Risk management of natural hazards in Switzerland

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This document is still under construction, but represents the current basic principles of the risk management of natural hazards in Switzerland.

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ABSTRACT

Natural hazards have ever been an elementary issue in the everyday life in Switzerland. For centuries, the federal government, the cantons and the municipalities have made considerable efforts to mitigate their impact. But still, damages increased at an alarming rate. Admittedly, absolute safety cannot be achieved, but great steps forward were made in the past few years on the road from conventional hazard protection to an integrated risk management. The latter approach is based on a balanced equilibrium of preparedness, response and recovery measures. A residual risk, which has to be defined considering social, economical and ecological criteria of well-being, must thereby be accepted. This ultimately leads to a sustainable risk management.

1. Introduction

Many areas in Switzerland are prone to floods, debris flows, avalanches, landslides, or rockfall. Every year these hazards cause damage and destruction. In the last 30 years, two thirds of all communes have experienced flooding. The total loss during this period amounts to CHF 13 billion. In 1987, 1993, 2000, 2005 and 2007, disastrous floods confirmed that the effects of extraordinary natural events can only partly be controlled by structural measures.

The major damaging events of the past years revealed that hazard protection efforts in Switzerland show clear gaps or even deficiencies. The reasons are manifold and quite often obvious:

- intense land use and increasing economic value in endangered areas
- increasing vulnerability of buildings and infrastructure
- missing space for the propagation of large-scale events
- conceptual and construction deficiencies of protective measures
- neglected maintenance

The main emphasis today must be put on reducing the damage potential, i.e. basically on reducing vulnerability. This requires an **integrated risk management** approach, which follows the **subsidiary principle**. There is a shared responsibility between federal, cantonal (state) and communal authorities, which is extended to the insurance business and landowners as well as to various technical institutions, organizations and associations. Furthermore, it is founded on the three cornerstones **preparedness, response and recovery** (Figure 1) and on the principle of **sustainability**.

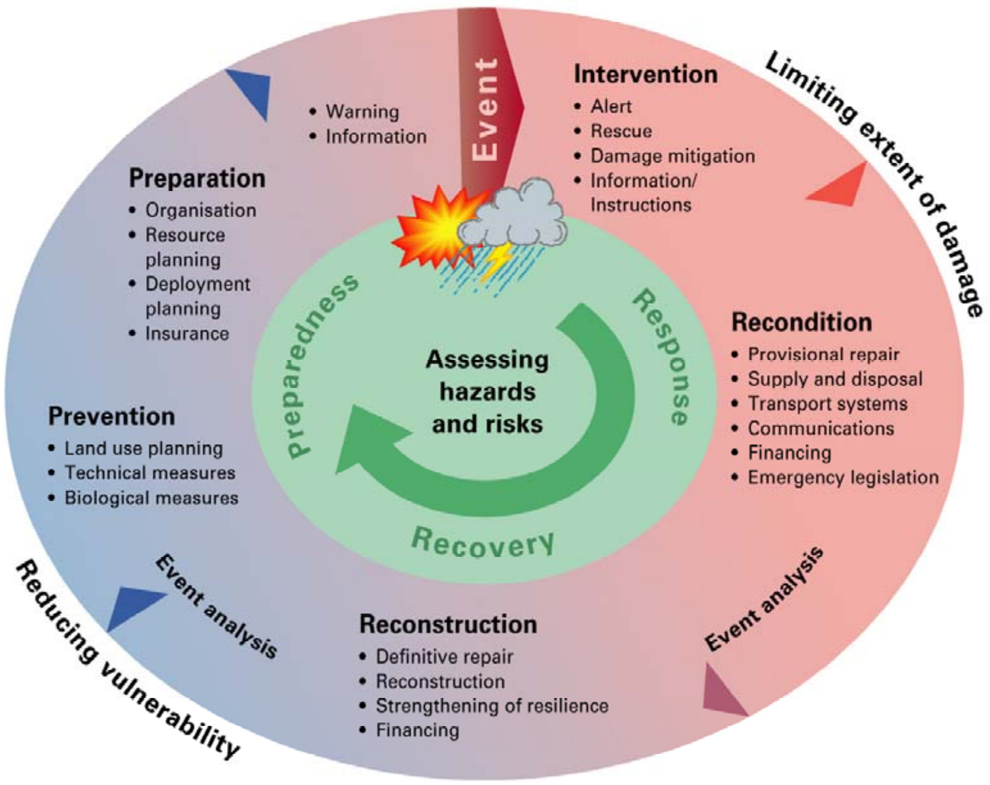


Figure 1: Integrated risk management.

2. The approach for natural hazard protection

The federal acts on hydraulic engineering (flood protection) and on forestry, which were enforced in 1991 to face the above mentioned problems of increasing damage potential, are based on an **integrated approach** to protect people and assets from natural hazards (Figure 2). The purpose of this legislation is the protection of human life and high value property from natural hazards with a minimum of structural countermeasures. The existing or future land use and the ecological conditions have thereby also to be considered.

Risk management planning has to be undertaken for all types of natural hazards, i.e. floods, mass movements, rockfalls and avalanches. The main elements of the planning process are as followed:

A) Hazard assessment,

B) Definition of protection requirements,

C) Planning of preventive measures,

D) Emergency planning.

The following procedure is illustrated for the example of flood hazard, but can also be adapted for the other types of hazards.

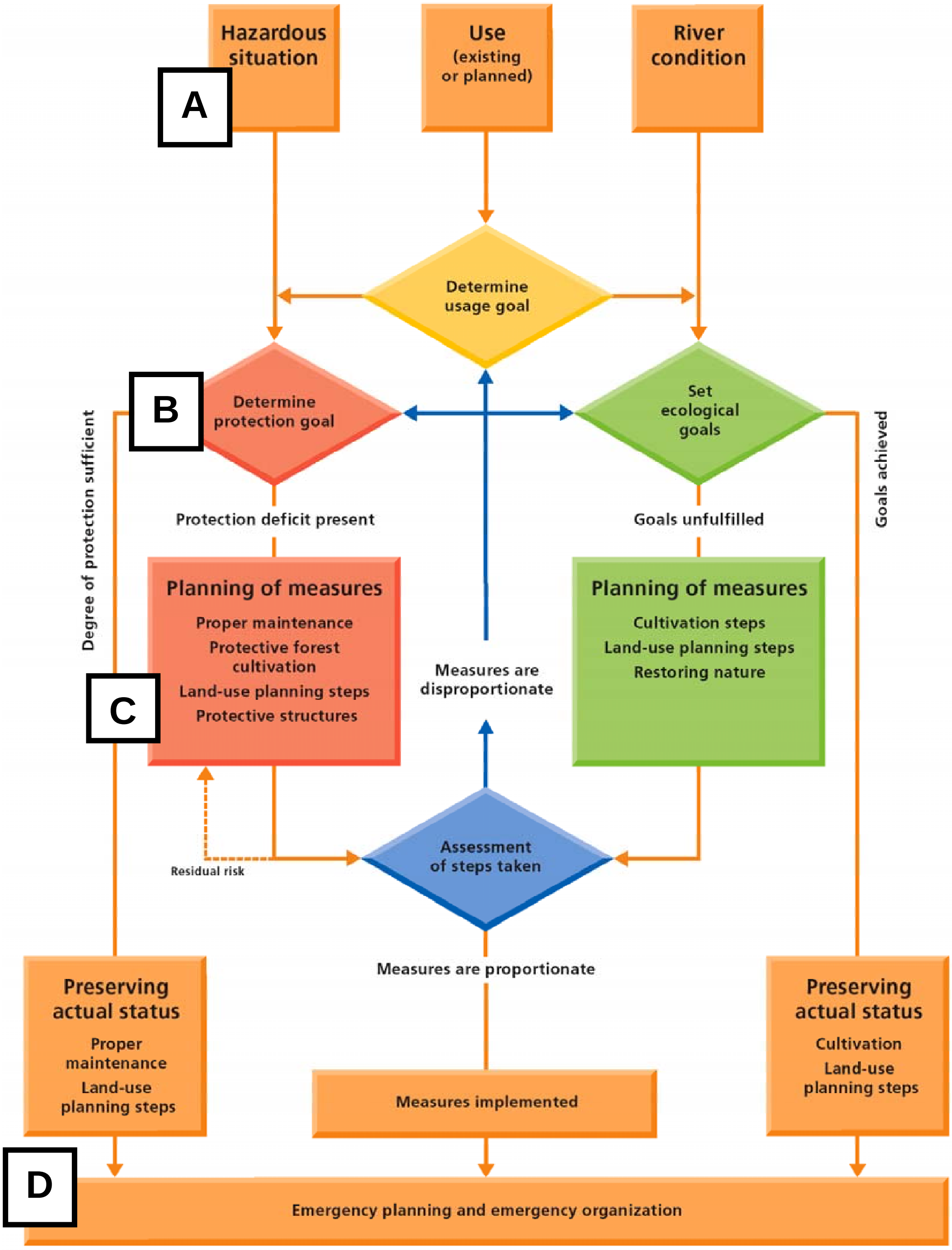


Figure 2: Procedure for the planning of protection measures.

A Hazard Assessment

As shown in Figure 1 and Figure 2, the very initial step for all actions is a comprehensive assessment of the hazards. Only if the hazards are well apprised, actions can be taken to improve the safety of the living space. Based on the hazard assessment a variety of specific products could be derived for different uses as shown in Figure 3.

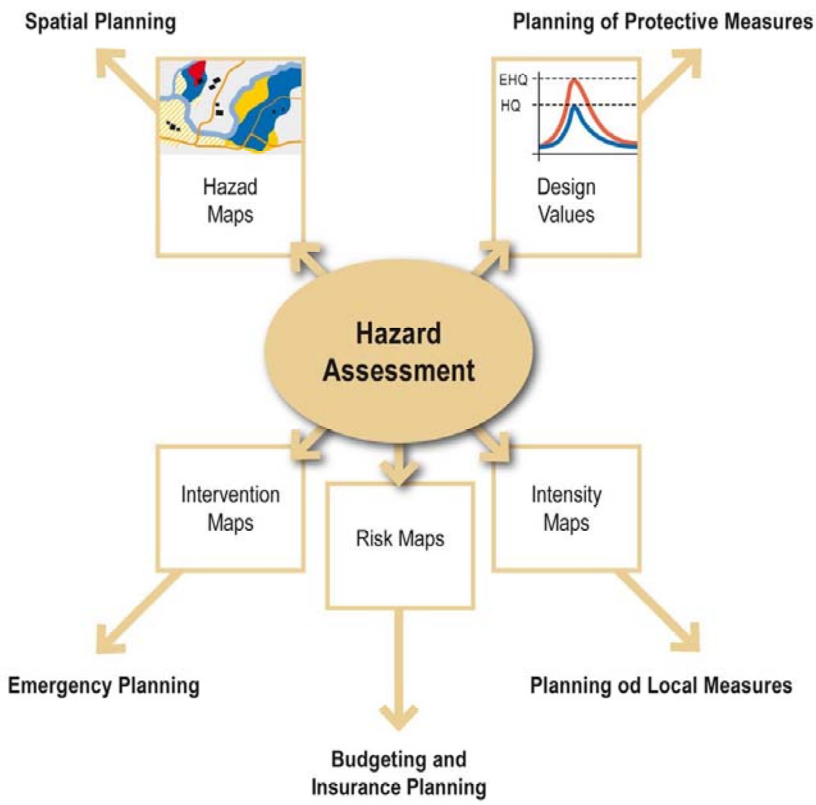


Figure 3: Hazard assessment is the first step in the process of risk management.

In the Federal Act on Hydraulic Engineering (flood protection), the cantons have the directive to establish so-called **hazard maps** for water-related processes, which have to be incorporated into regional and local development plans. Correspondingly, the same applies for the other hazard types on the basis of the Federal Act on Forests. The cantons are responsible for taking the initiative for the establishment of hazards maps. The federal authorities subsidize it with 50 % of the cost. In Switzerland, several types of flood maps are produced. The techniques for developing hazard maps are outlined in the recommendations "Consideration of Flood Hazards for Activities with Spatial Impact", "Consideration of Mass Movements Hazards for Activities with Spatial Impact" issued in 1997 and "Consideration of Avalanche Hazards for Activities with Spatial Impact" issued in 1984.

The method of hazard mapping universally used in Switzerland is briefly illustrated below. "**Hazard**" means the combination of the magnitude of the impact of a potentially damaging phenomenon with given probabilities of occurrence within a specific period of time in a given area.[1]

The first step normally consists in a rough overview of potentially endangered areas based on known past events and/or on modelling the hazards without very high accuracy. The product is a so called **hazard index map** (for flood it corresponds basically to a preliminary flood extension map for the extreme event) as shown in Figure 4. The maps are produced on a scale of 1:25,000 to 50,000, and the extreme event is generally set equal to a return period of 1,000 yrs. The maps provide the basis to quickly identify the areas with the most critical conflicts between hazard and land use and serve also to set priorities for a more accurate hazard assessment.

[1] The definition of „hazard maps" is not consistent with the use of the term flood hazard maps in the context of the European Flood Directive, where it is used for the extent of inundation for a given probability of occurrence.

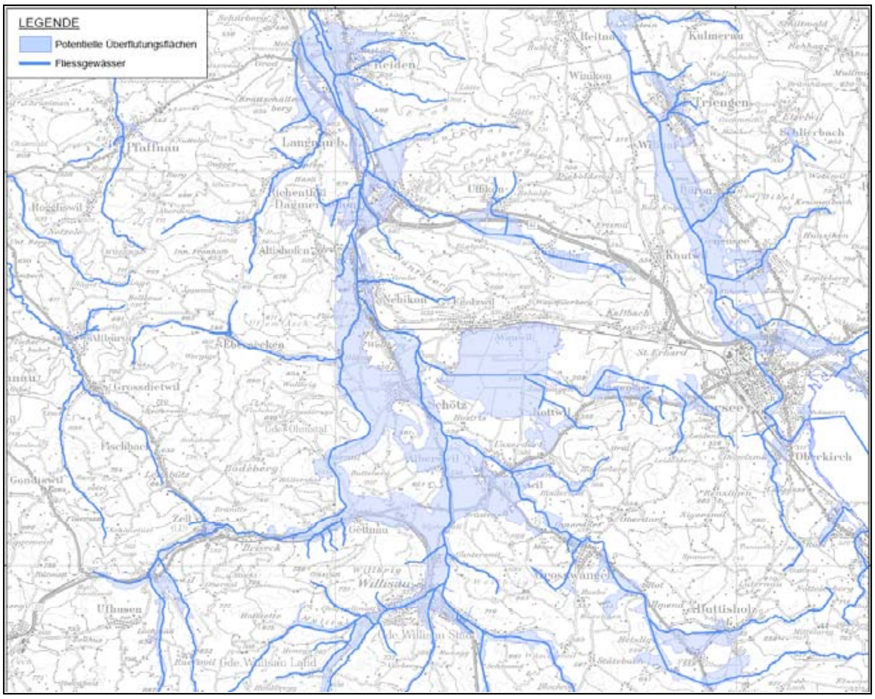


Figure 4: Example cutout of a hazard index map for flooding.

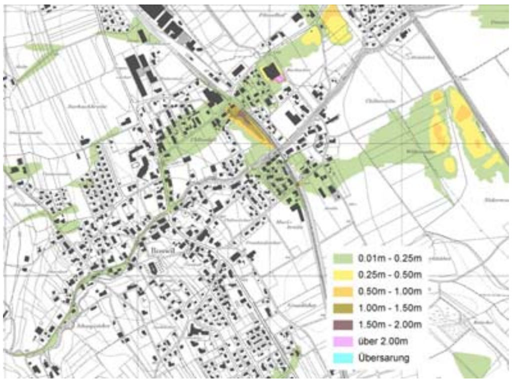
Detailed Hazard assessment implies the determination of the **magnitude** (*intensity* or severity) of an event and its **frequencies** (probability of occurrence, or return period). Three levels of magnitudes are considered, i.e. “high, average and low” (Table 1). Regarding probability, four levels “high, average, low and very low” are used, with the corresponding return periods “1 – 30, 30 – 100, 100 – 300 and > 300 years”. For a potential hazard, its magnitudes have therefore to be determined for the chosen levels of probability at selected points of a specified area of investigation. This is achieved by various means, for instance by modelling the underlying processes (either by a numerical or a physical model, calibrated on the basis of past events). The magnitude of flooding depends thereby basically on the depth of inundation and flow velocity; for other hazards, different criteria apply.

Table 1: Criteria for intensity of different hazards.

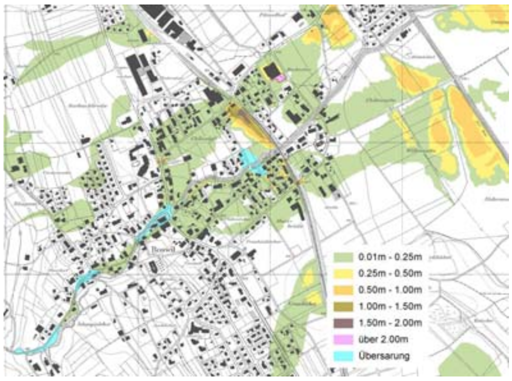
Process	**Low intensity**	**average intensity**	**high intensity**
Rockfall	E < 30 kJ	30 kJ < E < 300 kJ	E > 300 kJ
Landslide	Vs < 2 cm/year	Vs: dm/year	Vs > dm/day; Displacement > 1 m per event
Debris flow	--	D < 1 m and v < 1 m/s	D > 1 m and v > 1 m/s
Static flooding	h < 0.5 m	0.5 < h < 2 m	h > 2 m
Dynamic flooding	$q < 0.5\ m^2/s$	$0.5 < q < 2\ m^2/s$	$q > 2\ m^2/s$
Bank erosion	t < 0.5 m	0.5 < t < 2 m	t > 2 m
Snow avalanche	$P < 3\ kN/m^2$	$3\ kN/m^2 < P < 3\ kN/m^2$	$P > 30\ kN/m^2$

E = kinetic energy; Vs = mean annual velocity of landslide; D = thickness of debris front; v = flow velocity (flood or debris flow); h = flow depth; q = specific discharge ($m^3/s/m$) = h x v; t = extent of lateral erosion; P = avalanche pressure exerted on an obstacle

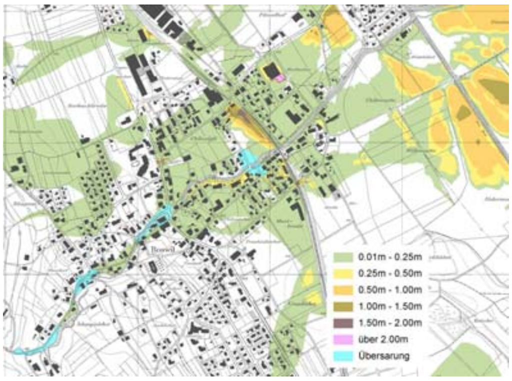
The basis for the production of hazard maps is the so-called “intensity map”. The intensity (or magnitude) of a particular process is delineated for each level of probability. An example of flood “intensity maps” is shown in Figure 5 for an event with four different return periods with the flood depth indicated in steps of 0.25 m. “Intensity maps” are essential for the planning and design of all structural and non-structural protective measures (including emergency planning).



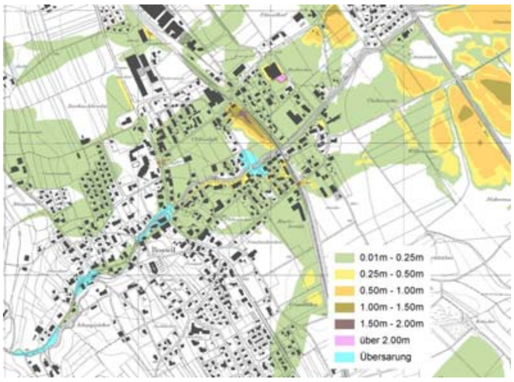
High probability (return period 1-30 years)



Average probability (return period 30-100 years)



Low probability (return period 100-300 years)



Very low probability (return period > 300 years)

Figure 5: Example cutout of an “intensity map” for flooding (inundation depth).

The next step is to classify the results according to the magnitude-probability diagram (hazard level diagram), which combines the magnitude (i.e. “intensity”) of flooding (inundation depth or product from depth and velocity) and the related probability (Figure 6 below).

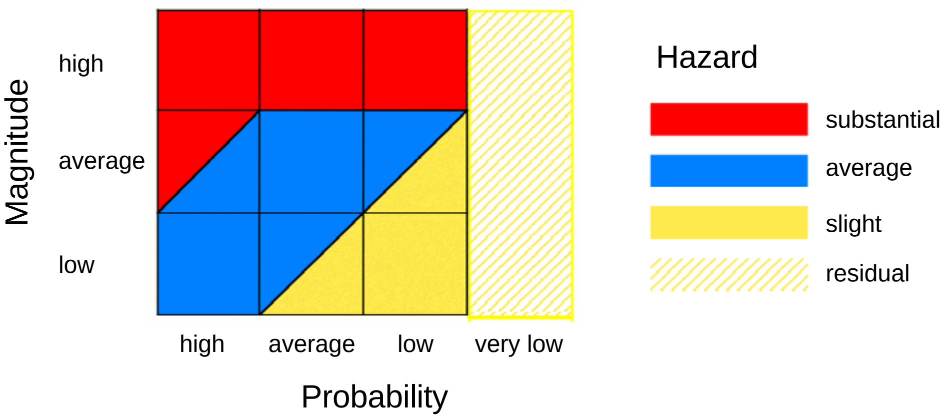


Figure 6: Diagram of hazard levels (“dangers”) as a function of probability and intensity.

Four classes of hazard levels are distinguished on Figure 6 and graphically identified with colours, i.e. “substantial (**red**), average (**blue**), slight (**yellow**) as well as residual hazard (**yellow-white hatched**). Additionally, areas are defined where no or negligible hazard exist according to the present status of knowledge (**white**).

Based on the results of the modelling process and with respect to Figure 6, the expected hazard level can thus be determined for any location on a given map. The end-result is the so-called **hazard map** indicating the endangered areas corresponding to the hazard levels shown in Figure 6. For flooding, yellow-white hatched would imply “**very little endangered**”. The word “danger” thereby denotes the degree of exposure of persons, buildings, material goods and/or infrastructure to a potential hazard of a specified level. Flood hazard maps are produced in a scale of 1:5,000 to 1:2,000 and are used for **Local Land use planning**. Figure 7 below shows an example extract of a hazard map for flooding.

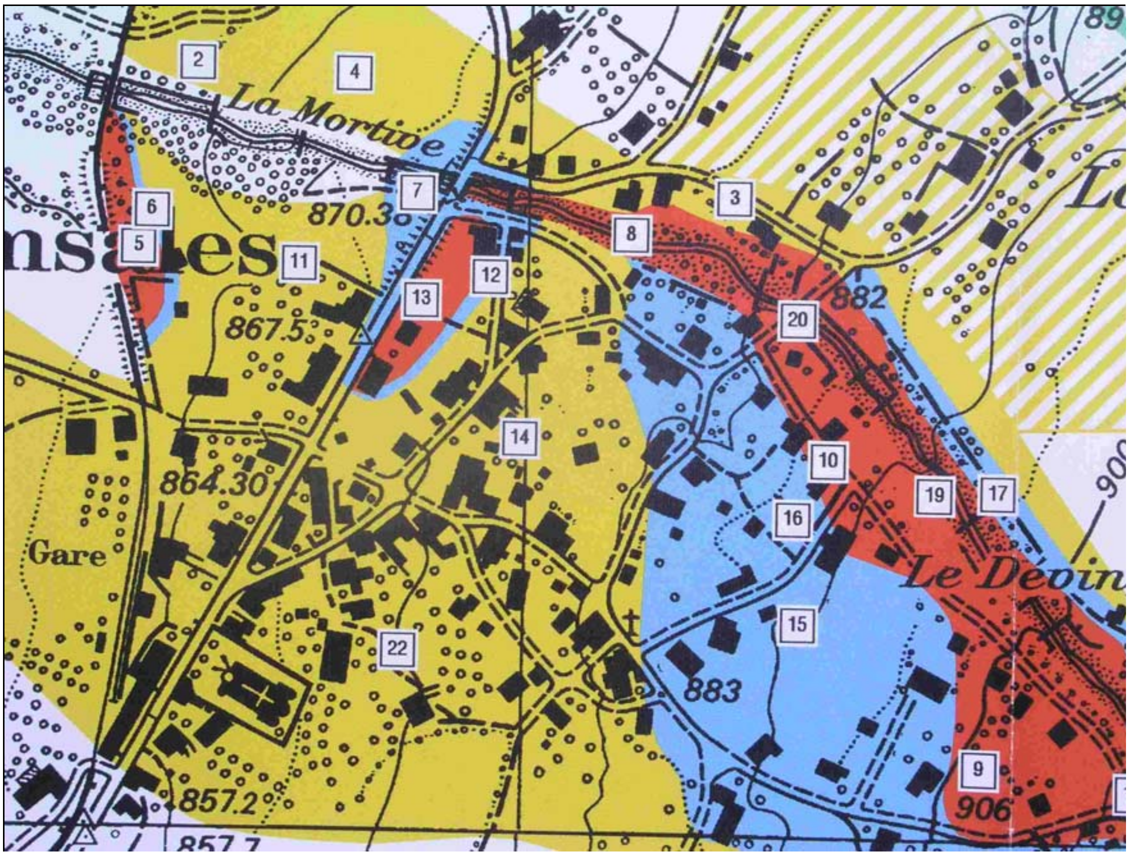


Figure 7: Example cutout of a hazard map for flooding.

The direct interpretation of the hazard classes (red, blue, yellow, yellow-white) constitutes an excellent opportunity to directly implement the hazard maps into spatial planning and building regulations. As shown in Figure 8, red areas imply prohibition or severe restriction of construction activities. In the blue areas construction is allowed, but restrictive regulations are enforced. In the yellow areas, principally no restrictions exist (except for highly sensitive infrastructure), but the residents are made aware of the flood hazards. White areas imply that, on the basis of current knowledge, no danger exists.

Red: substantial hazard

- Persons are endangered both within and outside buildings.
- The sudden destruction of buildings may occur.

or:

- Although the events may occur in less intensive form, their probability is higher. In these cases, persons are mainly endangered outside buildings.

In the main, the red area is a **prohibited area.**

Blue: average hazard

- While persons are hardly at risk inside buildings, they are so outside.
- Damage to buildings must be expected, but sudden collapse is unlikely in this area provided that certain requirements on building design are fulfilled.

In the main, the blue area is a **restricted area,** in which heavy damage can be avoided by suitable precautionary measures (restrictions).

Yellow: slight hazard

- Persons hardly at risk.
- Slight damage to buildings and/or obstructions must be anticipated, however substantial damage to buildings are possible.

In the main, the yellow area is a **warning area.**

Yellow-white hatched: residual hazard

Hazards with a very low probability of occurrence and high magnitude may be designated by a yellow-white hatched marking.

The yellow-white hatched area is a **warning area,** indicating a residual hazard, respectively a residual risk.

White: no or negligible hazard according to present status of knowledge

Figure 8: Definition of hazard zones or hazard levels (degree of hazard). The classification into different zones has direct consequences for land use planning.

B *Definition of protection requirements*

The protection requirements are defined on the basis of the following questions:

- What level of protection is required, for whom and why?
- What level of residual risk can be tolerated?
- What level of protection can we afford?

The novelty introduced into the Swiss flood management approach after 1987 is the so-called **concept of differentiated protection objectives**. The determination of different levels of safety, and thus of the design flood discharge is a decision related to major technical and economic consequences. In former days, the design for protective structures was generally based on a flood with a return period of 100 years (Q_{100}). Today, a differentiation of protection objectives is applied (Figure 9). According to the importance or value of structures and estates to be protected, the respective degree of safety shall be chosen. Where properties with a very high value have to be protected, it is recommended to increase the degree of safety and to use a design discharge which is higher than the centennial flood. In contrary, for agricultural land, the degree of safety can be much lower.

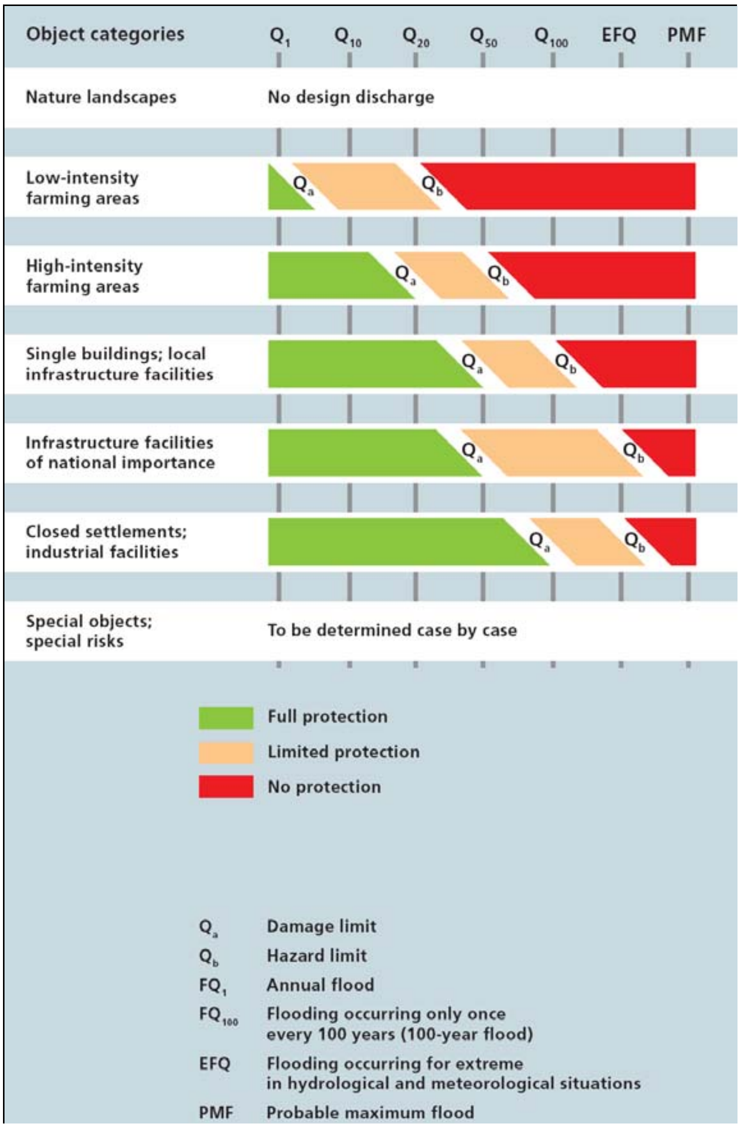


Figure 9: Differentiated protection objectives. According to the safety objectives, a variable design flood can be applied for flood control measures.

In Switzerland, flood risk maps are not yet widely established. However, a qualitative or semi quantitative risk can be depicted by overlaying the hazard zones with the various land use classes (these classes are related to the damage potential). In a first attempt, this is done by just using the generally available topographic information (settlements, housing or industrial estates, transport infrastructure etc.) as shown in Figure 10.

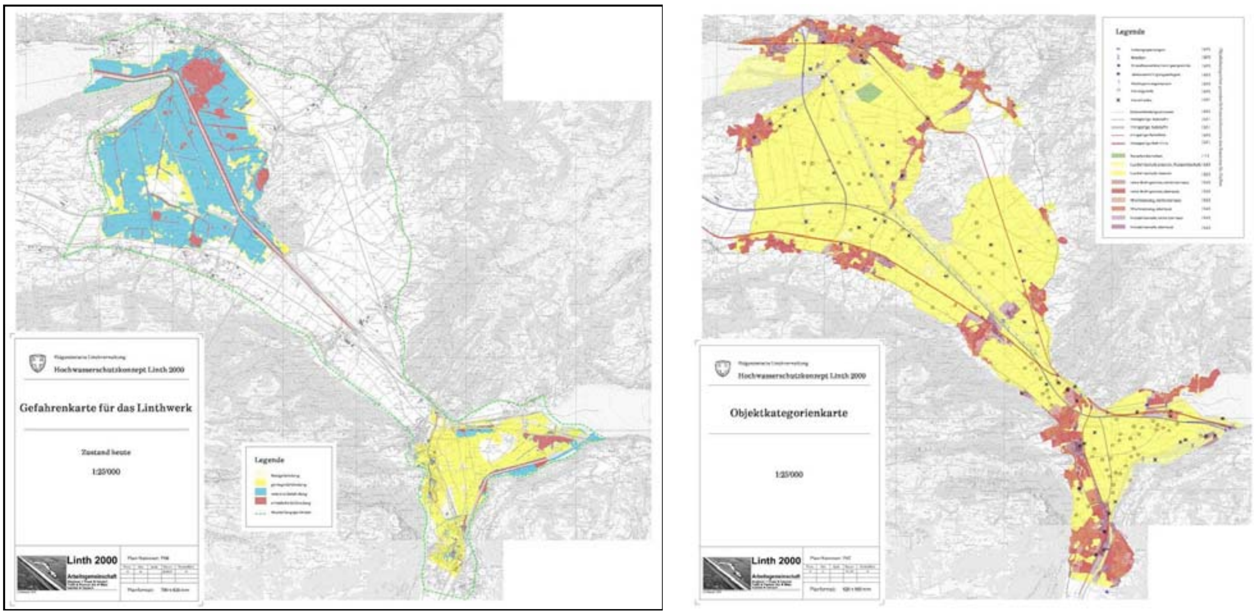


Figure 10: Hazard map for flooding and map with the land use classes showing the assets at risk.

An important instrument is the so-called "Map of Safety Deficits" relating flood risks with protection objectives (i.e. Figure 9) as shown in Figure 11. This map shows the parts of territory with a lack of protection. In a next step measures have to be taken to improve the safety.

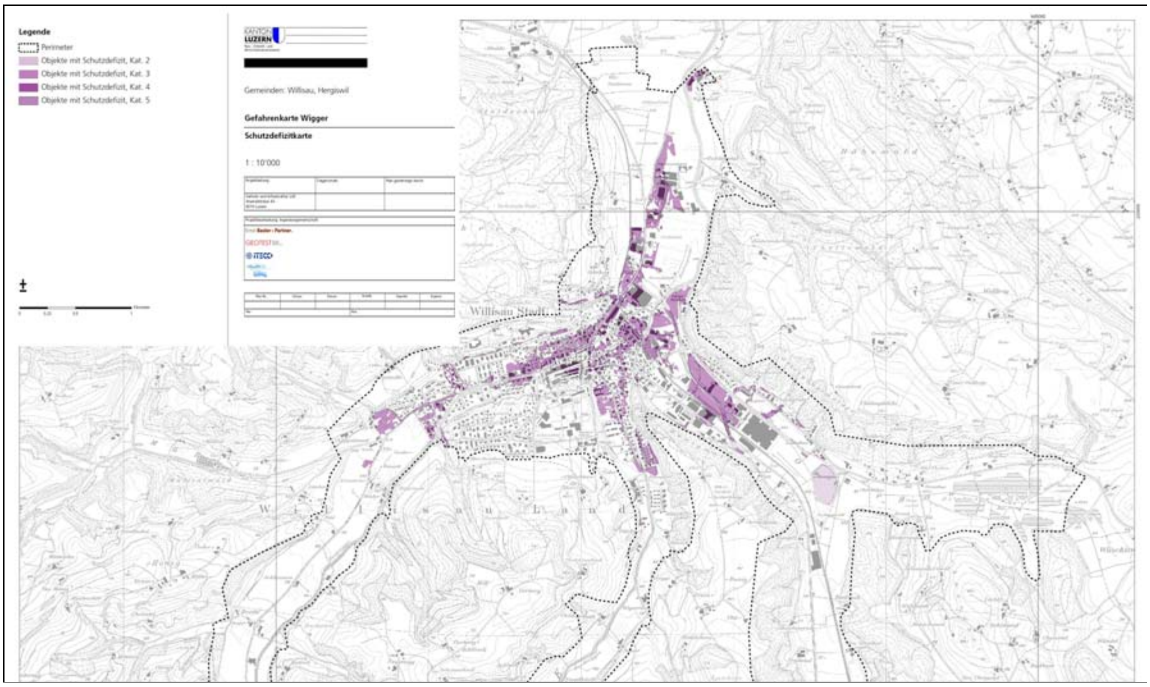


Figure 11: Map of safety deficit showing the degree of the lack of protection.

In a next step the risk can be calculated as the product of hazard and vulnerability and expressed in monetary value as damage per unit area and year (e.g. CHF per $100m^2$ and year). This information is needed to carry out a cost-benefit analysis (CBA). The tool used in Switzerland to carry out this CBA is accessible under *http://www.econome.admin.ch*.

The risk can be represented in a map as shown in Figure 12.

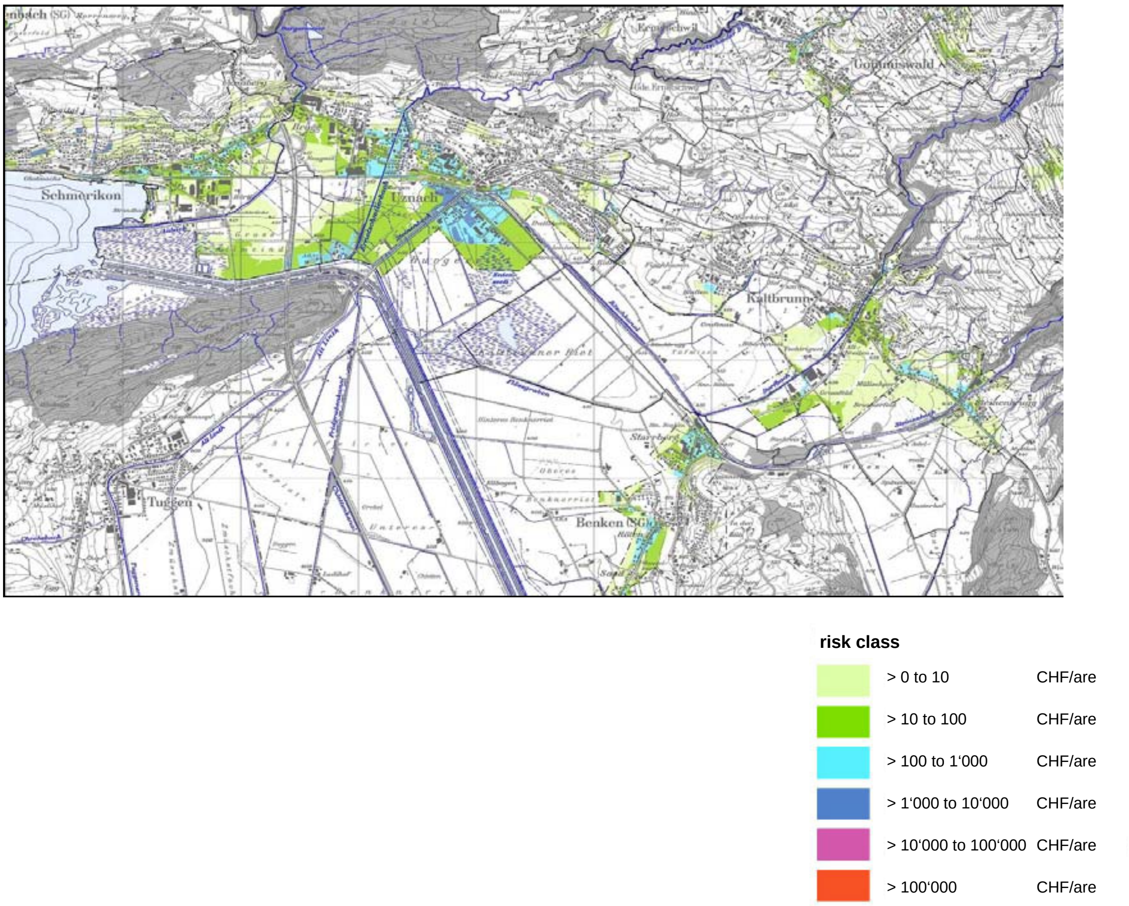


Figure 12: Risk map showing loss per unit area and year.

Figure 13 shows the amount of the expected annual loss per commune according to the different hazards. This allows setting priorities in the planning of measures.

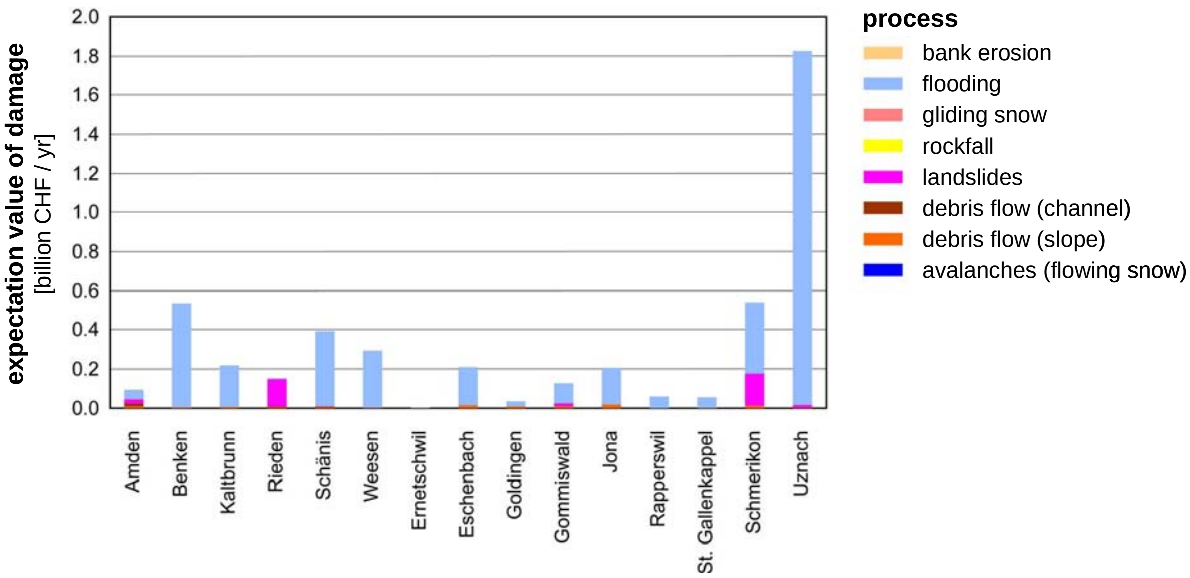


Figure 13: Expected annual loss.

C *Planning of preventive measures*

Measures have to be planned and assessed. **First priority** is given to proper **maintenance**, including repair of minor damages to protective structures. In addition, first priority also applies to **land use planning**, which includes the delineation of hazard zones, the issuing of building codes, reinforcement of existing structures, warning systems etc. Hazard zoning is based on the results of hazard mapping. Only **second priority** is on the other hand given to **structural protection measures** (river engineering works). Due to a high economic growth in urban as well as the many rural areas of Switzerland over the past few decades many residential and industrial estates, traffic or tourist infrastructure or other technical installations were developed within hazard zones. Today, a distinct lack of protection for many areas occurs. The risk in such places can no longer be reduced by means of the maintenance or by planning measures. More structural measures will be needed in future. Overall safety concepts and the design of particular structures require knowledge about the nature of the governing processes and about the possibility of their control.

Special attention has to be claimed to events, which exceed the design values. Each protection measure can be overloaded. This indicates that solutions have to be found, which take into account these events. A successful example is the river Engelberger Aa (for more information see: Kanton Nidwalden, 2009). The excessive water volume is diverted into a newly defined flood plain and then conveyed to the Lake Lucerne. The discharge corridor is secured by the local land use plan. No construction of new buildings is allowed in this zone. The existing settlements are protected by secondary dikes. In 2005, it was the first time that an event exceeding the design event occurred, as it is shown in Figure 14. The damage was at least ten times lower than without this solution.

Figure 14: Example of the Engelberger Aa: the excess water leaves the river channel and flows through the discharge corridor towards Lake Lucerne.

At the latest since the revision of the federal decree on flood protection (1999), a new set of **ecological criteria** has to be applied during the planning stage of protection measures as well; the ecological functions of the river corridors must thereby be maintained at the present level or even be improved, depending on prevailing conditions. Flood protection, based on a minimum of active interventions, can only be sustained, if more space is provided for the river corridors. This particular space should be delimited by means of land use planning.

D Emergency planning

Many disasters in the past demonstrated that a 100 % safety cannot be achieved. A residual risk always remains. An estimate of the impact of an event, which exceeds the design event, provides information about the residual risks. In case of the occurrence of such a disaster, the non-permanent (emergency) measures can provide additional safety for the population at risk and can considerably reduce the number of casualties. Particularly local agencies have to be involved in the installation and operation of early warning systems, in the preparation of evacuation schemes, and in the training of rescue units.

Emergency maps (an example is shown in Figure 15) are an important tool for crisis management and rescue services. Information of importance is e.g. number of people affected, evacuation routes, safe havens/temporary refuge centres, installations at risk, transport disruption, locations where erection of temporary defences is needed, etc.

Different kinds of maps are likely to be required for public information and for the use by emergency response.

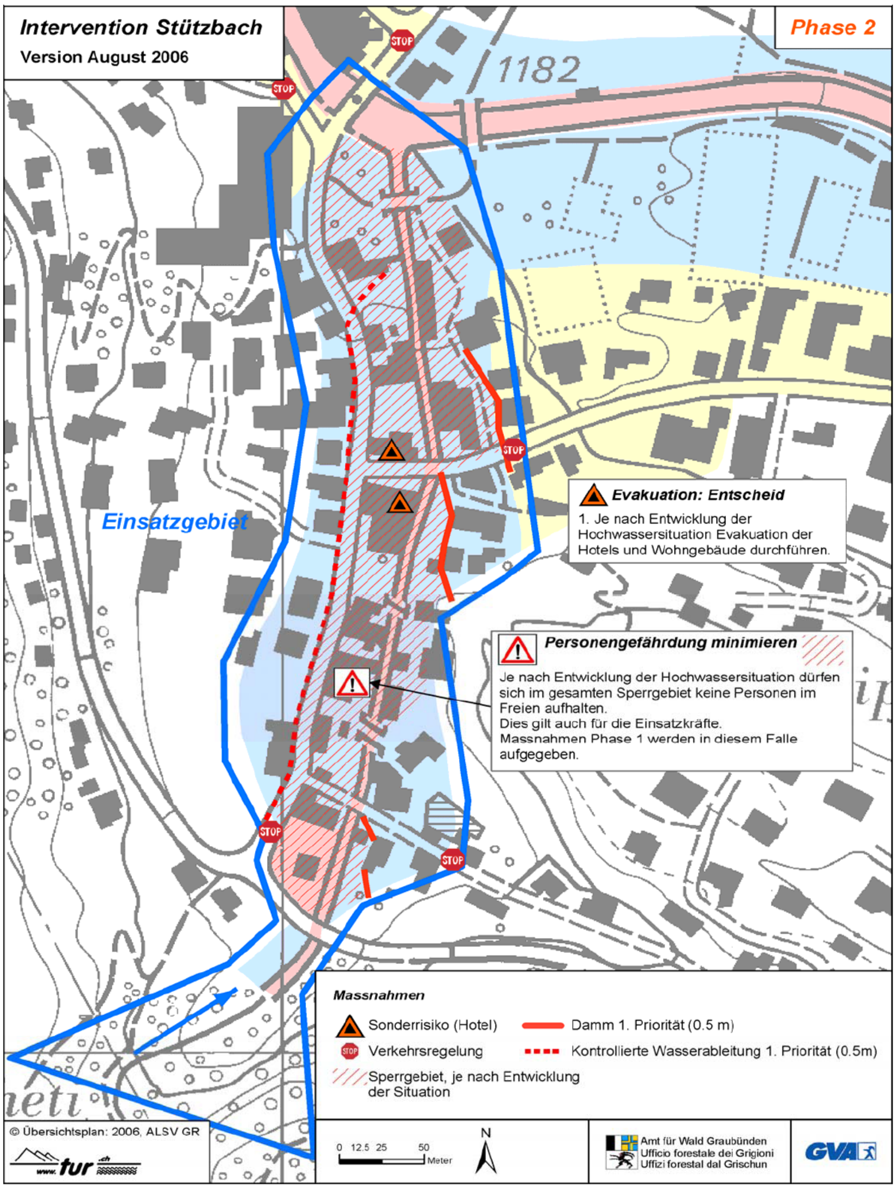


Figure 15: Emergency map for Klosters (Grisons).

3. Conclusions

Switzerland looks back on a long tradition of dealing with natural hazards. In the past, the emphasis was put on protective measures. The risk situation was aggravated by development in hazardous areas. The social and economic consequences of natural hazards exerted an impact on policy considerations and Switzerland has moved to an integrated risk management founded on preparedness, response and recovery measures.

The main emphasis is put on preventive measures based on the following cornerstones:

- Assessment of hazards and risks as a basis for risk management. Until 2011 all hazard maps should be accomplished.
- Different consequences (damages) require different protection levels and different measures. Protection of human life has the outmost priority.
- Maintenance of existing protective structures as well as land use planning have priority over structural protection measures.
- The impact of extreme events higher than the design event has to be examined and to be considered in the emergency planning.
- The reduction of natural disasters requires an integral prevention concept as well as an integrated risk management. The natural hazards, the ecological objectives, the socio-economic conditions and the cultural values have to be considered equally (sustainability).
- The implementation of the above mentioned measures requires the co-operation with the directly affected population.
- A 100 percent safety cannot be achieved. The land use defines the necessary safety objectives.
- Information on the residual risks must be given to everyone concerned and involved in the decision making process. Hazard maps are a tool to spread this information.

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