwerte vor Naturereignissen schützen, namentlich an:

- a) die Erstellung, die Instandstellung und den Ersatz von Schutzbauten und -anlagen;
- c) die Erstellung von Gefahrenkatastern und Gefahrenkarten, die Einrichtung und den Betrieb von Messstellen sowie den Aufbau von Frühwarndiensten zur Sicherung von Siedlungen und Verkehrswegen.

#### **Verordnung vom 30. November 1992 über den Wald (WaV, SR 921.01)**

#### Art. 15: Grundlagen

<sup>1</sup> Die Kantone erarbeiten die Grundlagen für den Schutz vor Naturereignissen. Sie:

- a) führen Inventare über Bauten und Anlagen, die für den Schutz vor Naturereignissen von Bedeutung sind (Schutzbautenkataster);
- b) dokumentieren Schadenereignisse (Ereigniskataster) und analysieren, soweit erforderlich, grössere Schadenereignisse;
- c) erstellen Gefahrenkarten und, für den Ereignisfall, Notfallplanungen und führen diese periodisch nach.

<sup>2</sup> Bei der Erarbeitung der Grundlagen berücksichtigen sie die von den Fachstellen des Bundes durchgeführten Arbeiten und aufgestellten technischen Richtlinien.

<sup>3</sup> Die Kantone berücksichtigen die Grundlagen bei allen raumwirksamen Tätigkeiten, insbesondere in der Richt- und Nutzungsplanung.

<sup>4</sup> Sie stellen die Grundlagen dem Bundesamt auf Verlangen zur Verfügung und machen sie der Öffentlichkeit in geeigneter Form zugänglich.

#### Art. 16: Frühwarndienste

<sup>1</sup> Wo es der Schutz von Menschen oder erheblichen Sachwerten erfordert, errichten die Kantone Frühwarndienste. Sie sorgen für den Aufbau sowie den Betrieb der dazugehörigen Messstellen und Informationssysteme.

<sup>2</sup> Bei der Errichtung und beim Betrieb der Frühwarndienste berücksichtigen sie die von den Fachstellen des Bundes durchgeführten Arbeiten und aufgestellten technischen Richtlinien.

<sup>3</sup> Sie sorgen dafür, dass die Daten der Messstellen und Informationssysteme dem Bundesamt auf Verlangen zur Verfügung gestellt und der Öffentlichkeit in geeigneter Form zugänglich gemacht werden.

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#### Art. 17: Sicherung von Gefahrengebieten

<sup>1</sup> Die Sicherung von Gefahrengebieten umfasst:

- a) waldbauliche Massnahmen;
- b) bauliche Massnahmen zur Verhinderung von Lawinenschäden und ausnahmsweise die Erstellung von Anlagen zur vorsorglichen Auslösung von Lawinen;
- c) begleitende Massnahmen im Gerinne, die mit der Walderhaltung im Zusammenhang stehen (forstlicher Bachverbau);
- d) den Rutschhang- und Rufenverbau, entsprechende Entwässerungen sowie den Erosionsschutz;
- e) Steinschlag- und Felssturzverbauungen, Auffangwerke sowie ausnahmsweise die vorsorgliche Auslösung von absturzgefährdetem Material;
- f) die Verlegung gefährdeter Bauten und Anlagen an sichere Orte.

<sup>2</sup> Die Arbeiten sind wenn möglich mit ingenieurb biologischen und waldbaulichen Massnahmen zu kombinieren.

<sup>3</sup> Die Kantone sorgen für eine integrale Planung; diese berücksichtigt insbesondere die Interessen der Bewirtschaftung des Waldes, des Natur- und Landschaftsschutzes, des Wasserbaus, der Landwirtschaft und der Raumplanung.

#### Art. 39: Schutz vor Naturereignissen

<sup>1</sup> Abgeltungen an die Massnahmen und die Erstellung von Gefahrengrundlagen werden in der Regel global gewährt. Die Höhe der globalen Abgeltungen wird zwischen dem Bundesamt und dem betroffenen Kanton ausgehandelt und richtet sich nach:

- a) dem Gefahren- und Schadenpotenzial;
- b) dem Umfang und der Qualität der Massnahmen sowie von deren Planung.

<sup>2</sup> Abgeltungen können einzeln gewährt werden, wenn die Massnahmen:

- a) einen kantonsübergreifenden Bezug aufweisen;
- b) Schutzgebiete oder Objekte nationaler Inventare berühren;
- c) wegen der möglichen Alternativen oder aus anderen Gründen in besonderem Mass eine komplexe oder spezielle fachliche Beurteilung erfordern; oder
- d) unvorhersehbar waren.

<sup>3</sup> Der Beitrag an die Kosten der Massnahmen nach Absatz 2 beträgt zwischen 35 und 45 Prozent und richtet sich nach:

- a) dem Gefahren- und Schadenpotenzial;
- b) dem Grad der Umsetzung einer umfassenden Risikobetrachtung;
- c) dem Umfang und der Qualität der Massnahmen sowie von deren Planung.

<sup>4</sup> Wird ein Kanton durch ausserordentliche Schutzmassnahmen, namentlich nach Unwetterschäden, erheblich belastet, so kann der Beitrag nach Absatz 3 ausnahmsweise auf höchstens 65 Prozent der Kosten der Massnahmen erhöht werden.

<sup>5</sup> Keine Abgeltungen werden gewährt an:

- a) Massnahmen zum Schutz von Bauten und Anlagen, die zum Zeitpunkt der Errichtung:
  - 1. in bereits ausgeschiedenen Gefahrenzonen oder bekannten Gefahrengebieten erstellt wurden, und
  - 2. nicht zwingend an diesen Standort gebunden waren;
- b) Massnahmen zum Schutz touristischer Bauten und Anlagen wie Seilbahnen, Skilifte, Skipisten oder Wanderwege, die sich ausserhalb des Siedlungsgebietes befinden.

#### Art. 66a Geoinformation

Das Bundesamt gibt die minimalen Geodatenmodelle und Darstellungsmodelle für Geobasisdaten nach dieser Verordnung vor, für die es im Anhang 1 der Geoinformationsverordnung vom 21. Mai 2008 als Fachstelle des Bundes bezeichnet ist.

#### **Bundesgesetz vom 21. Juni 1991 über den Wasserbau (WBG, SR 721.100)**

##### Art. 3: Massnahmen

<sup>1</sup> Die Kantone gewährleisten den Hochwasserschutz in erster Linie durch den Unterhalt der Gewässer und durch raumplanerische Massnahmen.

<sup>2</sup> Reicht dies nicht aus, so müssen Massnahmen wie Verbauungen, Eindämmungen, Korrekturen, Geschiebe- und Hochwasserrückhalteanlagen sowie alle weiteren Vorkehrungen, die Bodenbewegungen verhindern, getroffen werden.

<sup>3</sup> Diese Massnahmen sind mit jenen aus anderen Bereichen gesamthaft und in ihrem Zusammenwirken zu beurteilen.

##### Art. 6: Abgeltungen an Massnahmen des Hochwasserschutzes

<sup>1</sup> Der Bund fördert im Rahmen der bewilligten Kredite Massnahmen, die dazu dienen, Menschen und erhebliche Sachwerte vor den Gefahren des Wassers zu schützen.

<sup>2</sup> Er leistet Abgeltungen namentlich für:

- b) die Erstellung von Gefahrenkatastern und Gefahrenkarten, die Einrichtung und den Betrieb von Messstellen sowie den Aufbau von Frühwarndiensten zur Sicherung von Siedlungen und Verkehrswegen.

#### **Verordnung vom 2. November 1994 über den Wasserbau (WBV, SR 721.100.1)**

##### Art. 20: Richtlinien

Das BAFU erlässt Richtlinien namentlich über:

- b) die Erstellung der Gefahrenkataster und -karten;

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#### Art. 21: Gefahrengebiete und Raumbedarf der Gewässer

<sup>1</sup> Die Kantone bezeichnen die Gefahrengebiete.

<sup>3</sup> Sie berücksichtigen die Gefahrengebiete [...] bei ihrer Richt- und Nutzungsplanung sowie bei ihrer übrigen raumwirksamen Tätigkeit.

#### Art. 22: Überwachung

Die Kantone überprüfen periodisch die Gefahrensituation an den Gewässern und die Wirksamkeit der getroffenen Massnahmen des Hochwasserschutzes.

#### Art. 27: Grundlagenbeschaffung durch die Kantone

<sup>1</sup> Die Kantone erarbeiten die Grundlagen für den Schutz vor Naturereignissen. Sie:

- a) führen Inventare über Bauten und Anlagen, die für die Hochwassersicherheit von Bedeutung sind (Schutzbautenkataster);
- b) dokumentieren Schadenereignisse (Ereigniskataster) und analysieren, soweit erforderlich, grössere Schadenereignisse;
- c) erstellen Gefahrenkarten und, für den Ereignisfall, Notfallplanungen und führen diese periodisch nach;
- d) erheben den Zustand der Gewässer und ihre Veränderung; und
- f) richten die im Interesse des Hochwasserschutzes erforderlichen Messstellen ein und betreiben sie.

<sup>2</sup> Sie berücksichtigen die vom Bund erhobenen Grundlagen und seine technischen Richtlinien.

<sup>3</sup> Sie stellen die Daten dem BAFU auf Verlangen zur Verfügung und machen sie der Öffentlichkeit in geeigneter Form zugänglich.

### **Bundesgesetz vom 1. Oktober 2010 über die Stauanlagen (Stauanlagengesetz, StAG, SR 721.101)**

#### Art. 2: Geltungsbereich

<sup>1</sup> Dieses Gesetz gilt für Stauanlagen, die eine der folgenden Voraussetzungen erfüllen:

- a) Die Stauhöhe über Niederwasser des Gewässers oder über Geländehöhe beträgt mindestens 10 m.
- b) Die Stauhöhe beträgt mindestens 5 m und die Anlage weist einen Stauraum von mehr als 50 000 m<sup>3</sup> auf.

<sup>2</sup> Die Aufsichtsbehörde des Bundes (Art. 22) kann:

- a) Stauanlagen mit geringeren Ausmassen diesem Gesetz unterstellen, wenn sie ein besonderes Gefährdungspotenzial darstellen;
- b) Stauanlagen, für die nachgewiesen wird, dass sie kein besonderes Gefährdungspotenzial darstellen, vom Geltungsbereich dieses Gesetzes ausnehmen.

### Art. 3: Begriffe

<sup>1</sup> Stauanlagen sind Einrichtungen zum Aufstau oder zur Speicherung von Wasser oder Schlamm. Als Stauanlagen gelten auch Bauwerke für den Rückhalt von Geschiebe, Eis und Schnee oder für den kurzfristigen Rückhalt von Wasser (Rückhaltebecken).

### Art. 10: Vorkehrungen für den Notfall

<sup>1</sup> Die Betreiberin trifft Vorkehrungen für den Fall, dass der sichere Betrieb einer Stauanlage aufgrund von Verhaltensanomalien, Naturereignissen oder Sabotageakten nicht mehr gewährleistet ist.

<sup>2</sup> Sie muss bei einem Notfall alle erforderlichen Massnahmen treffen, um Gefährdungen von Personen, Sachen und der Umwelt zu verhindern.

### Art. 12: Schutz der Bevölkerung im Notfall

<sup>1</sup> Bund, Kantone und Gemeinden sorgen bei einem Notfall mit Hilfe der Mittel und Strukturen des Bevölkerungsschutzes für die Verbreitung von Verhaltensanweisungen an die Bevölkerung und für deren allfällige Evakuierung.

## **Stauanlagenverordnung vom 17. Oktober 2012 (StAV, SR 721.101.1)**

### Art. 1: Begriffe

<sup>1</sup> Eine Stauanlage besteht aus:

- a) dem Absperrbauwerk;
- b) dem zugehörigen Stauraum;
- c) den Nebenanlagen.

<sup>2</sup> Als Absperrbauwerke gelten:

- a) Beton- oder Natursteinmauern;
- b) Schüttdämme;
- c) Wehre einer Flussstauhaltung mit zugehörigen Seitendämmen.

### Art. 2: Stauanlagen mit besonderem Gefährdungspotenzial

<sup>1</sup> Ein besonderes Gefährdungspotenzial besteht, wenn im Falle eines Bruches des Absperrbauwerks Menschenleben gefährdet oder grössere Sachschäden verursacht werden können.

<sup>2</sup> Die betroffenen Kantone melden der Aufsichtsbehörde des Bundes (Bundesamt für Energie, BFE) Stauanlagen, die aufgrund ihrer Grösse nicht dem StAG unterstehen, aber voraussichtlich ein besonderes Gefährdungspotenzial aufweisen.

### Art. 3: Stauanlagen ohne besonderes Gefährdungspotenzial

<sup>1</sup> Die Betreiberin muss dem Antrag, ihre Stauanlage vom Geltungsbereich des StAG auszunehmen, sämtliche zur Prüfung des Gefährdungspotenzials notwendigen Unterlagen beilegen.

## **A2 Identification of mass movement processes**

To provide effective protection against mass movements, knowledge of the main processes involved is very important. Each of the phenomena has specific characteristics in relation to the causes, fracture mechanisms, velocity, dynamics, affected areas and volumes of material involved. The understanding of the associated processes and mechanisms enables the detailed evaluation of the hazard involved and provides the basis for the planning of measures. Hazard maps provide information about the threats to which an area is exposed and is necessary as a decision basis for protective measures. The basic types of mass movements are described briefly in the following sections.

### **A2-1 Definition of mass movements**

The Forest Act deals with the following processes: avalanches, landslides, erosion and rockfall (natural) (Art. 1 para. 2 ForA). All fall processes are dealt with by analogy in this guideline: rockfall, rock avalanche, ice fall, collapse processes.

The concept of process change is important addition to the definitions. Several processes can arise in succession and always involve the same mass of rock. For example, a spontaneous slide can break off from the very steep front of a continuous slow slide (“first move”) onto a secondary sliding surface and then fall as a hillslope debris flow (“second move”). All processes and the sequence in which they unfold are important for hazard evaluation and should be evaluated together (Varnes 1978, Turner und Schuster 1996).

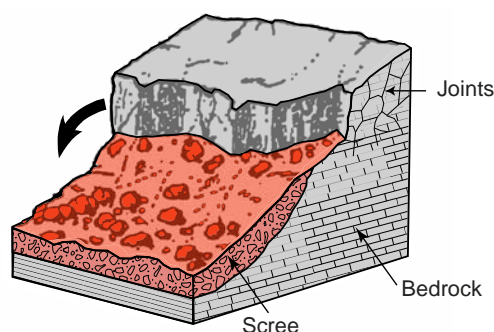
### **A2-2 Fall processes**

The detachment of bedrock or unconsolidated material on a steep site is referred to as a fall process. In most cases, the material falls freely or bounces down to the bottom of the slope (Fig. 19). Fall processes are rapid mass movements and are classified into four categories according to event volume and the size of the components (Tab. 5). The size and shape of the falling rocks are mainly determined by the structure of the bedrock (jointing etc.). If the fracture surfaces are very active and affect rock masses near the surface, a rock topple process may trigger rockfalls and rock avalanches.



**Fig. 19 > Rockfall**

*With fall processes, part of the mass movement is in free fall. This is followed by bounces and then rolling until the material comes to a halt.*



adapted from Amanti et al. 1992

**Tab. 5 > Classification of rockfall processes based on rock diameter and event volume**

Process	Diameter of the components	Volume	Velocity	Comment
Rockfall (Steinschlag)	<50 cm	-	<30 m/s	Usually individual rocks per event
Rockfall (Blockschlag)	≥50 cm	Vol.<100 m <sup>3</sup>	<30 m/s	Usually individual boulders per event
Rock avalanche (Felssturz)	-	Vol.>100 m <sup>3</sup> and Vol.<1 million m <sup>3</sup>	10–40 m/s	Rock avalanche mass, usually the fall of a large number of rocks and boulders followed by their fragmentation. Rock avalanches can unfold in different phases (partial avalanches).
Rock avalanche (Bergsturz)	-	Vol.>1 million m <sup>3</sup>	>40 m/s	Initial phase with compact rock avalanche mass. The process area involved, including the depositional area, can be very extensive.

### A2-3 Slide processes (landslides)

Slide processes are understood as movements of bedrock and/or unconsolidated material (and soil material) on a sliding surface down a slope. In special cases, a series of sliding surfaces can arise within a shear zone of several metres in size. Natural instabilities of this kind are extremely common in Switzerland and assume a wide variety of forms. The most extensive destruction caused by a landslide in recent times arose in Falli Hölli in the canton of Freiburg in 1994 when around 40 houses and a hotel slid around six metres per day in the direction of Höllbach and were completely destroyed (Raetzo 1997). Hydrogeological conditions influence the activity of a sliding mass. For this reason, the water underground and on the surface plays a very important role in relation to the sliding mechanism and activity. The following criteria are important for understanding the process involved:

## A2-3.1 Mechanism

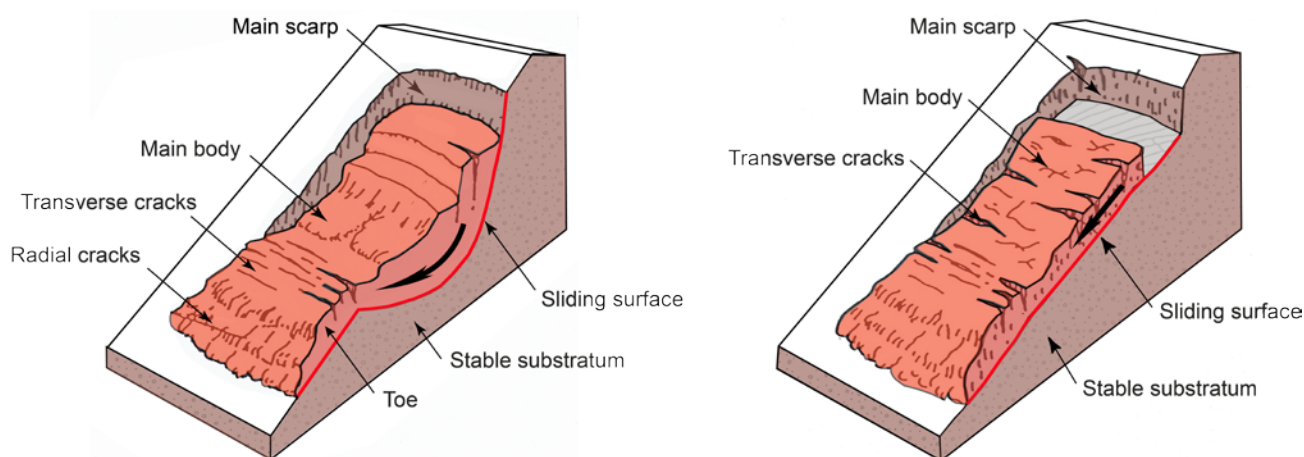
Sackungen are gravitational movements in bedrock with a pronounced vertical component of movement (sagging is also used). The transition to a landslide is continuous and the modes of action are similar. Therefore the Sackung processes are evaluated with the same criteria as for landslides. If fall processes (second move) occur within the Sackung (first move) the criteria for fall processes are applied.

In the case of so-called *rotational landslides* the landslide mass slides by gravitational force down a concave rupture surface (Fig. 20). Crevasses and fissures are often visible in the upper part of the slide. Due to compression, a landslide toe typically forms at the front of the sliding mass. This type of landslide forms in homogenous and, above all, clayey and silty unconsolidated material.

When layers or entire packets of layers slide along an existing almost flat surface of weakness, the process is referred to as a *translational landslide*. The areal spread of such landslides is highly variable and can cover several km<sup>2</sup> and even reach 45 km<sup>2</sup> in Switzerland. The sliding masses are often greater than many tens of metres in thickness. Areas featuring flysch and marl shale are particularly susceptible to the formation of such landslides. Mixed forms of rotational and translational landslides are frequently observed. Varnes refers to these mixed forms as “complex” (1978).

**Fig. 20** > Rotational landslide (left) and translational landslide (right)

A circular sliding surface is characteristic of rotational landslide. Translational landslides arise on relatively flat to planar sliding surfaces; due to this geometry, they can reach larger maximum velocities.



adapted from Varnes 1978; USGS 2004

Creep processes are specific types that are assessed in the same manner as slide processes. Mechanisms of creep are various and the definitions vary in the different regions.

Creep movements

With creep, the velocity of the movement on the surface is equal to that of a slide, however, it is mainly caused by a sheer deformation in the moving mass (i.e. without sliding, in a strict sense). These deformations decline with increasing depth.

Creep arises in unconsolidated material formations and soil strata. The sheer deformation arises due to a loss of cohesion in the unconsolidated material due to oversaturation with water or ice. Surface 'creep' can arise through reptation or freeze/thaw cycles. Creep movements can cover large areas encompassing several square kilometres in the Alps.

From a geotechnical perspective, the term 'creep' is primarily used to describe shallow movements. In German-speaking areas, the verb '*kriechen*' (i.e. creep) was also used sometimes to designate slow, deep slide processes and rock creep (*Talzus Schub*). Rock topple processes (*Hakenwurf*), which also lack a sliding surface, should only be partly classified as creep. In contrast, such processes are definitive when a well-formed fracture system enables movement of the rocks near the surface.

#### A2-3.2 Velocities

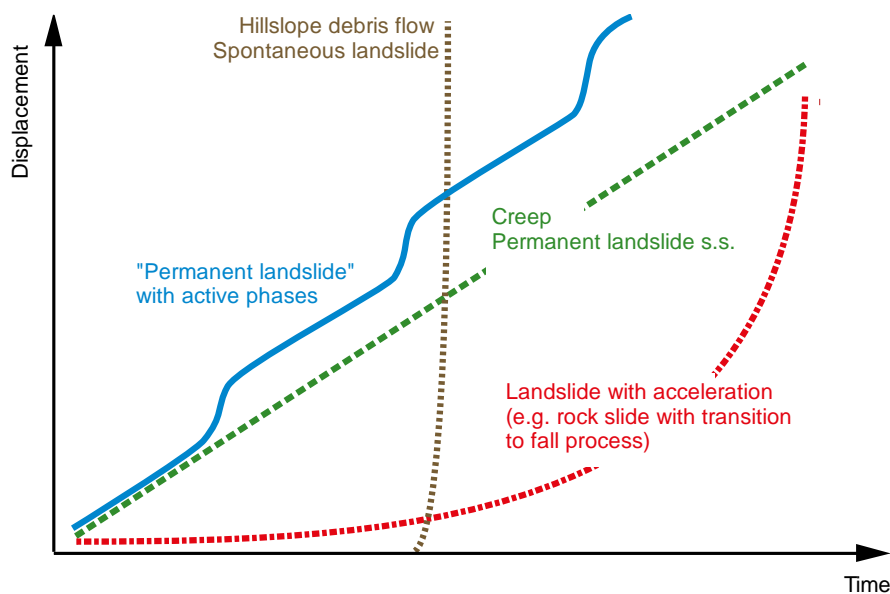
The speed at which an active landslide moves is variable over extended observation periods and subject to constant fluctuations. The determination of the long-term medium velocity ( $v$ ) is useful for the purpose of hazard evaluation. In the event of regular movements, it is recommended that the term 'permanent landslide' be applied even if minimal variability arises due to the natural fluctuations in the groundwater, crevasse water or slope water conditions. If acceleration occurs (up to  $v_{\max}$ ), the intensity of the landslide increases. In extreme cases, a rapid acceleration phase can give rise to a spontaneous change in the process. Thus an active landslide can suddenly become a hillslope debris flow. Hence changes in velocity are an important criterion for the evaluation of the associated hazard potential (see chapter 2, or section 2.5 ff).

The change in velocity ( $v_{\max}$ ) can be linked with a probability. This is dependent on different factors, among which precipitation, mechanical rock properties, slope water conditions, pore water pressure, mechanism, depth of the rupture surface and volume play an important role. These and other factors should be taken into account in the evaluation of the  $v_{\max}$ . Ideally, actually recorded changes in velocity should be used in the determination of  $v_{\max}$ .

In the case of movements in the range of decimetres during a crisis phase or of one metre or more per event, a high intensity should generally be selected as human life and material assets are under considerable threat in the short term here. In extreme cases, the change in velocity ( $v_{\max}$ ) can rise from zero to several metres per year. Such cases are referred to as reactivated landslides (see chapter 2.9).

**Fig. 21 > Schematic representation of different displacement curves in landslide areas**

*'Permanent' velocity in the strict sense can only be referred to in the case of the green curve. The velocity for all other curves is variable.*



adapted from PLANAT 2009

### A2-3.3 Sliding surface

The depth of the sliding surface generally has a direct influence on the disposition to reactivation and differential movements. Shallow landslides react faster to changes in individual parameters (e.g. slope water conditions, surface properties, interaction with watercourses) than deep landslides. As a result, unstable or seemingly stable slopes can experience a spontaneous loss of stability during a storm. In the case of shallow landslides, in particular, sudden sliding can arise and, possibly also, rapid flow processes. In very deep landslides, the sliding surface is located at a depth of around 30 m or more.

Medium and large landslides often have several sliding surfaces and all deformations and discontinuities are crucial for the hazard evaluation. Secondary sliding surfaces at depths of several metres are often relevant to the susceptibility and deformations. In the case of very deep landslides it should be noted that secondary sliding surfaces may be present above the basal sliding surface.

With regard to the depth of the displaced mass (T, for *Tiefe* [depth]), the following classes are valid:

- > 0–2 m shallow (superficial)
- > 2–10 m medium depth
- > 10–30 m deep
- > T>30 m very deep (new)

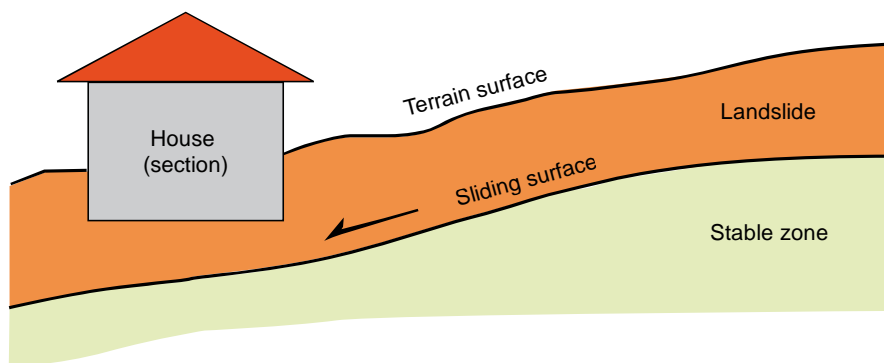
A2-3.4 Differential movements

In the boundary areas of zones with different velocities and/or directions, shear forces take effect that can cause damage to buildings and infrastructure (Fig. 22).

**Fig. 22 > Impacts of differential movements**

*Rotation and tilting of buildings, formation of cracks in the masonry, shearing off of building parts*

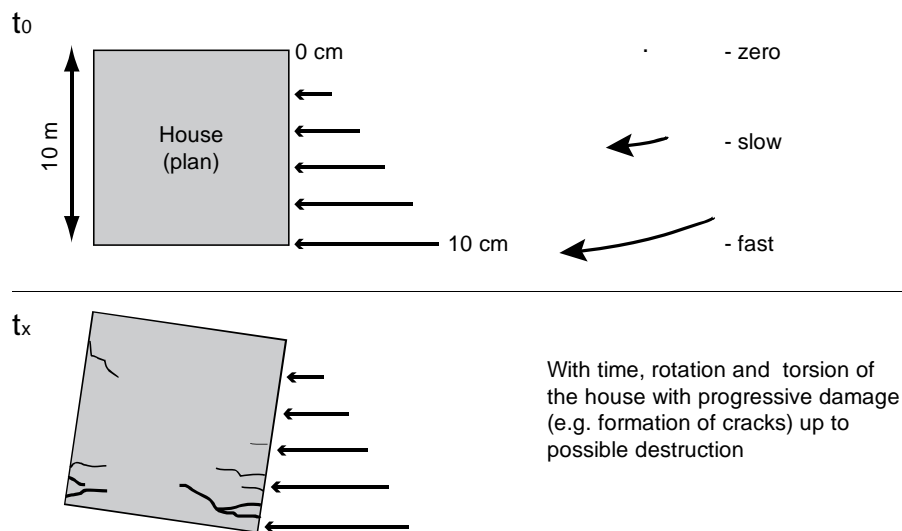
**Section**



**Plan**

Displacement:

Landslide velocity  
(with differential movements)



Attention should also be focused on the zones of extension (fissures) and compression (landslide toe). These differential movements (D) can cause extensive damage and constitute, therefore, an important criterion in the context of hazard evaluation. Differential movements should be taken into account in the creation of hazard maps (see chapter 2).

#### A2-4 Flow processes (hillslope debris flows)

Flow processes include:

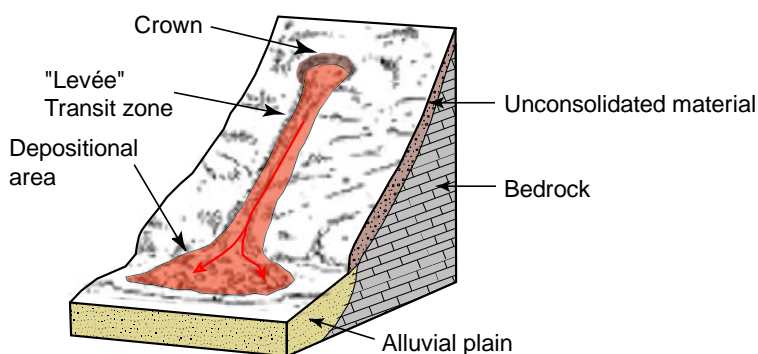
- > hillslope debris flows comprising a mixture of soil, stones and water that flows outside of a channel.
- > channel-type debris flows which flow down to the valley in an existing channel and consist of a mixture of soil, stone and water.

Debris flow and the corresponding hazard evaluation methods are not covered by this guideline because this process was already covered by the recommendations of 1997 and guideline of 2001 (BWW et al. 1997, BWG 2001).

Shallow movements which do not involve shear surfaces or arise at most in the initial phase are classified as flow processes. The velocity distribution of the transported mass is similar to that of a viscous process. Heavy precipitation and subsurface water inflow play a crucial role in the triggering of flow movements.

**Fig. 23 > Flow process: hillslope debris flow**

*When flow processes arise outside of a channel, i.e. on a slope, they are generally referred to as hillslope debris flows (Hangmuren). The term channel-type debris flow (Murgang) is usually used for flow processes that occur within channels.*



adapted from Amanti et al. 1992

A mixture of unconsolidated material and water which flows in a viscous mass down the slope is characteristic of the hillslope debris flow. The velocity at the side of the debris mass is lower and this sometimes results the formation of small 'levées'. The movement of the mass slows down at the foot of the slope. It then spreads in a tongue-shaped formation and eventually comes to a halt. The high water content, in particular, is responsible for the rapid speed of debris flow processes that are often more destructive in their effect. Steep slopes with relatively impermeable Quaternary cover (clayey moraine and slope loam) and a more permeable substrate are particularly prone to this type of slope instability. These contrasts in the permeability of the rock layers enables the formation of high water pressure and hence present a common cause of landslides that develop into hillslope debris flows.

The depth of the mobilisable layer and the deposit can be used as criteria for the evaluation of intensity.

#### **A2-5 Mass movements in permafrost**

Permafrost is underground material that is frozen all year round ( $\leq 0^\circ\text{C}$ ). This means that permafrost is largely impermeable to moving water and ice formation processes arise in the pore and crevasse space. Depending on the exposition, extensive permafrost may be expected in the Alps from altitudes of 2500–3000 m asl. The layer on the surface above the permafrost is referred to as the seasonal thaw layer and is characterised by seasonal thawing and often high water saturation levels.

Various creep movements (e.g. rock glaciers) can arise in permafrost areas. Creep within one meter of the surface (solifluction) is also favoured by the existence of permafrost as water saturation often arises in the thaw layer due to the impermeability of the permafrost below.

Both creep and other mass movements in the high Alpine process area react sensitively to changes in temperature: the viscosity and fracture strength of ice and the expansion of a permafrost body adapts to the changing surface temperatures with a time lag. The possible consequences of a rise in temperature include the acceleration of rock glaciers and landslides, increased debris flow activity and the destabilisation of rock masses.

#### **A2-6 Collapses and sinkholes**

Sinkholes often arise in karstified regions. Collapse, topple processes and sinkhole processes can occur in connection with the leaching of a water-soluble substrate (limestone, dolomite, gypsum and rauhwacke), erosion or existing underground hollow spaces. In gypsum rocks, the leaching can progress relatively quickly if the necessary water is available. These Karst phenomena can also result in problematic hollow spaces in limestone and dolomite rocks. In these cases, ruptures can result in a sudden collapse. It is difficult to predict the timing of this collapse (concerns sinkholes and topple processes). These water-soluble rocks are common in the Jura mountains, in the limestone Helvetic nappes and in the Pre-Alps. The susceptibility to instabilities is increased by fault zones and folds.

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## **A3 Determination of the probability of flow processes**

Appendix 3 is a complement to chapters 2.8.2 and 2.8.3 for the criteria of landslides and flow processes. There are two possible methods for the determination of the probabilities: the diagram of probability and a flow chart.

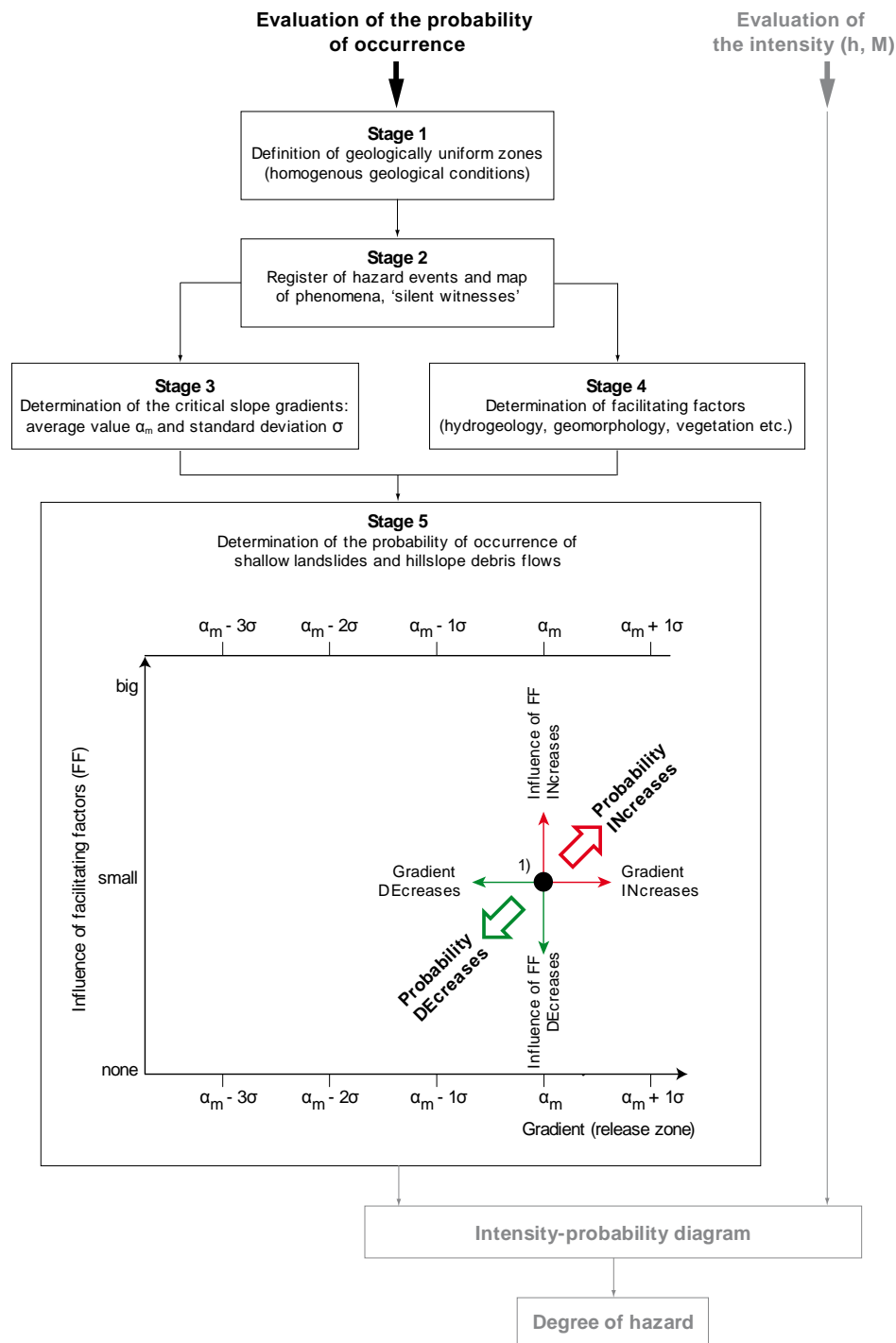
### **A3-1 Determination of the probability with the diagram**

This method includes the statistical slope gradients (Fig. 24, stage 3) and the facilitating factors (stage 4). In the case of slope gradient that lie far below the critical values, in the absence of facilitating factors, an annual probability of occurrence of less than 0.003 is calculated. Such cases should be considered as residual hazard.



**Fig. 24 > Determination of the probability of hillslope debris flows**

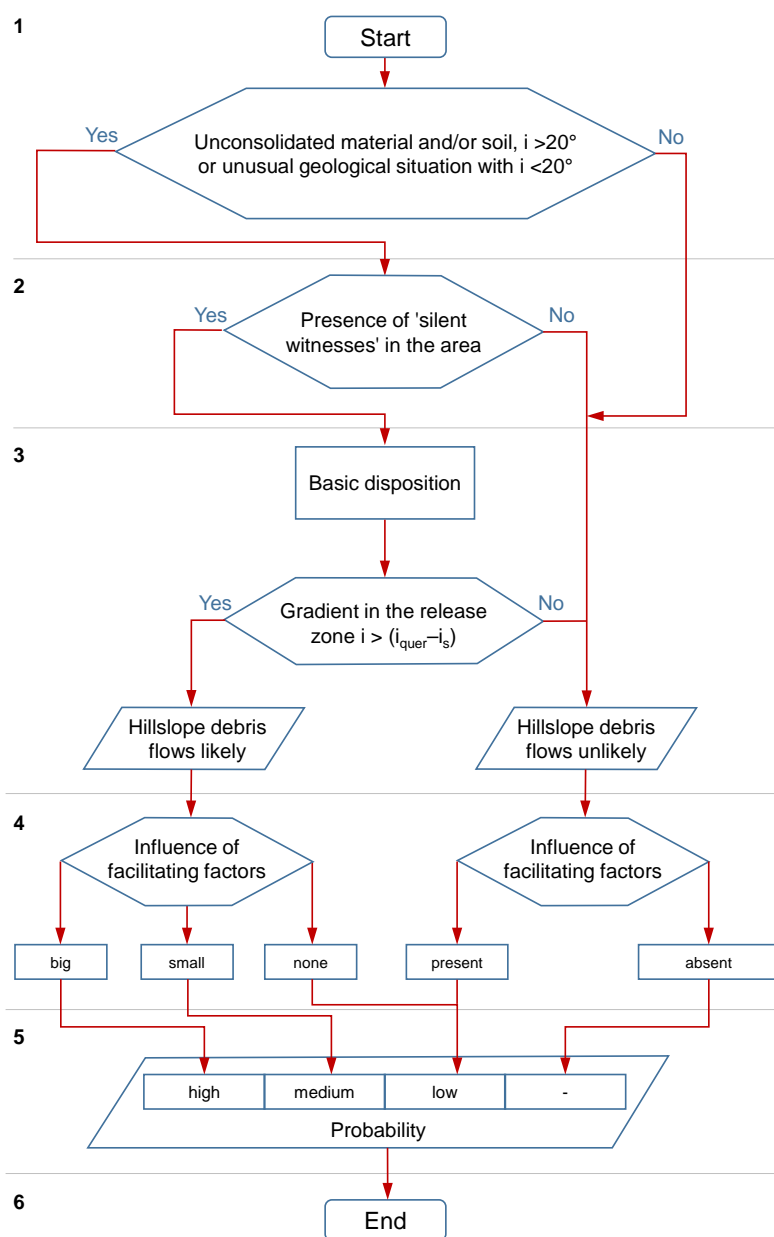
Stages and probability diagram. The position of point 1) in the graph of stage 5 corresponds to an average probability (as example). This point of reference is at the critical slope gradient and takes a minor influence of facilitating factors into account. For the determination of the degree of hazard, the intensity must also be evaluated.



### A3-2 Determination of the probability with the flow chart

The working group on Geology and Natural Hazards made a proposal with the flow chart in figure 25 (AGN 2004). The method was used by several cantons. The facilitating factors and the critical slope gradients (release zone ca.  $20^{\circ}$ – $28^{\circ}$ ) are used for the determination of the probability. Proposed values: critical slope gradient ( $i_{\text{quer}}$ ), standard deviation ( $i_s$ ).






Fig. 25 > Determination of the probability with the flow chart



## A4 Application of Hazard Documentation in Spatial planning

**Tab. 6 > Possible consequences of the different degrees of hazard for land-use zone designation and for the construction and zoning regulations**

*In addition to the spatial planners and the verifying and authorising authorities at cantonal and communal level, other actors like insurance companies, architects, engineers, emergency services etc. must be involved in the process, in particular in the case of non-spatial-planning measures.*

	Hazard zone	Zone designation	Construction and zoning regulations	Other measures – not involving spatial planning
	Prohibited zone (Verbotszone) considerable hazard (red)	<ul style="list-style-type: none"> <li>No designation of new development zones</li> <li>Re-designation of unused development zones</li> </ul>	<ul style="list-style-type: none"> <li>No erection or extension of structures and facilities</li> <li>Enacting of necessary use restrictions for existing structures;</li> <li>Conversions and changes in use only with risk reduction requirements;</li> <li>Reconstruction of demolished structures only authorised in exceptional cases and with requirements.</li> </ul>	<ul style="list-style-type: none"> <li>Rapid informing of affected land and property owners about existing threat and necessary measures</li> <li>Noting of use restrictions in land registry if required</li> <li>Rapid planning and implementation of the necessary technical and organisational protective measures</li> </ul>
	Bidding zone (Gebotszone) medium risk (blue)	<ul style="list-style-type: none"> <li>Designation of new development zones only with requirements and after the verification of other options and weighing up of interests.</li> </ul>	<ul style="list-style-type: none"> <li>No creation of vulnerable objects</li> <li>Planning permission subject to requirements;</li> <li>Enacting of necessary use restrictions for existing structures</li> <li>Definition of requirements for the spatial arrangement use and design, possibly also accessing of structures and facilities</li> <li>Detailed regulations must take different protective measures into account depending on the hazard type and intensity</li> <li>Identical reconstruction of demolished structures in justified cases to be rejected in favour of optimisation.</li> </ul>	<ul style="list-style-type: none"> <li>Informing of affected land and property owners about existing threat.</li> </ul>
	Reference zone (Hinweiszone) Low risk (yellow)	<ul style="list-style-type: none"> <li>Avoidance of zones in which facilities with high damage potential can be established</li> <li>Reference to the hazard situation.</li> </ul>	<ul style="list-style-type: none"> <li>Recommendations for existing buildings</li> <li>Consideration of requirements for sensitive uses or major development based on risk.</li> </ul>	<ul style="list-style-type: none"> <li>Informing of affected land and property owners about the existing threat</li> <li>Provision of advice about possible damage prevention measures in cooperation with insurance companies;</li> <li>Implementation of special technical and organisational measures for vulnerable objects with insurance company requirements</li> </ul>
	Residual risk (yellow/white)	<ul style="list-style-type: none"> <li>Only very restrained extensions of existing development zones or designation of new development zones</li> <li>Avoidance of zones in which facilities with high damage potential can be established</li> <li>Reference to the hazard situation</li> </ul>	<ul style="list-style-type: none"> <li>Recommendations for existing structures</li> <li>Consideration of requirements for sensitive uses or major development based on risk</li> </ul>	<ul style="list-style-type: none"> <li>Informing of affected land and property owners about the existing threat</li> <li>Provision of advice about possible damage prevention measures in cooperation with insurance companies</li> <li>Implementation of special technical and organisational measures for vulnerable objects with insurance company requirements</li> </ul>
	No risk (white)	<ul style="list-style-type: none"> <li>To qualify for the statement that a certain area does not present any susceptibility according to the currently standard methods of risk evaluation, all sub-processes for all process sources must have been examined.</li> </ul>		

adapted from ARE et al. 2005

**Tab. 7 > Possible requirements and measures in the context of the planning permission process**

Process	Use restrictions and requirements	Construction measures in buildings	Surroundings/access
Rockfall	<ul style="list-style-type: none"> <li>To reduce the risk to persons, prohibition of residential components (like bedrooms and living rooms) and balconies and seating in the parts of the buildings most at risk; equipment and material rooms, cellars, corridors etc. are constructed on the exposed side of buildings (short durations of stay)</li> </ul>	<ul style="list-style-type: none"> <li>Careful selection of site within construction plot</li> <li>Design of building and adaptation to the terrain so that only a few parts of the building are exposed to the risk (probability of being hit reduced in this way)</li> <li>Basement and ground floor constructed as rigid and monolithic reinforced concrete box</li> <li>Reinforcement of the endangered external walls using reinforced concrete or cladding</li> <li>Protection through banking and filling</li> <li>Avoidance of openings like windows and doors in exposed parts of buildings or keeping them as small as possible and use of reinforced design</li> </ul>	<ul style="list-style-type: none"> <li>Prohibition of the positioning of drive and access and external play and recreational spaces in sectors most at risk</li> </ul>
Deep permanent landslides		<ul style="list-style-type: none"> <li>Careful selection of site within construction plot</li> <li>Organisation of terrain so that excavated material and filling have a decelerating effect (on the landslide, also during the construction phase)</li> <li>Shallow foundation using reinforced base slab; basement constructed as rigid and monolithic reinforced concrete box; avoidance of vulnerable geometry (e.g. L- or U-shapes); construction of foundations on soil with good weight-bearing capacity</li> <li>Ductile and deformable external pipe connection</li> <li>Collection and controlled discharge of surface water (roof water, parking etc.); abstention from stormwater infiltration</li> </ul>	<ul style="list-style-type: none"> <li>Collection, containing and channelling of water (on surface and underground; see chapter 4.7 for the possible measures)</li> </ul>
Hillslope debris flow and spontaneous landslide (shallow)	<ul style="list-style-type: none"> <li>To reduce the risk to persons, prohibition of residential components (like bedrooms and living rooms) and balconies and seating in the parts of the buildings most at risk; equipment and material rooms, cellars, corridors etc. are constructed on the exposed side of buildings (short durations of stay)</li> </ul>	<ul style="list-style-type: none"> <li>Careful selection of site within construction plot</li> <li>Design of building and adaptation to the terrain so that only a few parts of the building are exposed to the risk (probability of being hit reduced in this way)</li> <li>Basement and ground floor constructed as rigid and monolithic reinforced concrete box</li> <li>Reinforcement of the endangered external walls using reinforced concrete or cladding</li> <li>Protection through banking and filling</li> <li>Avoidance of openings like windows and doors in exposed parts of buildings or keeping them as small as possible and use of reinforced design; reinforcements can also be applied temporarily, for example during a storm</li> <li>Collection and controlled discharge of surface water (roof water, parking etc.); abstention from stormwater infiltration</li> </ul>	<ul style="list-style-type: none"> <li>Prohibition of the positioning of drive and access and external play and recreational spaces in sectors most at risk</li> <li>Collection, containing and channelling of water (on surface and underground; see chapter 4.7 for the possible measures)</li> </ul>

**Further information**





- > *Spatial planning and natural hazards (ARE et al. 2005)*
- > *Wegleitung Objektschutz gegen gravitative Naturgefahren (Egli 2005)*
- > *SIA standards 260, 261 and 261/1*

## A5 Example Protection Objective Diagram

**Fig. 26** > Example of a protection objective diagram for land-use provisions as used in a similar form in the cantons

























*Reading aid: the aim is to provide complete protection for closed settlements (object category 3.2) up to a 100-year event. Weak intensities are acceptable between the 100- and 300-year event. Average intensities are tolerable for more rare events.*

### Legende

	= vollständiger Schutz	= keine Intensität zulässig	= 0
	= Schutz vor mittleren und starken Intensitäten	= schwache Intensität zulässig	= 1
	= Schutz vor starken Intensitäten	= mittlere Intensität zulässig	= 2
	= fehlender Schutz	= starke Intensität zulässig	= 3

### Objektkategorie

### Schutzziele

				Wiederkehrperiode (Jahre)			
				1–30	30–100	100–300	>300
				häufig	selten	sehr selten	extrem selten
Nr.	Sachwerte	Infrastruktur-Anlagen	Naturwert				
1		Berg- und Skitouren- routen (gemäss Karten SAC u.a.)	Naturlandschaften				
2.1		Kommerzielle Wander- wege und Loipen, Flur- wege, Leitungen von kommunaler Bedeutung					
2.2	Unbewohnte Gebäude (Remisen, Weidescheu- nen u.a.)	Verkehrswege von kommunaler Bedeu- tung, Leitungen von kommunaler Bedeutung	Wald mit Schutz- funktion, landwirt- schaftlich genutztes Land				
2.3	Zeitweise oder dauernd bewohnte Einzelgebäu- de und Weiler, Ställe	Verkehrswege von kantonaler oder grosser kommunaler Bedeu- tung, Leitungen von nationaler Bedeutung, Bergbahnen, Zonen für Skiabfahrts- und –übungsgelände	Wald mit Schutzfunkti- on, sofern er geschlos- sene Siedlung schützt				
3.1		Verkehrswege von nationaler oder grosser kantonaler Bedeutung, Ski- und Sessellifte					
3.2	Geschlossene Sied- lungen, Gewerbe und Industrie, Bauzonen, Campingplätze, Frei- zeit- und Sportanlagen	Stationen diverser Beförderungsmittel					
3.3	Sonderrisiken bzw. besondere Schaden- anfälligkeit oder Sekundärschäden	Sonderrisiken bzw. besondere Schaden- anfälligkeit oder Sekundärschäden		Festlegung fallweise			

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**Further information**

- > *Spatial planning and natural hazards (ARE et al. 2005)*
- > *Brochure on natural hazards published by the canton of Bern's natural hazards working group (in German and French): Achtung Naturgefahr! Verantwortung des Kantons und der Gemeinden im Umgang mit Naturgefahren (Arbeitsgruppe Naturgefahren des Kantons Bern 2011)*

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FOEN:  
[www.bafu.admin.ch](http://www.bafu.admin.ch)

Data models:  
[www.bafu.admin.ch/geodatenmodelle](http://www.bafu.admin.ch/geodatenmodelle)

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[www.gin.admin.ch](http://www.gin.admin.ch)

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Federal natural hazard warnings:  
[www.naturgefahren.ch](http://www.naturgefahren.ch)

OWARNA:  
[www.planat.ch/de/behoerden/im-ereignisfall/owarna](http://www.planat.ch/de/behoerden/im-ereignisfall/owarna)

PLANAT:  
[www.planat.ch](http://www.planat.ch)

SilvaProtect:  
[www.bafu.admin.ch/naturgefahren](http://www.bafu.admin.ch/naturgefahren) > Fachinformationen Wasser, Rutschungen, Sturz, Lawinen > Gefahrensituation und Raumnutzung > Gefahrengrundlagen > SilvaProtect-CH

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