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Overview of landslide hazard and risk assessment practices

Work Package 2.1 - Harmonization and development of procedures for
quantifying landslide hazard

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SUMMARY

The objective of this deliverable is to review the current practices, regulations and codes in Europe for landslide mapping, susceptibility, hazard and risk assessment.

The contents of this deliverable refer to the existing official practices that are currently promoted or applied by administration offices, geological surveys, and decision makers (hazard and risk assessment procedures, regulations and codes). The reported countries and territories are: Andorra, Austria, France, Italy (selected river basins), Romania, Spain (Catalonia), Switzerland and United Kingdom.

New research developments in both qualitative and quantitative landslide hazard and risk assessment are not considered here and will be treated in deliverable D.2.4.

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1 INTRODUCTION

In Europe, various methodologies are being applied for landslide hazard and risk assessment. Before proceeding with the preparation of guidelines for landslide susceptibility, hazard and risk it is necessary to review those procedures that are currently applied by geological surveys, administration offices and decision makers (procedures, regulations and codes).

The terminology used for the description of the related hazard and risk often varies from procedure to procedure. The terminology used here for each country and case study (Sections 3 and 4) is the original one, as used by the authorities/institutions that applied it. However, it has been necessary to include a terminology section (Section 2), for the comparison of the procedures and their products (Sections 5 and 6).

Sections 3 and 4 describe the hazard and risk practices, respectively, in some selected case-studies in Europe. It has to be mentioned that in the European context only a few of risk procedures are applied officially by administrations, institutes or decision makers.

In Section 5, a comparison is made in view of hazard assessment practices and risk acceptability criteria. Section 6 is dedicated to outline the common points and the existing gaps and to put into light the necessary steps for a potential harmonisation of the hazard and risk assessment procedures.

2 GLOSSARY OF TERMS

2.1 LANDSLIDE RISK

The terminology used in this deliverable is that suggested in D.8.1 with three additions (exposure, magnitude and residual risk), based on the following references:

Fell, R., Corominas, J., Bonnard, C., Cascini, L., Leroi, E., Savage, W.Z., and on behalf of the JTC-1 Joint Technical Committee on Landslides and Engineered Slopes (2008): Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. *Engineering Geology*, Vol. 102, Issues 3-4, 1 Dec., pp 85-98. DOI:10.1016/j.enggeo.2008.03.022

Technical Committee 32 (Engineering Practice of Risk Assessment and Management) of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE): Risk assessment – Glossary of terms. http://www.engmath.dal.ca/tc32/2004Glossary_Draft1.pdf

Definitions of the main terms are:

- **Annual Exceedance Probability (AEP)** – The estimated probability that an event of specified magnitude will be exceeded in any year.
- **Consequence** – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.
- **Danger** – The natural phenomenon that could lead to damage, described in terms of its geometry, mechanical and other characteristics. The danger can be an existing one (such as a creeping slope) or a potential one (such as a rock fall). The characterization of a danger does not include any forecasting.
- **Elements at risk** – The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.
- **Environmental risk** – There are many definitions of this term depending on the context. To be defined explicitly when used in a SafeLand deliverable.
- **Exposure** – The temporal-spatial probability of the elements at risk within the landslide path.
- **Frequency** – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.
- **Hazard** – A condition with the potential for causing an undesirable consequence. The description of landslide hazard should include the location, volume (or area),

classification and velocity of the potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time.

- **Individual risk to life** – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.
- **Landslide inventory** – An inventory of the location, classification, volume, activity and date of occurrence of landsliding.
- **Landslide activity** – The stage of development of a landslide; pre-failure when the slope is strained throughout but is essentially intact; failure characterized by the formation of a continuous surface of rupture; post-failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (e.g. seasonal) or continuous (in which case the slide is “active”).
- **Landslide intensity** – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.
- **Landslide magnitude** – The measure of the landslide size. It may be quantitatively described by its volume or, indirectly by its area. The latter descriptors may refer to the landslide scar, the landslide deposit or both.
- **Landslide susceptibility** – A quantitative or qualitative assessment of the classification, volume (or area) and spatial distribution of landslides which exist or potentially may occur in an area. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.
- **Likelihood** – Used as a qualitative description of probability or frequency.
- **Probability** – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

(i) Statistical-frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an “objective” or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

(ii) *Subjective probability (degree of belief)* – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgement regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.

- **Qualitative risk analysis** – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.
- **Quantitative risk analysis** – An analysis based on numerical values of the probability, vulnerability and consequences, and resulting in a numerical value of the risk.
- **Residual risk** – the degree of existing risk given the presence of both stabilization and protection measures.
- **Risk** – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability \times consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.
- **Risk analysis** – The use of available information to estimate the risk to individuals, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: Scope definition, hazard identification, vulnerability evaluation and risk estimation.
- **Risk assessment** – The process of risk analysis and risk evaluation. In some communities (for instance those dealing with flood) risk assessment differs from risk evaluation by the fact that it includes subjective aspects such as risk perception.
- **Risk control or risk treatment** – The process of decision making for managing risk, and the implementation or enforcement of risk mitigation measures and the reevaluation of its effectiveness from time to time, using the results of risk assessment as one input.
- **Risk estimation** – The process used to produce a measure of the level of health, property, or environmental risks being analyzed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.
- **Risk evaluation** – The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

- **Risk management** – The complete process of risk assessment and risk control (or risk treatment).
- **Societal risk** – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.
- **Susceptibility** – see Landslide susceptibility.
- **Temporal–spatial probability** – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.
- **Tolerable risk** – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.
- **Vulnerability** – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide. Vulnerability could also refer to the propensity to loss (or the probability of loss), and not the degree of loss.
- **Zoning** – The division of land into homogeneous areas or domains and their ranking according to degrees of actual or potential landslide susceptibility, hazard or risk.

2.2 LANDSLIDE CLASSIFICATION

It is important that those carrying out landslide mapping use consistent terminology to classify and describe the landslides. It is recommended that the classifications of Cruden and Varnes (1996) are used for landslide classification in SafeLand:

- Cruden, D.M., and Varnes, D.J. (1996): Landslide types and processes. In: A.K. Turner and R.L. Schuster, Editors, Landslides: Investigation and Mitigation, Special Report Vol. 247, Transportation Research Board, National Research Council, Washington DC.

3 HAZARD ASSESSMENT PRACTICES

In this section a review of some methodologies that are officially applied for landslide hazard assessment in Europe is presented. The procedures that are reported here and their outputs are accepted by national, regional, or local authorities for urban and land use planning, even if, in some cases, they are not established legally. For each country or region, initially the general context in which the hazard assessment is performed is described (area, past events, general concepts and purposes for the hazard assessment) and following this, some important points of the used methodologies and/or outputs are outlined (purpose of the document, users of the document, type of the document, scale, type and mechanisms of landslides, basic documents required, methodology, hazard matrix, hazard levels, used legends, zoning, recommendations-restrictions).

In some cases, the policies for hazard assessment are applied at a national level (Andorra, Austria, France, United Kingdom and Switzerland) and in some other only regionally (River Basins in Italy and Catalonia in Spain).

3.1 ANDORRA

(contributor: UPC)

A summary of the actions undertaken in the Principality of Andorra for landslide hazard assessment and risk management is found at Corominas (2007). The efforts of the Andorran administration in natural hazards management began in the early eighties. In June 1980 the Consell General (Government Council of Andorra) promoted a hazard regulation for building in places threatened by snow avalanches, rock falls, and torrential activity. The resolution foresaw the preparation of an inventory of hazards and the possibility of the suspension of building permits in the identified threatened sites. However, the building restriction was seldom put into practice because the comprehensive hazard inventory was completed only for the snow avalanche phenomenon. In October 1987, rains lasting for several days triggered a landslide in a quarry located next to the road to La Massana. About 50,000 m³ of rock slid down and hit several cars. Three people died in this episode and the Valira del Nord valley and all its villages remained isolated for several weeks.

The first global initiative in the domain of the landslide hazard assessment and prevention was the natural hazards maps at 1:25,000 scale, which included landslides, torrential floods and flood-prone areas. In 1989 the first sheet covering the Valira d'Orient and Gran Valira valleys was completed, and in 1991 that of Valira del Nord (Corominas et al. 1990). In the year 2001, a new landslide hazard map at 1:5,000 scale was prepared which has become a basic document for the development of building codes and land use regulations. Depending on the hazard level assigned, private developments must set up the necessary stabilization and/or protective measures in order to obtain building permits in the threatened areas. The map has given way to more detailed studies at 1:2,000 scale in the most conflicting areas of the Principality and to the execution of remediation projects and development of strategies for living with risk. On December 2001 the Plan was officially published (BOPA, number 105, 12/12/2001) and public audience and amendment period was open until February 2002. The Administration has made the population aware of the existing level of hazard by informing

the municipalities, promoting open informative sessions and by publishing it as a decree in the official journal in August 2001. By asking documents such as Acknowledgement Form (AF) and Technical Report (TR) to the developers, the Administration guarantees that the potential hazard has been taken into account and that either protective or remedial measures will be implemented. In case of completion of the TR and the subsequent protective works, the Administration will deliver the corresponding building permits.

- **Name of the document**

Geohazard Plan (Zonificació del Territori Relativa a Riscos Naturals Geològics- Geotècnics. BOPA, n° 105, 12/12/2001)

- **Purpose of the document**

The purpose of the Geotechnical and Landslide Hazard Zoning Plan of Andorra (hereafter refer to Geohazard Plan) was to identify, locate and assess the natural hazards along with the geological and geotechnical constraints that may affect future construction works in the Andorran territory.

- **Users of the document**

The users of the document are the administrative offices of Andorra that are responsible for the land and urban planning. The hazard map is integrated in a GIS, thus allowing the knowledge of the type of hazard that threatens a particular site. Therefore, private owners and developers of this site may know in advance what kind of technical report they will be asked for.

- **Type of the document**

The document is legally binding.

- **Scale**

The scale of work was 1:5,000, which has enough detail to identify most of the existing and potential hazards but it does not allow a proper definition of the landslide boundaries (both source and runout area) for cadastral purposes.

- **Type of hazards. Type and mechanisms of landslides**

The landslides considered here are: rock falls, shallow slide, debris flow and large landslides.

- **Basic documents required**

The basic documents for the hazard evaluation are:

- Topographical data: Official topographical maps and DEM,
- Geological data (geological maps and superficial formations map),
- Landslide inventory (derived from chronicles and disaster documentation, aerial photointerpretation and field work).

- **Methodology**

The preparation of the map involved several steps (Corominas et al 2003): the assessment of the potential slope failures and the estimation of both the landslide volume and runout distance. The susceptible areas were defined based on the presence of superficial formations and threshold angles (shallow landslide and debris flows), presence of steep slopes, open cracks and menacing blocks (rockfalls) and mapped large landslides. In the identified susceptible areas, landslide magnitude and frequency was determined in order to obtain the hazard zoning map. For shallow landslides and debris flows, frequency was taken as that of the rainy episodes responsible for landsliding occurrence in the past while for large landslides the presence of activity indicators (deformed buildings and structures, tilted trees, open cracks and recent scarps) was considered. Data required for hazard assessment were introduced into a GIS or derived directly from available Digital Terrain Models. The assessment of intensity and frequency for all landslide types was carried out in a GIS at each susceptible cell. For rockfalls, trajectographic analyses were performed at selected slopes to obtain kinetic energies and runout distances. As a result all cells were classified according to the considered hazard matrix (presented in the following) and then the resultant hazard zoning map was prepared following criteria similar to those used elsewhere (Lateltin , 1997).

An extract of the map is illustrated in the following figure.

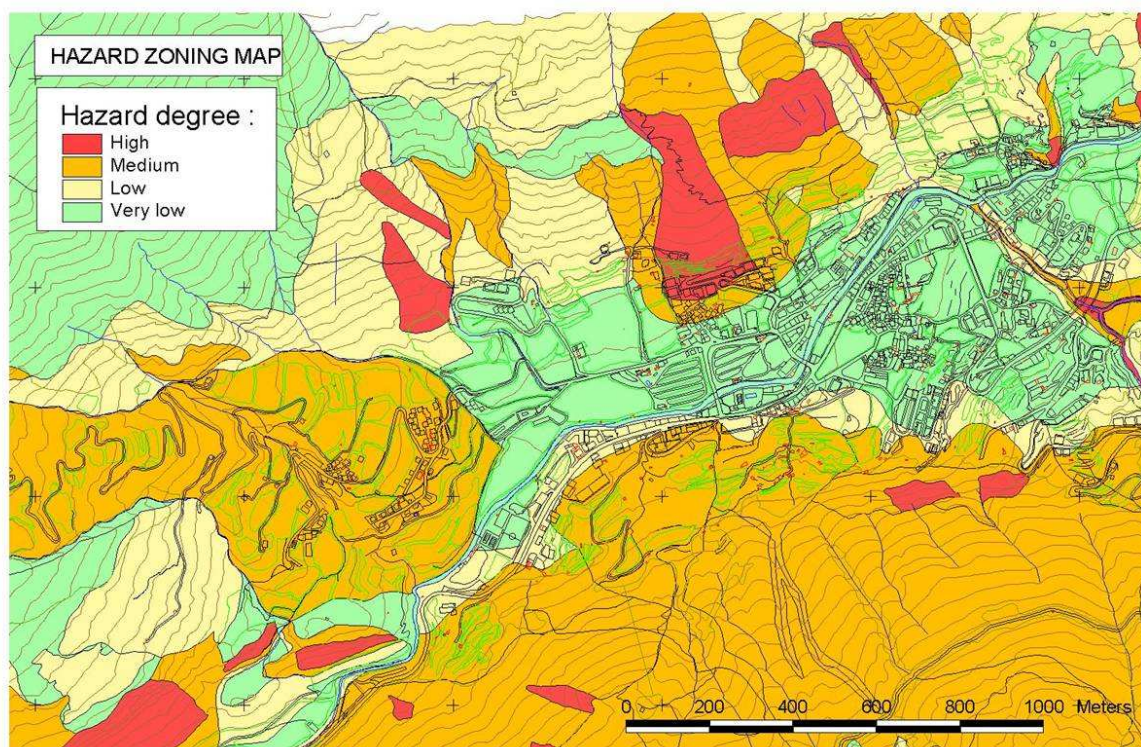


Figure 3-1. Landslide hazard map of the Encamp area at 1:5,000 scale, obtained by overlapping of rock fall, shallow slide, debris flow and large landslide hazard maps. In case of coincidence of different landslide types in the same site, the highest hazard class is shown.

- **Hazard matrix**

The hazard matrix used was the one presented here:

Table 3-1 . Hazard matrix for rockfalls in Andorra

Frequency (return periods)		< 40 yr	40-500 yr	> 500 yr
Intensity	High > 10000KJ	High	High	Moderate
	Medium	Moderate	Moderate	Low
	Low < 2000 KJ	Low	Low	Very low
Non-susceptible areas		Very low	Very low	Very low

Shallow landslides and debris flow were all considered as having low to moderate intensity while large landslides were all considered as having a potential for high intensity.

- **Hazard levels**

The map has four hazard categories: (a) very low, in which no potential hazard has been observed; (b) low, in areas that may be affected by small-size slope failures with moderate-high frequency and that can be mitigated at low cost; (c) moderate, corresponding to areas where either frequent landslides of small magnitude or large landslides with low frequency may take place. Landslide countermeasures are feasible; and (d) high hazard is assigned to areas where large landslides may reactivate or are active. Landslide countermeasures are not feasible.

- **Legends**

The following legend is used.



Figure 3-2. Legend used for hazard maps in Andorra

- **Zoning, recommendations-restrictions**

An administrative procedure has been established for delivering building permits taking into account the hazard classes defined at the Landslide Hazard Map (Corominas et al. 2003b).

Different documents may be asked for new developments or infrastructures according to the degree of hazard of the site, which are synthesized in Table 3-2. For areas classified as very low landslide hazard, no specific document is required. For low hazard areas, the owner or developer must fill a form of acknowledgement of the type of threat that may affect the property. This form is signed by the engineer or architect responsible of the project, mentioning that the possible hazard has been taken into account for the project design. For moderate hazard areas, besides the acknowledgement form a technical report is required. This report must include specifically the countermeasures that will be undertaken in order to avoid or mitigate the potential hazard along with an estimation of the residual risk (particularly for those events of large return periods). In this hazard category sensitive buildings such as schools or hospitals are not allowed. Finally, for high hazardous areas new constructions or facilities are forbidden. A few exceptions are, however, envisaged. Warehouses with no permanent activity, linear infrastructures (i.e. water pipes) that will not threat population or the environment in case of failure, or roads without alternative corridors might be allowed and, in this case, both acknowledgement form and technical document will be required to justify technically the project

Table 3-2 . Administrative procedure for delivering building permits

Hazard Category	Documents required
Very low	None
Low	Acknowledgement form (AF)
Moderate	AF + Technical report (TR)
High	Building forbidden Exceptions: AF + TR

The procedure lets open the possibility of authorization to build in high hazard areas if the promoter provides the adequate technical studies showing that countermeasures to avoid or mitigate instability are feasible.

The landslide hazard map at 1:5,000, showed that some areas subjected to an intense urban pressure are considered of a moderate hazard. Most of these areas correspond to either large dormant or slow moving landslides or debris fans with a defined debris source located upstream. The characteristics of such landslides make the completion of the AFs and TRs too complex and costly for the private owners. In order to speed up the whole procedure and to avoid unnecessary delays in the urban development of the Principality, the Ministry of Publics Works commissioned detailed studies at several landslide sites that have required further landslide hazard analyses (Hürlimann et al. 2006). Each study included landslide hazard maps at 1:2,000 scale and a diagnosis of the degree of hazard; the location of the zones to be avoided; the recommendations for building and earthworks; and the necessary protective works for achieving an acceptable risk. All these studies have been published in the official journal of the Principality. In the areas where the detailed studies have been performed by either the administration or private promoters, TR for any specific development will simply require the inclusion of the measures recommended in the detailed study. The relevant landsliding events and actions undertaken by the Andorra government are outlined in Figure 3-3.

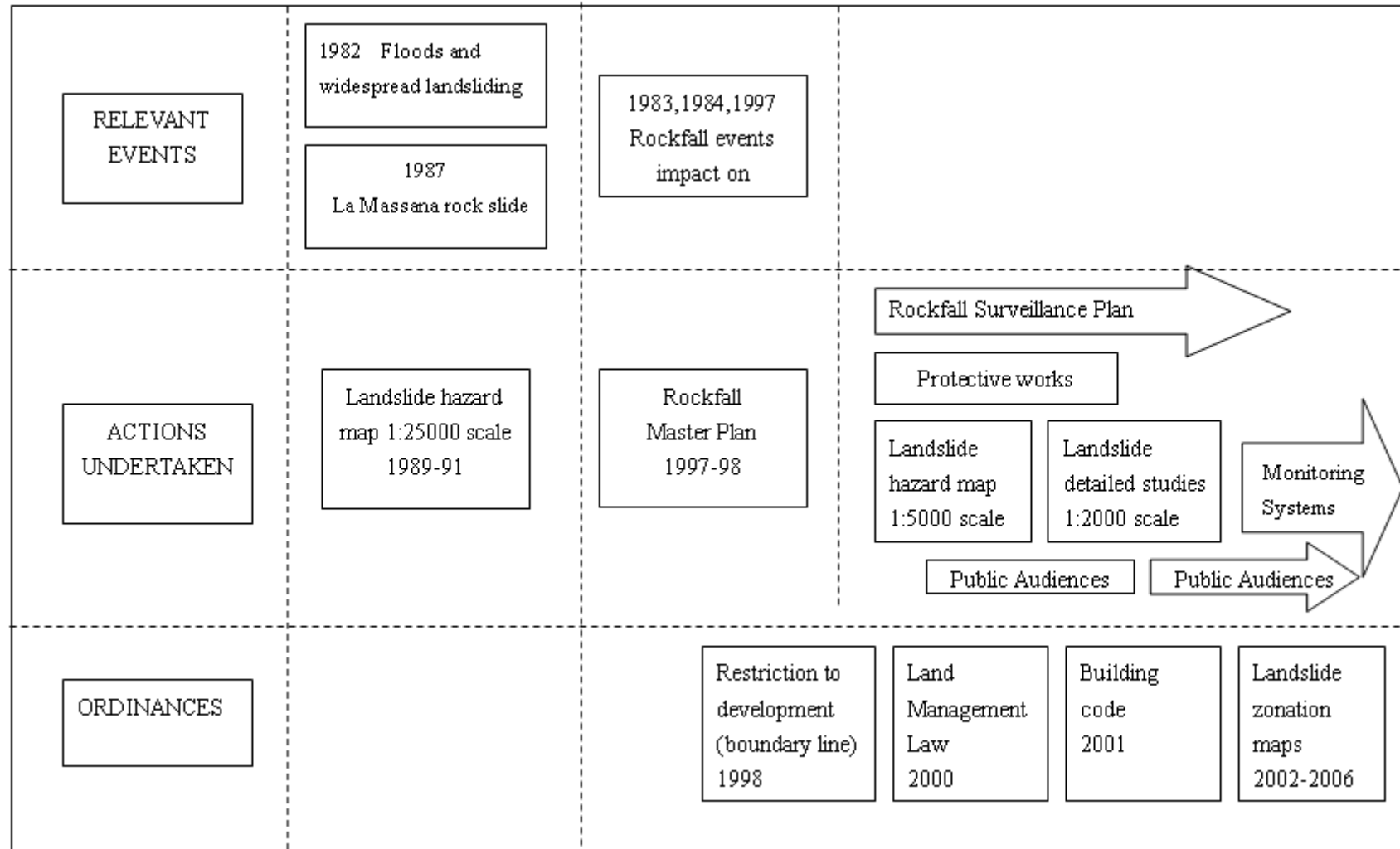


Figure 3-3. Relevant landsliding events and action undertaken by the Andorra government (Corominas, 2007)

Detailed studies

The capital of Andorra, Andorra la Vella and its neighbor urban area are situated at the toe of the Solà d'Andorra rock wall. The slope presents an important rockfall activity which is made obvious by the accumulated rock blocks on the talus slope located at its base. Given that the space for urban development is limited due to the intense relief of the area (located in the East-Central Pyrenees), many buildings were built near the area affected by rockfalls.

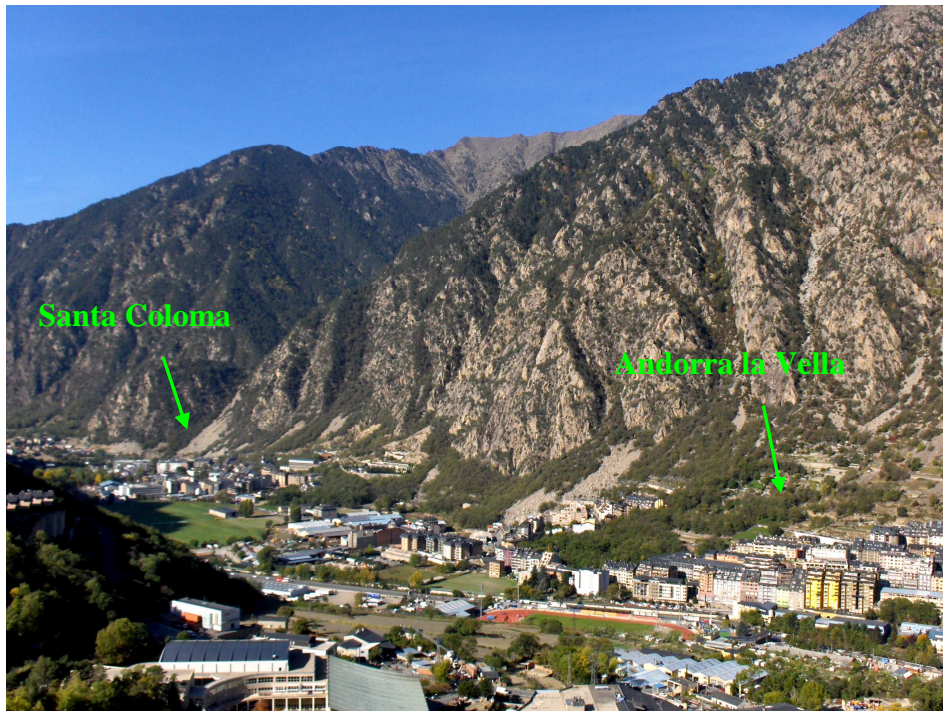


Figure 3-4. The Solà de Andorra and the urban areas of Santa Coloma and Andorra la Vella

Three rockfall events, one on December of 1983, one on January of 1994 and one on January 1997, caused the impact of rock blocks on buildings located at the foot of the slope. In the last case a person was injured. The 1997 event forced to the Andorran administration to undertake several initiatives. The most important one was the Rockfall Risk Management Master Plan (RFMP) of the Solà d'Andorra which was completed in May 1998 (Copons et al. 2004). The RFMP defined an upper boundary line above which building is forbidden. The line was published in the official registrar of the Principality in 1998 (BOPA - Butlletí Oficial del Principat d'Andorra, núm. 24, 27/5/98). And since then it has been used by the Andorra administration for authorization of new developments. When the development line was defined, some of the existing buildings were already within the exclusion area. For all the cases, the RFMP considered the design of defences against rock falls (Copons et al. 2000). Details are given in the following.

- **Name of the document**

Pla Director davant de la caiguda de blocs rocosos a la solana d'Andorra la Vella i Santa Coloma (Rockfall Risk Management Master Plan (RFMP)).

It is officially registered at BOPA (Butlletí Oficial del Principat d'Andorra) núm. 24, 27/5/98.

- **Purpose of the document**

The purpose of the document was to support the planning of the hazard management due to rockfalls and the application of proper protection measures for the risk mitigation in Solà d'Andorra. Additionally, it was intended to establish zones for the control of development in areas threaten by rockfalls.

- **Users of the document**

The document is used by the local authorities (Ministeri d'Ordenament Territorial del Govern d'Andorra) to authorize the construction of structures in rockfall prone zones (according to document BOPA núm. 61, 2/12/1998) and to promote construction projects for their protection (rockfall fences, barriers etc.). The RFMP is available to the public:

- online (<http://www.bopa.ad>), in catalan
- at the "Casa Comuna" (Town Hall) – original plans.

- **Type of the document**

The RFMP includes rockfall hazard plans of the Solà d'Andorra and the adjacent urban areas (Andorra la Vella and Santa Coloma) with a limit line that separates areas of high rockfall hazard (where construction is not permitted) from areas of low rockfall hazard (where construction is permitted with restrictions) (Figure 3-5). It is legally binding for the issue of construction permissions (BOPA núm. 61, 2/12/1998).



Figure 3-5. Extract from RFMP. The limit that separates the high from the low hazard zone is marked with a dark line.

- **Scale**

The scale is 1:1,000.

- **Type of hazards. Type and mechanisms of landslides**

Exclusively rockfalls are treated.

- **Basic documents required**

The basic documents for the hazard evaluation are:

- Topographical data: Official topographical maps and DEM,
- Geological data (lithological map),
- Joint sets
- Land use planning, existing buildings and other facilities,
- Thematic maps (rockfall sources, menacing blocks),
- Event catalogue (derived from chronicles, silent witnesses in the field and disaster documentation),
- Measurements of the distribution of block sizes at sample plots of the talus slope.

- **Methodology**

Eurobloc methodology was used for the development of the Master Plan. It was developed by Euroconsult and Eurogeotècnica consultant companies and it consists of 4 main steps:

1. Location of rockfall sources and assessment of potential rockfall volumes
2. Assessing frequency distribution of the rock blocks
3. Performance of trajectographic analyses for determination of runout distances, height of rebounds and kinetic energies of the blocks
4. Integration of the protective work in the trajectographic analyses to determine the residual hazard at the protected areas.

In the first step, different chutes have been identified at the Solà area. Each chute has a source and a depositional zone and particular rockfall dynamic characteristics. For every chute a thematic cartography is made (past rockfall sources, potentially unstable rocks etc.) and a volumetric analysis of the rock blocks. Then, the natural conditions of terrain are mapped, to be used for the calibration of the simulation models (evaluation of the restitution coefficient etc.)

During the elaboration of the obtained field data, distribution of the rock volumes that may reach the exposed elements (persons, houses) and the rockfall activity are determined. It has been observed that the rocks that reach the protection fences in the area are slightly greater than the deposits situated nearer the slope source. For this reason, a corrected volume is used for the volumetric distribution of the rocks that may reach the protection fences.

$$V_c = \frac{4V_t + V_v}{5}$$

where:

V_c: corrected volume

V_t: volume of rocks at the deposit (measured)

V_v: volume of rocks at the rockfall source (evaluated).

The volumetric study as well as the one of the rockfall activity is made for each unit separately.

The three-dimensional simulation of the rock-path, for the determination of the energies and the bouncing height of the fragmented rocks, is made in function of the volume. The simulation is made using the software Eurobloc (Lopez et al., 1997, Copons et al., 2000). The range of simulated volumes is 0.5-10 m³. The input data are the DEM, the block volume, the rockfall source and the terrain typology (roughness) and the existing vegetation. The calibration of the terrain parameters is made using field data from past events. The trajectory analysis provides results for the run-out zone for each volume, the three-dimensional distribution of the energy of the rocks and the number of blocks for each energy level that can be captured by a protection fence of a certain dissipation capacity. This permits the calculation of the number of rocks that are not retained by the protection measures and reach the urban area. The protection level Gp is equal to their percentage of the rocks that are retained.

After the installation of protection measures the residual hazard is calculated as:

$$Pr = Fe \frac{(100 - Gp)}{100}$$

Where

Pr: residual hazard

Fe: frequency of events (events/m)

Gp: protection level

- **Hazard matrix**

No hazard matrix is applied here.

- **Hazard level**

- **Legends**

———— Boundary line that separates developable from non-developable zones

- **Zoning**

There exist three zones (Altimir et al., 2001):

1. Zone above the boundary line of the RFMP. Construction is not allowed.
2. Zone with exposed elements below the boundary line of the RFMP. Construction is permitted only if sufficient protective measures exist.
3. Zone with non-exposed elements below the boundary line of the RFMP. Construction is permitted without restrictions.

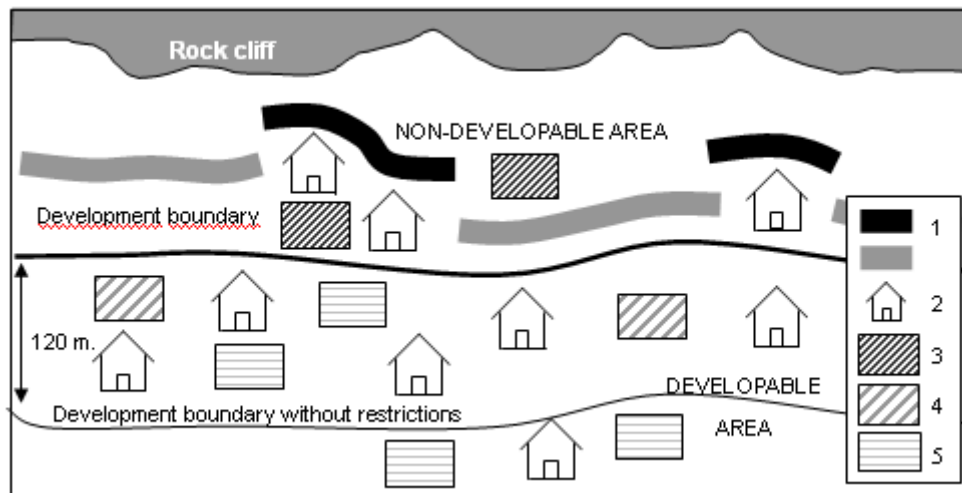


Figure 3-6. Sketch of development zoning in the Andorra la Vella – Santa Coloma area with both the proposed development restriction and the protection measures: 1 - Protection embankments and fences; 2 – Buildings; 3 – Plots non-developable; 4 – Developable plots with protective structures required; 5 – developable plots without restrictions (from Copons et al. 2004)

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3.2 AUSTRIA

(contributor: JRC)

In Austria, six major organisations operating at national level collect data on landslides and publish various types of landslide-related maps (i.e. inventory maps, susceptibility maps and hazard maps) and databases (Schweigl and Hervás, 2009). These organisations are the Austrian Service for Torrent and Avalanche Control (Forsttechnischer Dienst, Wildbach- und Lawinenverbauung, WLV), the Geological Survey of Austria (Geologische Bundesanstalt, GBA), Joanneum Research, AlpS (Zentrum für Naturgefahrenmanagement), the Austrian Railways (Österreichische Bundesbahnen, ÖBB), and the Austrian Highway Company ASFINAG. Apart from these organizations landslide-related maps have also been produced by geological surveys of different federal states and universities. Table 3-3 provides an overview of the different types of landslide-related maps produced by various administrations in Austria. Landslide inventory maps and susceptibility maps are most common. Their coverage, scale, content (and map legend), spatial representation (symbolology) and accessibility differ from one another.

In the Austrian legislation, multiple regulations with respect to natural hazards exist (e.g. Fig. 1 in Holub and Fuchs, 2009). With regard to the collection of landslide data, the state law, Forschungsorganisationsgesetz BGBl, Nr. 47/2000, regulates that this is the task of the Geological Survey of Austria (GBA; Schweigl and Hervás, 2009). They have a large Mass Movements (Massenbewegungen) database, of which a subset of 860 occurrences is available online (<http://geomap.geolba.ac.at/MASS/index.cfm>).

With regard to landslide hazard, the most important article at the federal level is the Austrian Forest Act of 1975. On the Länder level, there are laws regulating spatial planning and land use planning that also have to take account of landslides and other natural hazards.

As stated above, the most important legal Documents for delimiting hazard zones are:

- The Austria forest law (national legal act): Republik Österreich: Abschnitt II, forstliche Raumplanung, des Forstgesetzes (in §§ 7, 8 and 11) 1975, BGBl. 440/1975, 1975;
- The Austrian hazard zone regulation (associated decree): Republik Österreich: Verordnung des Bundesministers für Land und Forstwirtschaft vom 30. Juli 1976 über die Gefahrenzonenpläne, BGBl. 436/1976, 1976; and
- Different spatial and construction laws (Raumordnungsgesetze und Bauordnungen) of the nine federal states.

The Austrian Forest Act (§ 8b) of 1975 prescribes the delimitation of hazard zones in catchment areas susceptible to natural hazards such as torrential floods or avalanches (Forest Act § 99) and areas reserved for mitigation measures. In § 11, the compilation of hazard maps and the involvement of communes and population are regularized.

The contents and designs of these maps (official name: Hazard Zone Plan in Torrent and Avalanche Control) are specified by the decree associated to the Forest Act. According to § 5(2) of this Decree on Hazard Zoning, all available data and information on natural hazards as well as interactions between individual hazard processes have to be considered during the compilation of hazard maps. Furthermore, interferences with the human environment, such as infrastructure facilities and settlements have to be taken into account. Hazard maps are usually based on the area of an individual community, and should be compiled in a reproducible manner to allow for validation during the approval process by the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) (Holub and Fuchs, 2009).

Responsible by law: The Austrian Service for Torrent and Avalanche Control (Forsttechnischer Dienst, Wildbach- und Lawinenverbauung, WVL)¹ an office of the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW).

More information on WVL can be found in Schweigl and Hervás (2009; p.21 first paragraph).

To ensure that throughout Austria the same rules are used for hazard mapping a special experienced responsible (Gefahrenzonenplanreferent) is entitled within each section of the WVL (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2006).

A description of the Hazard Zone Plan in Torrent and Avalanche Control follows:

- **Name of the document**

The Hazard Zone Plan in Torrent and Avalanche Control
(Der Gefahrenzonenplan des Forsttechnischen Dienstes für Wildbach- und Lawinenverbauung)

- **Purpose of the document**

The main objective of the document is the hazard mapping for floods, avalanches and debris flows. The secondary objective is the landslide susceptibility mapping (there is no nationwide hazard map for landslides other than debris flows). Both documents are finally placed on the same map.

- **Users of the document**

The documents should be used by all administrative bodies. WVL makes the maps available to the municipalities as the competent authorities for local land-use planning, construction planning and safety planning.

¹ The WVL is only responsible in the upper parts of the catchments and the Federal Water Engineering Administration is responsible for the lower parts of the catchments.

*Table 3-3. Availability of landslide maps in Austria
(modified from Schweigl and Hervas, 2009)*

Organisation	Maps produced Digital (D) or Paper (P)	Coverage	Scale	Date Created	Accessibility
Austrian Service for Torrent and Avalanche Control (WLV)	Landslide inventory (D, P)	National	1:50,000 – 1:25,000	Since 1975	Restricted
	Hazard maps	National	1:5000 – 1:2000	Since 1975	Public
Geological Survey of Austria (GBA)	Landslide inventory (D)	National	1:25,000 – 1:50,000	Since 2002	Restricted
	Landslide inventory (D)	National (selected landslides)	1:300,000	Since 2005	Public (web)
	Landslide susceptibility (D)	Regional	1:50,000 – 1:750,000	Since 2005	Restricted
	Landslide hazard (D)	Local	1:10,000	Since 2006	Restricted
Joanneum Research	Landslide inventory (D)	Local (Styria, Tyrol)	1:25,000	Since 2001	Restricted
	Landslide susceptibility (D)	Local	1:5000 – 1:50,000	Since 2001	Restricted
AlpS	Landslide inventory (D)	Regional (Tyrol and surroundings)	1:200,000	Since 2005	Restricted
Austrian Railways (OBB)	No inventory, single reports	National: railway buffer zone			
	Landslide susceptibility (D)	National: railway corridors only	1:25,000	2007 - 2008	Restricted
	Landslide susceptibility (D)	National: railway corridors only	1:5000 – 1:10,000	2008 - 2010	Restricted
Geological Survey of Burgenland	No inventory, single reports Landslide susceptibility (D)	Burgenland Federal State	1:25,000	2005 - 2009	Restricted
Dept. of Bridge and Civil Engineering, Vienna Federal State	No inventory, single reports	Local			Restricted
Geological Survey of Lower Austria	Landslide inventory (D)	Lower Austria Federal State	1:50,000	2002 - 2009	Restricted
	Landslide susceptibility -heuristic- (D)	Local	1:50,000	2008	Restricted
	Landslide susceptibility, -statistical- (D)	Federal State	1:25,000	2009 - 2013	Restricted
Construction Group, GIS Department, Styria Federal State	Inventory only for slides (D)	Styria Federal State	1:1000 – 1:5000	Since 2007	Public
Geological Survey of Carinthia	Landslide inventory (D)	Carinthia Federal State	1:50,000	Since 2003	Restricted
	Landslide susceptibility -heuristic- (D)	Federal State	1:50,000	Since 2007	Restricted
	Landslide susceptibility -statistical- (D)	Federal State	1:25,000	2008 - 2011	Partly public
Geological Survey of Upper Austria	Landslide inventory (D)	Upper Austria Federal State	1:50,000	Since 2005	Restricted
	Landslide susceptibility -heuristic- (D)	Federal State	1:50,000	Since 2007	Restricted
Geological Survey of Salzburg	Landslide inventory (D)	Salzburg Federal State	1:25,000	Since 2006	Public
Geological Survey of Tyrol	No inventory, single reports	Local			Restricted
Geological Survey of Vorarlberg	No inventory, single reports Landslide susceptibility -heuristic, statistical- (D)	Local	1:20,000 – 1:25,000	1999 - 2003	Restricted

The documents are freely available in German at the communal administrative authority, at the district administrative authority, at the Provincial Government, and at the regional headquarters of the Forest Engineering Service in Torrent and Avalanche Control.

In some states (e.g. Styria) all data and maps are available in a digital database. The other states will follow. The mapping and digitalization of the whole Austria is planned to be finished in 2010. Currently about 93% of the country is covered (F. Schmid, personal communication, November 2009). Due to the fact that Austria is not completely covered with digital hazard zone maps, the documents are only occasionally used as an instrument for safety planning and crisis management (Rudolf-Miklau and Schmid, 2004).

- **Type of the document**

Hazard Zone Maps contain:

- General Hazard Map (covering one community);
- Detailed Hazard zone maps (showing the hazard zones and reserved areas for all relevant catchment areas; based on the land register/cadastré);
- Written document presenting e.g. the results of hazard assessment, the explanation for the outlined hazard zones and the delineation of the relevant areas; and
- Documents of the administrative process.

From a legal point of view, the hazard maps do not have any ordinance character; they do not bind land use planners directly in their decisions since the delimitation of hazard zones is not a statutory regulation in accordance with the Austrian Superior Administrative Court (VwGH 27.03.1995, 91/10/0090, Hattenberger, 2006; Kanonier, 2006 cited in Holub and Fuchs, 2009).

Hazard maps are only legally binding for spatial planning purpose if there is particular reference in the individual spatial planning law of the individual Länder, e.g. the Tyrolean Act on Spatial Planning explicitly addresses the protection of areas suitable for building activities against the adverse effects of natural hazards (Amt der Tiroler Landesregierung, 2006 § 1 Abs. 2 lit. d).

Nevertheless, the content of hazard maps is internally binding for any administrative body in terms of an order, in particular for the governmental departments of the Austrian Service for Torrent and Avalanche Control (WLV) and the Federal Water Engineering Administration (Hattenberger, 2006 cited in Holub and Fuchs, 2009).

- **Scale**

- General hazard map: 1/10,000 – 1/150,000
- Detailed hazard zone maps: 1/2,000

- **Type of hazards. Type and mechanisms of landslides**

Hazard maps are only created for debris flows.

For slides and falls susceptibility maps are produced. We cite from the WVL “Hazards due to landslides and rock fall are only visualized without assessing the intensity and frequency of the events.”

- **Basic documents required**

All available documents should be used (Rudolf-Miklau and Schmid, 2004):

- Event catalogue (derived from chronicles, testimonials in the field and disaster documentation)
- Topographical data: Official topographical maps, cadastre (land register), terrain models processed from remote sensing (laser scan) or survey
- Hydrological data (precipitation, run-off)
- Geological data (geological maps from the Geological Survey of Austria)
- Land use planning
- Environmental planning
- Agriculture and forestry
- Nature protection area
- GIS of the federation and the provinces
- Special databases: WISA (Wasserinformationssystem Austria), HORA (HOchwasserRisikozonierung Austria - Flood Risk Zonation Austria), etc.
- Digital torrent and avalanche cadastre
- Projects of the Austrian Service for Torrent and Avalanche Control
- Regional studies and surveys

- **Methodology**

For landslide susceptibility maps (Schweigl and Hervás, 2009):

- Landslides are mapped in the field.
- An expert decides from fieldwork, literature review and historical archives whether an area is susceptibility to landslides.
- Only two classes are distinguished: susceptible and not susceptible to landslides.

For the hazard maps for floods, avalanches and debris flows (Important: Hazard zones are only outlined in specific areas called “areas relevant to land use planning”):

- Sites “relevant to land-use planning” are (1) areas which are identified in the land development plan as category “building land“ [e.g. purely residential area, extended residential area (mixed – residential and industrial area), industrial area], and (2) areas for which hazard zoning seems to be advantageous due to their location, their level of development or any other function. (The criteria for selecting the sites relevant to land-use planning have to be justified briefly in text documents related to the hazard maps).

Hazard maps for floods, avalanches and debris flows are derived from field survey (supported by remote sensing methods and GIS data) and computer simulation:

- Hazard zoning is based on a design event with a recurrence interval (RI) of ca. 150 years (i.e. all possible scenarios which are expected with a RI of 150 years should be

taken into account). A hazard is characterized frequent when its probable RI lies within a period of 10 years.

- The outlining of the hazard zones is normally done in the field. The outlines of the red or yellow hazard zones (see below) represent the sum-line of all possible hazard scenarios that may occur or have to be considered within the framework of the design.

Hazard zoning has to take into account not only all available data, information and interactions concerning natural hazards, but also endangering caused by human interventions, that change and influence the balance of nature (e.g. ski areas, roads, settlement development, pollution, climate change).

This means that if conditions (e.g. as a result of structural measures) or their evaluation (e.g. change in criteria for evaluation of the hazard mechanisms) change in the catchment areas, the hazard zone plan must be revised (Holub and Fuchs, 2009), or as is written in the official document: “If the underlying principles or their evaluation change, the responsible offices must adapt the hazard zone plan to take the changed conditions into account.” (Excerpt from the “Ordinance by the Federal Minister of Agriculture and Forestry of 30 July 1976 on Hazard Zone Plans, Fed. Law Gazette No. 436/1976”).

- **Hazard matrix**

The hazard matrix for floods, avalanches and debris flows is qualitatively derived based on expert knowledge (see Table 3-4).

- **Hazard levels**

Five different levels are distinguished:

- Red: high hazard to floods, avalanches and debris flows
- Yellow: moderate hazard to floods, avalanches and debris flows
- Blue reservation areas: reserved for future protection measures by the WVL
- Violet reservation areas: areas that can be used as protection due to their natural properties, such as protection forests or natural retention basins
- Brown: high landslide (slide and rock fall) susceptibility (no assessment of intensity and frequency). Within the zones a letter indicates the type of landslides (i.e. R: slides; and ST: falls)

Areas that do not lie within a hazard zone are not significantly endangered by natural hazard although an influence cannot be totally excluded.

- **Legends**

The legend refers to the hazard level. Five different colors represent five levels (See hazard levels).

Table 3-4. Criteria for red and yellow hazard zones considering design or frequent event
(taken from Schmid, F., sd)

Criteria	zones	Recurrent design event	Frequent event (1 to 10 times/year)
1) Stagnant water	TR	water depth $\geq 1,5$ m	water level mark HQ10 > 50 cm, HQ 1 > 20 cm
	TY	water depth $< 1,5$ m	water level mark HQ10 > 50 cm, HQ 1 < 20 cm
2) Running water	TR	height of energy line $\geq 1,5$ m	HQ10: height of energy line $\geq 0,25$ m
	TY	height of energy line $< 1,5$ m	HQ10: height of energy line $< 0,25$ m
3) Erosion gullies	TR	depth $\geq 1,5$ m	erosion gullies possible
	TY	depth $< 1,5$ m	runoff without erosion gullies, thus see no. 2!
4) Bedload-deposits	TR	height of deposits $\geq 0,7$ m	Bedload deposits possible
	TY	height of deposits $< 0,7$ m	no bedload deposits, thus see no. 2!
5) Post-failure slope movement consequently depth/lateral erosion	TR	Upper edge of the post-failure slope movement area	—
	TY	safety distance	—
6) Debris and earth flows	TR	boundary of marked debris flow deposits	—
7) Retrogressive erosion	TR	possible extent	no assessment
	TY	take note of points 3 and 5	

Remarks:

ad. point 1): bog pools, ponds, wells, small synclines are not represented

ad point 5): - Reason for the width of the safety distance in the individual case

- In order to record and define post-failure slope movement areas a check-list is being worked out

• **Zoning, recommendations/restrictions**

Five different zones exist:

- Red: all construction activities are forbidden

“Areas are threatened by torrents or avalanches to such a degree that their permanent use for settlement and traffic purposes is not possible or only possible at unreasonably high costs due to the anticipated damaging impact of the assessed event or the frequency of the hazard.” (Except from the “Ordinance by the Federal Minister of

Agriculture and Forestry of 30 July 1976 on Hazard Zone Plans, Fed. Law Gazette No. 436/1976”).

This means an absolute ban on the construction of new buildings in red hazard zones. Exceptions are only possible if existing buildings are modernized and this is associated with an improvement of their safety. This requires an “Application for exemption from the consequences of an obstructing reason”, which can be filled up at the Department IV/5 of the Federal Ministry of Agriculture, Forestry, Environment and Water Management through the competent regional office.

- Yellow: construction activities are allowed under certain conditions (damage of objects is possible, but not high)
“Other areas threatened by torrents or avalanches, in which the permanent use for settlement or traffic purposes is strongly impaired as a result of these hazards.” (Excerpt from the “Ordinance by the Federal Minister of Agriculture and Forestry of 30 July 1976 on Hazard Zone Plans, Fed. Law Gazette No. 436/1976”).
Therefore, construction in yellow hazard zones is only possible subject to stipulations that are imposed within the scope of an individual expertise by the responsible regional office in the course of the construction approval procedure.
- Blue reservation areas: dedicated to implement forestry, biological or technical measures (e.g. protection dam)
Developments other than protection measures are not allowed.
- Violet reservation areas: areas that can be used as protection due to their natural properties, such as protection forests or natural retention basins
Developments other than reservation areas for flood zoning are not allowed.
- Brown: for development of such an area the building authority requires the expert opinion of a geologist or another specialist in soil mechanics.

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Acknowledgement

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3.3 FRANCE

(contributor: BRGM - CNRS)

Description of French RAM PPR

(extract of the RAMSOIL Project Deliverable; Malet, 2007).

Risk prevention plans (PPRN: Plan de Prévention des Risques Naturels), established by the law of February 2nd, 1995 imply a location of the vulnerable zones exposed to the hazard. The PPRN collects informative documents (a note of presentation, a localization map of the phenomena, a hazard map and some statutory documents (risk zoning map at a scale of 1:10,000 or at 1:5,000 for the urban zones, and a regulation).

Inventory of processes

The Risk Assessment Methodology RAM consists first in the elaboration of an informative map of the natural phenomena. It represents on a topographic map at 1:25,000, the observed and known phenomena inventoried from archives, aerial photographs and field work.

Hazard map

The hazard map is established by a forward-looking approach where areas where any phenomena have been observed can be classified in hazard zone. The map is constructed through the combination of predisposing factors. The susceptibility of the site to landslide is estimated by a qualitative approach and is considered maximal where all the unfavourable factors (slope, lithology ...) are present.

The risk mapping using the hazard map and the additional map of major asset is described in Section 4. Additional information is provided concerning the risk prevention at local and regional level.

In the following a brief description of the PPRN is presented.

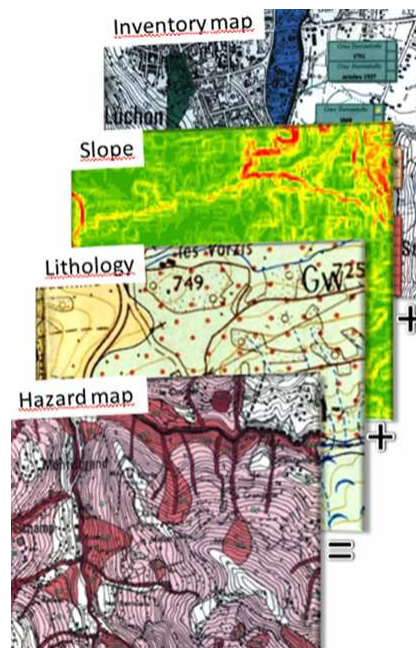


Figure 3-7. Schematic representation of the GIS workflow for the PPR methodology

- **Name of the document**

The PPRN (“Plans de Prévention des Risques Naturels” or natural risks prevention plans).

- **Purpose of the document**

Risk mapping: PPRN (Plan de Prévention des Risques Naturels; 1995) - Zoning of the areas at risk.

- **Users of the document**

Contractor: Ministry of Interior and Ministry of the Environment, Prefect, Mayor.

Project manager: The prefect and more specifically by local state administration at Department level. The ‘Instructor Service’ is one of the departmental service (DDE ‘Direction Départementale de l’Equipement’ & CETE ‘Centre d’Etudes Techniques de l’Equipement’, DDA ‘Direction Départementale de l’Agriculture’ & ONF-RTM ‘Office Nationale des Forêts – Service de Restauration des Terrains en Montagne), with the assistance of public (BRGM) or private technical and scientific companies.

Users: Municipalities, State organizations, Private companies...

- **Type of the documents**

The output documents constitute legal information. The risk map is used as statutory support in the decision of land zoning. It imposes limitations on the construction and the traffic in areas at risk.

- **Scale**

The scale of the official 'PPRN' document is 1:10,000. In some cases, maps at 1:5,000 scale are produced in densely populated areas or in mountain environments.

- **Type of hazards. Type and mechanisms of landslides**

The definition of the landslide mechanisms is not directly considered in the PPRN, and the differentiation in landslide types is not obligatory. In some cases, the inventory maps of PPRN differentiate broad landslide categories (rockfalls, landslides, debris flow), in some cases, the inventory maps do not give any indication. In general, the PPRN is more focusing on the spatial susceptibility and the (possible) extension of existent mass movements.

- **Basic documents required**

Topography, lithology, soil map, landslide inventory, land use and elements at risk (stake).

- **Methodology**

The general methodology is based on a Qualitative approach (expert analysis);

Data are collected and analyzed through various techniques: historical archives, field observations, remote sensing techniques, GIS... On the basis of these data and expert knowledge of the phenomenon/area, the expert prepares the maps.

- **Hazard matrix**

The 'PPRN' methodology is not constructed using a hazard matrix. The hazard map is established by a forward-looking approach in which areas where any phenomenon has been observed can be classified in hazard zone. The map is constructed through the combination of predisposing factors. The susceptibility of the site to landslide is estimated by a qualitative approach and is considered maximal where all the unfavourable factors (slope, lithology, ...) are present.

- **Hazard levels**

Four hazard levels are defined (low hazard, eg. A1; medium hazard, eg. A2; high hazard, eg. A3; very high or major hazard, eg. A4). The hazard levels are assessed through a ranking in terms of intensity.

The intensity is assessed qualitatively and indirectly through the estimation of (1) the potential damage that can be caused by the source of the danger or (2) the order of magnitude of the possible cost of mitigation for a reference event of return period of 100 years.

- **Legends**

Three zones are defined: Red zone, Blue zone and White zone.

- **Zoning**

Red zones can concern zones where the measures of prevention are impossible or too costly, so no construction will be authorized.

Blue zones can concern zones where the measures of prevention are possible; thus new construction are possible but under conditions.

White zones: no restrictions for any kind of buildings.

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3.4 ITALY

3.4.1 General legal framework

(contributor: UNISA)

In Italy at the beginning of the 20th century the so-called “hydrogeological hazards” (including floods and landslides) were indirectly accounted for in several national regulations devoted to the management of river network and hydraulic constructions (Royal Decree 523/1904) and to soil/forest protection in mountainous areas (Law 445/1908; Royal Decree 3267/1923). These regulations generally impose legal bindings and land-use limitations to specific areas or activities.

Following the 1966 severe flooding of Florence, Governmental Institutions became aware of the need of basin-scale land-planning in order to prevent further disasters through the management of the hydrogeological risk. This led to the enactment of Law 183/1989 aimed at “land protection, water resource reclaim, use and management of the water resources for the proper economical and social development, safeguard of the environmental issues”.

The Law establishes that the reference terrain unit is the “hydrographic basin” to which the contents of the same Law have to be applied. This allows overcoming the fragmentation and confusion related to land-planning using administrative limits. The Basin Authorities (Figure

3-8) are therefore the Institutions in charge of both programming and planning land policies through the so-called “Basin Plans”.

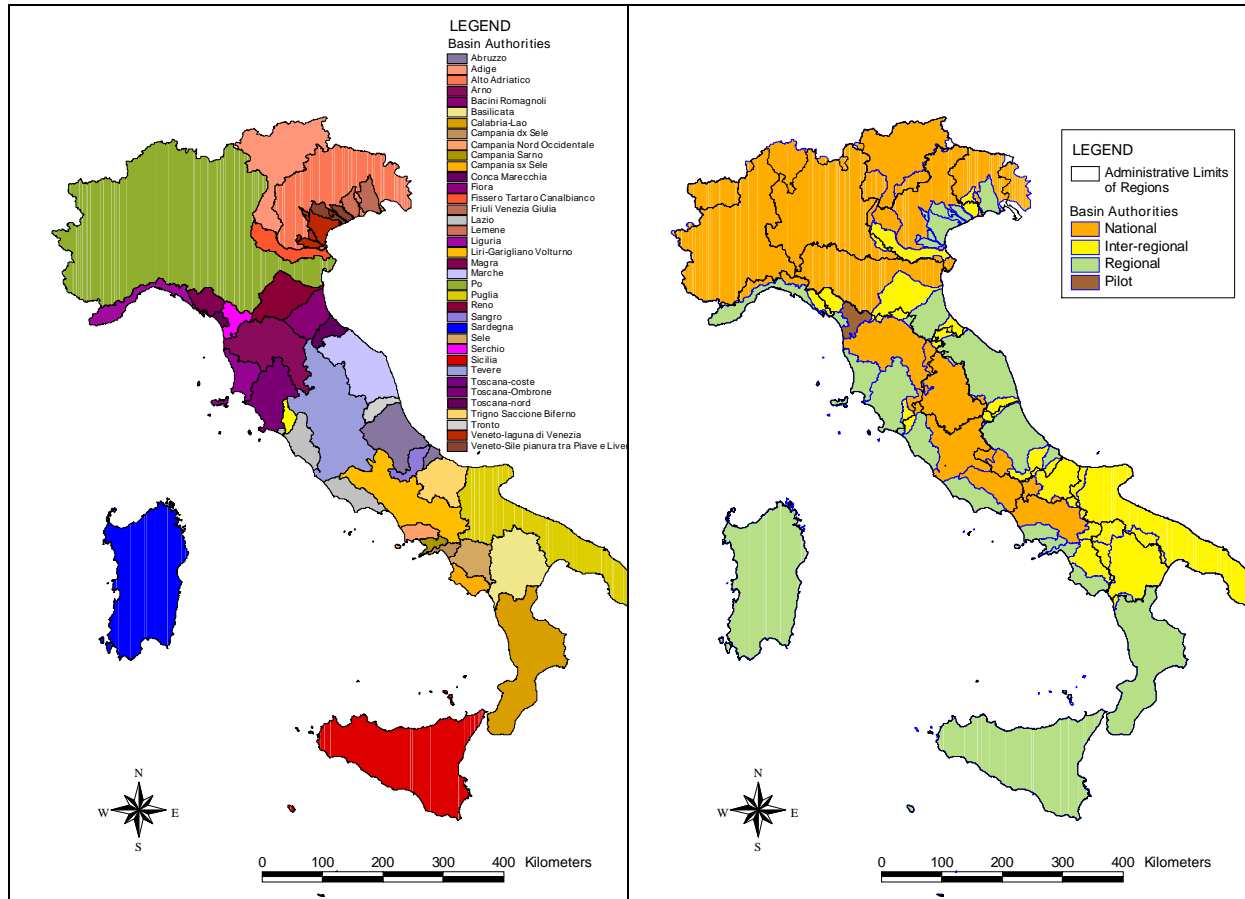


Figure 3-8.(a) Distribution of the Basin Authorities over the Italian territory; (b) Basin Authorities distinguished in National, Inter-regional, Regional (1 is Pilot)

Today, the Italian hydrographical basins are distinguished as: 11 national basins, supervised by 6 National Basin Authorities; 18 inter-regional basins, supervised by 13 Inter-regional Basin Authorities; 17 “Regional” basins; 1 “Pilot” basin (Figure 3-8).

The process leading to both flood and landslide hazard and risk zoning accelerated immediately after the occurrence, in 1998, of a natural disaster, involving some portions of the territory of the Campania region (Southern Italy). This disaster was originated by flow-like fast-moving landslides and caused victims and considerable economic damage (Cascini, 2005a). Owing to the huge consequences of the event, the Italian Government referred to the Scientific Community for the solution of several questions, such as the residual risk evaluation inside the towns threatened by the phenomena and the identification of other sites affected by an analogous risk in the Campania region (Cascini, 2002; Cascini, 2004; Cascini, 2005b). Thanks to the obtained results, a few months later the Central Government promulgated a Law (L. 267/1998) requiring the Basin Authorities to zone the hydrogeological risk using simple and rapid procedures.

Risk zoning – and, within the territories of some Basin Authorities, hazard zoning – was firstly obtained all over the Italian territory (301,401 km²) for the “most at risk” areas according to the Law 226/1999. Later on, within the so-called “Hydrogeological Setting Plans” Projects (Law 365/2000), hazard and risk zoning was updated according to criteria given by the Central Government (D.P.C.M. 29/09/98). To assess the risk levels, general instructions were furnished but no specific technical advice was suggested; this resulted in different procedures adopted by each Authority, as explained in the examples that follow.

The end-products of the Hydrogeological Setting Plans are often available on the websites of the Basin Authorities; in most cases, they are available on the “National Cartographic Web Portal” (<http://www.pcn.minambiente.it/mdSearch/>). In the same Web Portal all the data acquired by the “Extraordinary Plan for Environmental Remote Sensing” (Law 179/2002) will be available in order to support all the decision-based processes dealing with the hydrogeological risk.

Taking into account that hazard and risk zoning will be probably updated in the next future, since the Basin Authorities will be reorganised in 8 District Authorities covering the whole national territory (Legislative Decree 152/2006, according to the E.U. 2000/60 Directive about water resources management), in this Section examples of current landslide hazard assessment practices are reported for some Basin Authorities.

3.4.2 Southern Italy

For the hazard assessment in Southern Italy, here are reported two examples: the procedures that are followed by the National Basin Authority of Liri-Garigliano and Volturno Rivers and the one by Regional Basin Authority of the “North-western” Basin of Campania Region.

3.4.2.1 National Basin Authority of Liri-Garigliano and Volturno Rivers

(contributor: UNISA)

The territory of the National Basin Authority of Liri-Garigliano and Volturno rivers (NBA LGV) extends for about 12,000 km² in central-southern Italy along the Apennine chain where several predisposing factors (lithology, tectonics, river network, etc.) can be recognised for mass slope movements. It is composed of two main sub-territories corresponding to the Liri-Garigliano and the Volturno river basins and it involves – partially or totally – the territories of 5 Regions (Abruzzo, Campania, Lazio, Molise and Puglia), 11 Provinces and 450 Municipalities (Figure 3-9).

- **Name of the document**

Hydrogeological Setting Plan – Landslide Risk (PsAI-Rf) – Approved by the Italian Government via the D.P.C.M. dated December 12, 2006.

- **Purpose of the document**

The PsAI-Rf, via its rules, is aimed at guarantying an adequate level of safety to the whole territory of Liri-Garigliano and Volturno River Basins with respect to landslides. The PsAI-Rf

is the cognitive, prescriptive, technical-operative tool by which the activities as well as the land-use codes related to the hydrogeological setting of the hydrographical basins are planned. It includes landslide risk zoning, restriction codes and the areas to be safeguarded and related measures.

Risks related to other natural hazards, such as floods, are addressed in separate documents.



Figure 3-9. Basins of Liri Garigliano and Volturno rivers.

- **Users of the document**

The users of the documents are local Authorities working on land management and/or urban planning.

- **Type of document**

The PsAI-Rf consists on four different types of documents, namely:

General Report. After a description of the Liri-Garigliano and Volturno river basin territories – in terms of their geology, geomorphology and land-use – the procedures adopted for landslide hazard and risk analysis and zoning are explained. Finally, information about the used Territorial Information System and the contents of the restriction codes as well as the Plan development are provided.

Cartography. The PsAI-Rf includes the following 13 maps at 1:25,000 scale:

- Map of the instability phenomena reported or furnished by Local Authorities
- Geological-Structural Map
- Geomorphological Map
- Soil cover Map
- Landslide Inventory Map
- Map of the Hydrogeological Binding and the National and Regional Parks (L. 3267/23, L. 394/96)
- Map of the Environmental and the Cultural Bindings (L. 1089/39, L. 1497/39, L. 431/85)
- Map of the Environmental detractors and of the Infrastructures
- Map of the potential damage and the highly vulnerable facilities
- Map of the damage reported by local Authorities

- Map of the landslide scenarios based on the maximum expected intensity
- Landslide risk scenarios Map

Restriction codes and safeguarding measures. This document includes the codes to be followed for a correct land-use as well as the rules to be applied in areas at landslide risk. Contents dealing with the so-called “Study of Hydrogeological Compatibility” are also described.

The program of risk mitigation. In this documents the activities to be carried out – immediately, in the short/medium/long term - in order to mitigate the landslide risk are summarised. These activities includes: territorial surveys, maintenance, in-situ investigations, instrumental monitoring; control works.

The information accessible on-line (<http://www2.autoritadibacino.it/>) deals with: *i*) the general report; *ii*) the restriction codes and safeguarding measures; *iii*) the program of risk mitigation. As for the cartography, it can be requested by filling a form.

- **Scale**

The adopted scale of analysis and zoning was 1:25,000.

- **Type and mechanisms of landslides**

The landslides are essentially mapped using Varnes’ classification system (1978), creep evidence, a simplified version of the landslide’s stages of movement given by Leroueil et al. (1996), state of activity (active – including active, reactivated and suspended phenomena according to Cruden and Varnes, 1996 - or quiescent, i.e. dormant phenomena). Types and mechanisms of mapped landslides are: falls and topples, flowslides, debris flows, fast earth-flows in marl-clayey soils, translational slides, rotational slides, earth flows, superficial and deep creeps, lateral spreads, deep-seated gravitational movements.

- **Basic documents required**

Detailed and territory-wide base maps (geology, geomorphology and soil cover) were preliminarily compiled by using basic methods. Subsequently, with the aid of such maps as well as of aerial photo interpretation and available information, 30,000 landslides together with their surrounding areas and zones potentially affected by fast slope movements were mapped.

- **Methodology**

Landslide susceptibility maps were obtained, at a preliminary level of zoning, by adopting velocity estimates of the active or quiescent existing landslides, as well as of the source and propagation areas potentially affected by first-failure phenomena, using a simplified version of the Cruden and Varnes’ criterion (1996). In particular, the landslide intensity I (i.e., the maximum expected velocity) was associated with each of the mapped landslide according to a nominal scale, as detailed in the Table 3-5.

Table 3-5. Intensity classes of the landslides

I	Landslide type
High	Falls and topples, Flowslides, Debris Flows, Fast earth-flows in marl-clayey soils
Medium	Translational slides, Rotational slides, Earth flows
Low	Superficial and deep creeps, lateral spreads, deep-seated gravitational movements

Finally, on the basis of landslides activity, hazard maps were produced by using the nominal scale synthesized in the Table 3-6.

Table 3-6. Hazard nominal scale

I	Landslide activity	Hazard
High	active	High
	quiescent	
Medium	active	High
	quiescent	Medium
Low	active	High
	quiescent	Medium

- **Hazard matrix**

The hazard matrix was defined qualitatively based on two parameters, namely the intensity and the state of activity of the landslide (Table 3-5 and Table 3-6).

- **Hazard levels**

As already specified, hazard levels were defined for different landslide types according to their intensity and state of activity.

- **Legends**

The legend of the “landslide inventory map” is shown in the Figure 3-10.

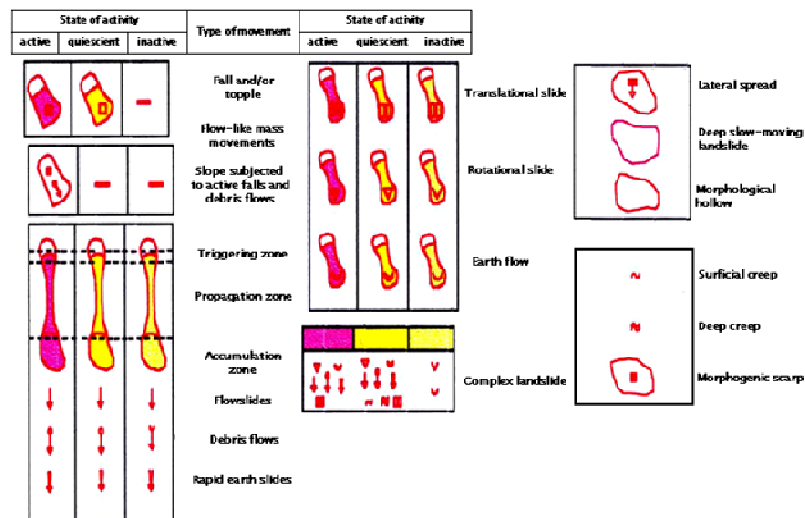


Figure 3-10. Legend used for the landslide inventory map at the river basins of Liri-Garigliano and Volturno

Further legends can be recovered in Cascini (2005a) and Cascini et al. (2005).

• **Zoning recommendations/restrictions**

Referring to the PsAI-Rf activities carried out by the National Basin Authority of “Liri-Garigliano and Volturno” rivers, not urbanized areas affected by existing or potential landslides are also mapped and classified, although that was not requested by the Italian Law (L. 365/2000). According to the risk levels described in the D.P.C.M. 29/09/98, these areas are considered worthy of attention on the basis of Cruden and Varnes’ (1996) suggestions about landslides’ velocity classes.

Particularly, the attention level is considered to be:

- High (A4), if the area is inside the source, transit and invasion zone of extremely rapid, very rapid or rapid landslides;
- Medium-High (A3), if it is inside a moderate or slow landslide, both active or quiescent, potentially triggered by an earthquake;
- Medium (A2), if the moderate or slow landslide is inside a not seismic area;
- Low (A1), if the area is involved in a very slow or extremely slow landslide.

Starting from the results of the landslide hazard zoning, the document entitled “Restriction codes and safeguarding measures” establishes, among other things, the policies to be followed within attention areas. These policies are summarised in the Section 4.2.2.1.

• **Improvement of landslide susceptibility zoning at 1:5,000 scale**

Within the so-called “Pilot Project” the NBA LGV promotes susceptibility analyses of fast-moving landslides at 1:5,000 scale to improve the Hazard assessment developed at the 1:25,000 scale essentially on the basis of geological and geomorphological criteria.

The adopted procedure is based on the “Design event approach” that allows the identification of the worst expected sliding scenario coming from the application of engineering physically-

based models with reference either to the mobilised volumes in the source areas or to the run-out distance.

As for the estimation of the mobilised volumes, they are computed with the aid of the so-called “distributed physically-based models” (TRIGRS, SHALSTAB) while, run-out distances are estimated via numerical models (FLO-2D, DAN, GEOFLOW, RUSH 3D).

The above procedure allows in many cases the significant reduction of the propagation areas previously defined only on the basis of heuristic criteria. An example of the effectiveness of the selected procedure for reducing the areas classified at “very high risk” (R4) within the PsAI-Rf project is furnished in Figure 3-11.

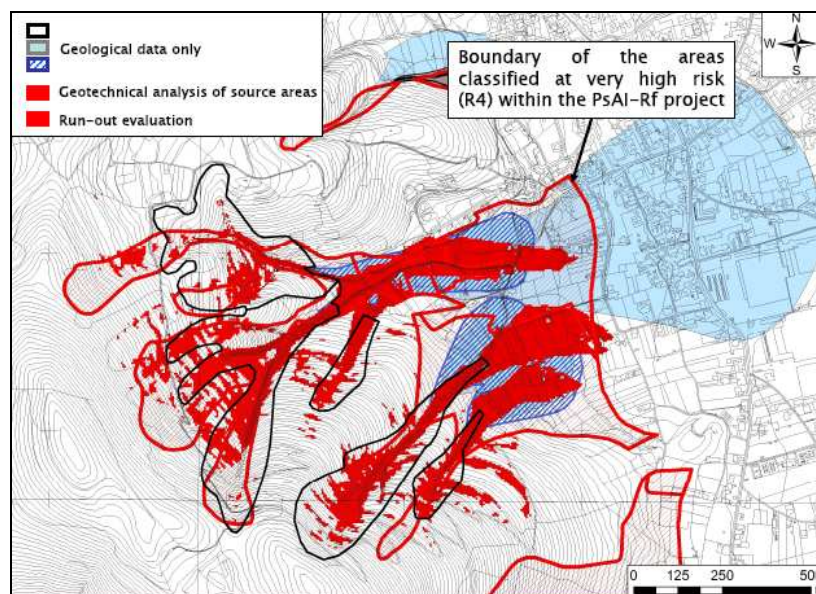


Figure 3-11. Improvement at 1:5.000 scale of the landslide susceptibility zoning developed, at 1:25.000 scale, within the PsAI-Rf.

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Legal documents:

Italian Law n. 183 of 18 May 1989 dealing with “Norme per il riassetto organizzativo e funzionale della difesa del suolo”;

Italian Law n. 267 of 3 August 1998 dealing with “Conversione in legge, con modificazioni, del decreto-legge 11 giugno 1998, n. 180, recante misure urgenti per la prevenzione del rischio idrogeologico ed a favore delle zone colpite da disastri franosi nella regione Campania”;

Italian Law n. 226 of 13 July 1999 dealing with “Conversione in legge, con modificazioni, del decreto-legge 13 luglio 1999, n. 132, recante interventi urgenti in materia di protezione civile”;

D.P.C.M. 29/09/98 (Decreto del Presidente del Consiglio dei Ministri 29 settembre 1998). Atto di indirizzo e coordinamento per l'individuazione dei criteri relativi agli adempimenti di cui all'art. 1, commi 1 e 2, del D.L. 11 giugno 1998, n. 180 (published on 5 January 1999).

Italian Law n. 365 of 11 December 2000 dealing with “Conversione in legge, con modificazioni, del decreto legge 12 ottobre 2000, n. 279, recante interventi urgenti per le aree a rischio idrogeologico molto elevato ed

in materia di protezione civile nonché a favore delle zone della Regione Calabria danneggiate dalle calamità idrogeologiche di settembre ed ottobre 2000.

Codes:

Decree of the Italian Public Works Department of 11 March 1988 dealing with “Norme tecniche riguardanti le indagini sui terreni e sulle rocce, la stabilità dei pendii naturali e delle scarpate, i criteri generali e le prescrizioni per la progettazione, l'esecuzione e il collaudo delle opere di sostegno delle terre e delle opere di fondazione”.

Scientific publications:

Cascini L. 2002. Il rischio da frana in aree urbane dell'Appennino Centro-meridionale. Proceedings of the XXI Italian Geotechnical Congress. L'Aquila, 11-13 September. Vol. 1, pp. 127-134, Pàtron Editore, Bologna. ISBN 88-555-2663-4 (in Italian)

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Cascini L. 2005a. Risk assessment of fast landslide. From theory to practice. General Report. Proceedings of the International Conference on “Fast Slope Movements – Prediction and Prevention for Risk Mitigation”. Picarelli L. (ed.), Vol. 2, pp. 33-52. Pàtron Editore, Bologna. ISBN: 88-555-2833-5

Cascini L. 2005b. La gestione scientifica dell'emergenza idrogeologica del maggio 1998 nella Regione Campania. Rubbettino Editore, 278 pp. ISBN: 88-498-0964-6 (in Italian)

Cascini L., Bonnard Ch., Corominas J., Jibson R., Montero-Olarte J. 2005. Landslide hazard and risk zoning for urban planning and development. – State of the Art report. Proceedings of the International Conference on Landslide Risk Management. Hungr O., Fell R., Couture R. & Eberhardt E. (eds.), pp. 199-235, A.A. Balkema Publishers. ISBN: 041538043X

3.4.2.2 Regional Basin Authority of the “North-western” Basin of Campania Region

(contributor: AMRA)

In the Hydrogeological Setting Plan (PAI) drafted by the North-western (NW) Regional Basin Authority of Campania (southern Italy), landslide hazard (2002) has been assessed at a large scale (1:5.000) by means of an integrated method, partly based on a statistical (i.e. quantitative) approach (Calcaterra et al., 2003). A similar approach (Di Crescenzo et al., 2008; Andriola et al., 2010) has been applied to the Regional Basin Authority of Sarno river in the process of PAI revisiting (2009-2010), too.

The methodology and results here illustrated are related to a variety of geological settings characterizing about 800 km² of regional territory (62 municipalities) where about 2 million people live (Figure 3-12).

The NW Campania Basin Authority manages a territory where three main geological settings are present:

- a) the Phlegraean Fields, including Naples and Phlegraean islands (Ischia and Procida), characterized by Late Pleistocene-Holocene volcanoclastic products;
- b) the Somma-Vesuvius area, where mainly Holocene lava and pyroclastic products crop out;
- c) the Mesozoic carbonate Apennine mantled by pyroclastic fall deposits, predominantly ejected by Somma-Vesuvius from 17,000 yrs b.p. to date.

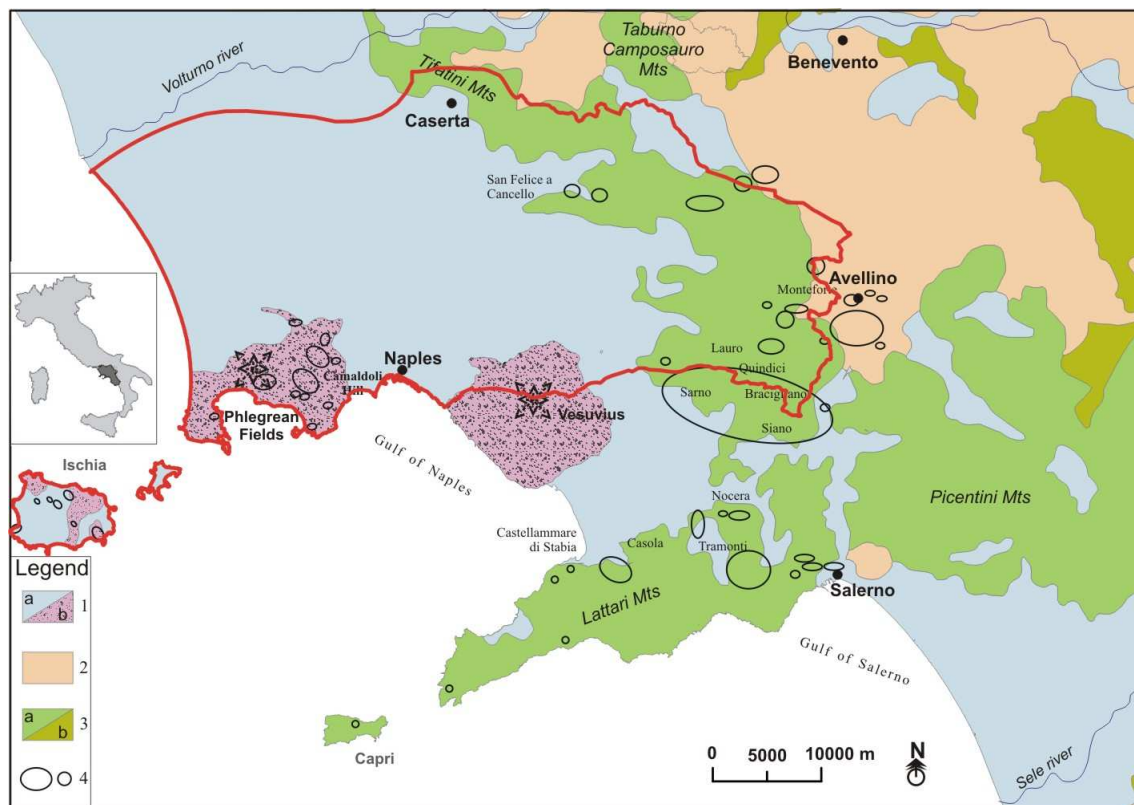


Figure 3-12. Geological sketch map and main localities cited in the text (the red line is the NW Authority Basin limit) Legend: 1) quaternary deposits: a) Pyroclastic air-fall and alluvial deposits; b) Lavas, pyroclastic flows and tuffs; 2) sin orogenic terrigenous deposits (Miocene-lower Pleistocene); 3) pre orogenic deposits (Mesozoic-Tertiary) of carbonatic platform (a) and of basins (b); 4) Flow-type landslide or group of flow-type landslides.

• Methodology

In the methodology used to produce Landslide Risk Maps by NW Campania Basin Authority, the “hazard” component is the one most closely linked to geological and geomorphological features. This component is expressed as susceptibility or relative hazard (prediction of the location, typology, intensity and evolution of the landslide event – Hartlen and Viberg, 1988). Susceptibility rather than absolute hazard was privileged in view of the prevailing type of landslides (flow-type landslides, falls), which evidence is easily obliterated due to several factors (rapid growth of vegetation, often limited dimensions, man-made actions), thus hampering the reconstruction of historical landslide events and estimation of recurrence intervals.

The adopted procedure allowed to estimate the landslide relative hazard within the study area, i.e. the likelihood of occurrence of mass movements for different areas on the map, without giving exact values and, above all, without predicting their temporal occurrence. Two “intermediate” predictive maps, produced on the basis of these assumptions, aim to defining the overall landslide susceptibility: the Landslide Susceptibility Map and Landslide Runout Map.

Landslide Susceptibility Map

The Landslide Susceptibility Map for flow-type landslides in the NW Campania Basin Authority area derived from the work of the Italian Geological Survey following the 5 May 1998 event in Campania (Amanti et al., 1998) and was adapted to the different geological and geomorphological contexts using 1:5000 scale topographic maps.

The method is based on verifying the landslide occurrence and frequency with respect to some factors which may play an important role in triggering landslides (Figure 3-13).

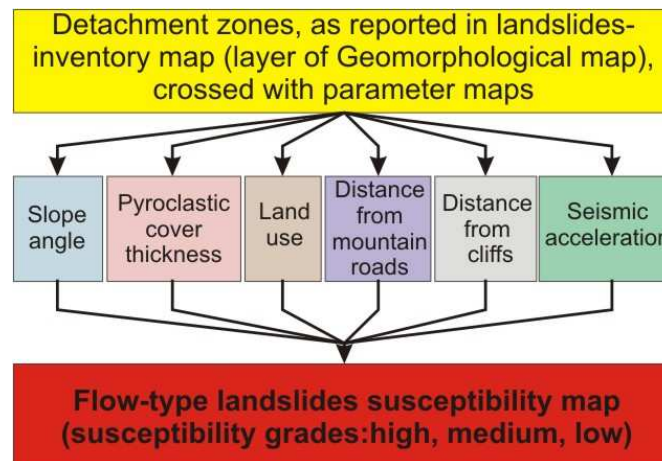


Figure 3-13. General procedure adopted for the Landslides susceptibility Map

In the formula proposed by Amanti et al. (1998), the following parameters were considered of significance:

$$I = [S (1+T+D)] \times L \times B$$

where I = susceptibility index; S slope angle; T = thickness of pyroclastic deposits; D distance to streams; L = land use; B = basin order.

The parameters S, T e D are expressed as percent frequency and probability, whereas L and B represent aggravating factors (therefore greater or equal to one).

To determine the validity of this formula in the area managed by the Basin Authority all the basic geological and geomorphologic data and maps were firstly acquired: geological, geomorphologic, thickness of pyroclastic cover, landslide inventory, slope gradient and land use. Secondly, preliminary sample areas were identified for which a large amount of highly detailed information was available (Avella ridge and Quindici - Lauro area, as concerns the carbonate Apennine; Camaldoli hill, Naples and northern slope of Mt. Epomeo, Ischia island in the Phlegraean district). The method used to define the Susceptibility Index (I) involved:

- compilation of a Slope Map using a DTM;
- cross-correlation between the frequency of detachment areas and slope gradient (S), thickness of pyroclastic cover (T), distance to tracks/roads (D) and land use (L), and construction of related graphs.

After this preliminary test, considered that a few factors were sometimes found to be non influential from a statistical point of view, the following equations were developed using a GIS:

$$I = [S (1+T+D)] \times L - \text{Carbonate ridges, where } D = \text{distance to man made tracks and cuts); (a)}$$

- $I = [S(1+T)]$ - Vesuvius and Phlegraean areas; (b)
 $I = S$ - Ischia island. (c)

As an example, the frequency distributions of detachment zones in the Quindici - Lauro area with respect to the factors considered in (b) is shown in Figure 3-14.

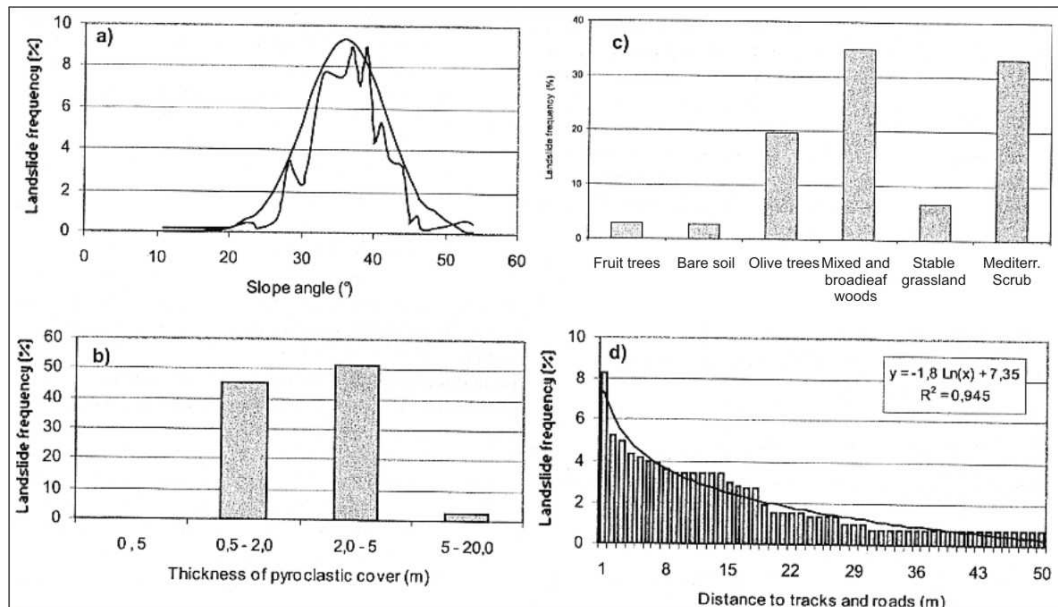


Figure 3-14. Frequency distributions of landslide detachment zones in the Quindici-Lauro area, with respect to the factors considered in equation (2). In a) the best-fit curve of the slope angle factor (S) is also reported

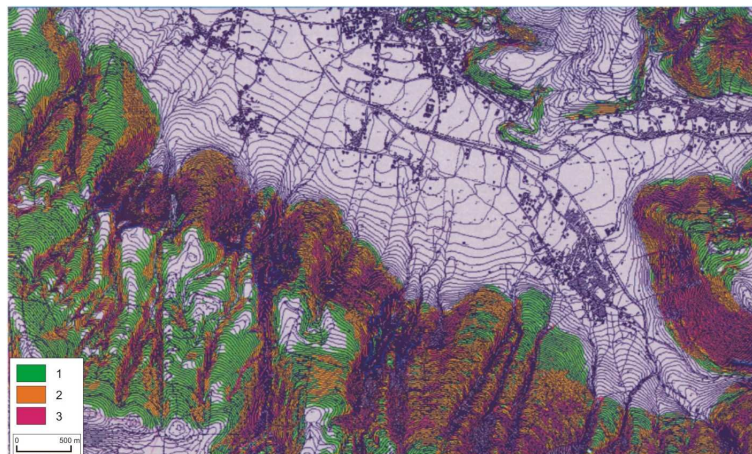


Figure 3-15. Landslide Susceptibility Map of the Quindici-Lauro area.
 Legend: 1) Low susceptibility; 2) medium susceptibility; 3) High susceptibility

The final steps of the described method entailed the definition of three classes (High, Medium and Low) of the susceptibility index (I) on the basis of S, T and L values (Figure 3-15). S was considered equal to either $\mu \pm \sigma$ or $\mu \pm 2\sigma$ (boundary from low to medium susceptibility) for the various settings and equal to $\mu \pm \sigma$ (medium to high susceptibility) in all three

contexts, with μ = mean value and σ = standard deviation; minimum T and maximum E values were assumed.

Landslide Runout Map

The invasion susceptibility of landslides such as those typically occurring in the study area (Figure 3-16) has been identified with the definition of the runout.



Figure 3-16. Aerial view of the flow-type landslides which occurred at Quindici in may 1998. The landslides covered long distances reached up to 3500-4000 m from the crown zone

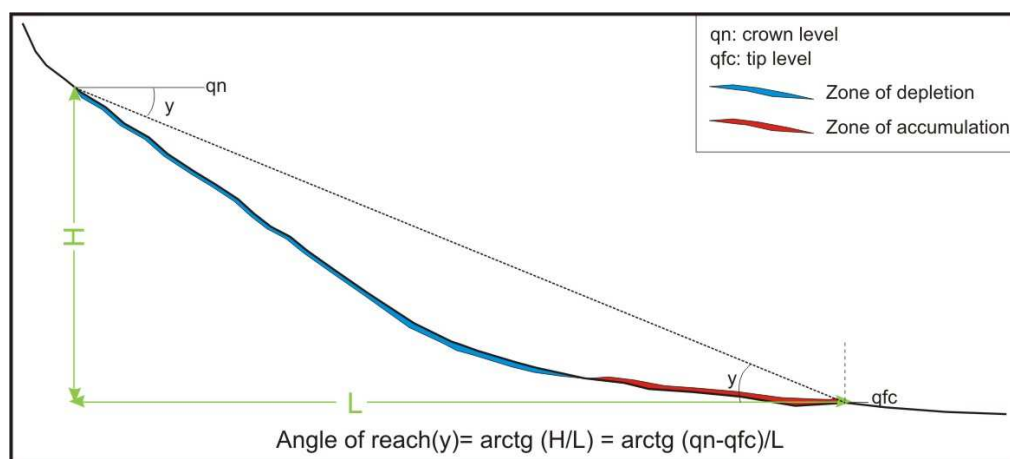


Figure 3-17. Sketch profile showing the basic parameters of the angle of reach (y)

The potential path of falls and flow-type landslides can be “simulated” using the method of energy lines (Heim, 1932; Shreve 1968; Scheidegger, 1973; Hsù, 1975; Corominas, 1996). In the absence of specific, reliable geotechnical and hydraulic data, the hazard of rapid landslides such as falls and debris-earth flows can be estimated on a geomorphologic basis, by determining some morphometric parameters (Figure 3-17).

The procedure involved the definition of possibly different points of maximum reach along the same profile, depending on the position of the corresponding potential detachment areas, in turn characterized by different susceptibility grades (Figure 3-19). Finally, the points on slope profiles coinciding with maximum runout distance were joined, thus defining preliminary areas susceptible to be invaded by slide-flows and/or falls. These results were then integrated with elements from the Geomorphological Map, such as the real extension of previous landslides, debris fans, talus deposits, significant man-made features (quarries, deposition basins, road embankments), etc. The preliminary areas were consequently redefined in order to create the final version of the Relative Hazard Map where three hazard categories are shown: P3 = High, P2 = Medium, P1 = Low (Figure 3-20); the latter are obtained by integrating both Landslide Susceptibility and Landslide Runout Maps.

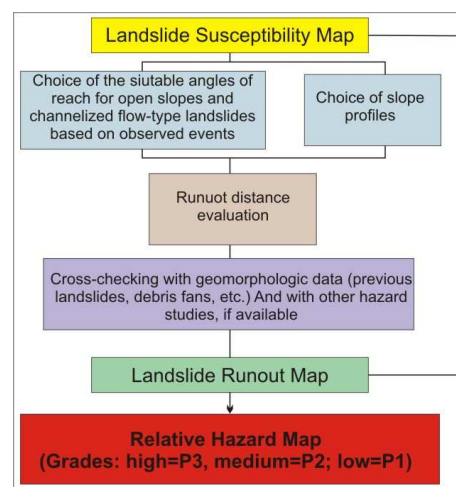


Figure 3-18. Procedure followed for the Landslide Runout map and the Relative hazard Map

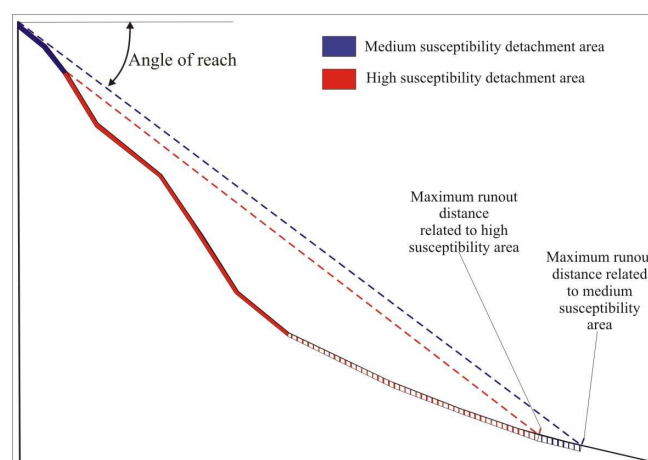


Figure 3-19. Scheme adopted for the evaluation of the runout distance

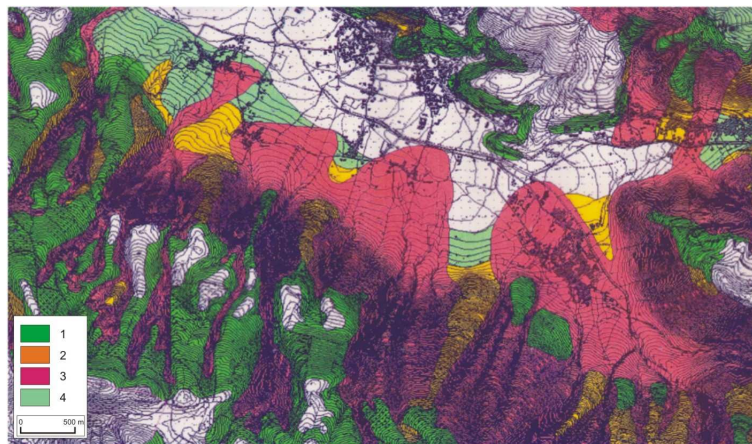


Figure 3-20. Landslide relative Hazard Map of the Quindici–Lauro area. Legend: 1) Low relative hazard (P1); 2) Medium relative hazard (P2); 3) high relative hazard (P3); 4) Area susceptible to be invaded by landslide whose classification requires more detailed studies.

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3.4.3 Central Italy

An example of the hazard assessment in central Italy is the procedure that is followed by the Arno River Basin Authority, which is described in the following.

3.4.3.1 Basin Authority of Arno River

(contributor: UNIFI)

A. This section is devoted to the description of the PAI prepared by the Arno River Basin Authority. Furthermore is reported a joint project carried out by the Arno River Basin Authority and the Department of Earth Sciences in which a quantitative risk assessment is done. The results of this project will be adopted by the Arno River Basin Authority as an official methodology.

The Arno River basin is located in the Northern Apennines, Italy, with an extension of 9116 km². This orogen is a complex thrust-belt system made up by the juxtaposition of several tectonic units, built up during the Tertiary under a compressive regime that was followed by extensional tectonics from the Upper Tortonian (Catani et al., 2005). In the reliefs on the eastern sector of the basin the outcropping rocks belong mainly to Oligocene-Miocene arenaceous turbiditic sequences and Jurassic-Eocene calcareous and argillaceous oceanic deposits. In the western sector the outcropping terrains consisting mainly of Miocene-Pliocene marine and alluvial deposits. The plain areas are filled with alluvial quaternary deposits in the upper basin and marine deposits towards the delta. The study area is strongly subjected to mass movements that have accumulated a large number of recorded cases and a huge total damage, both in properties and life losses.

- **Name of the document**

Hydrogeological Setting Plan (Piano di Assetto Idrogeologico, PAI) for the Arno River

- **Purpose of the document**

The PAI prepared by the Arno River Basin Authority has the general objective to define a framework for land planning in order to reduce the risk, caused by landslides and floods, associated to the elements at risk. This is achieved through the set up of a comprehensive cognitive frame, structural and non structural prevention and mitigation measures, policies and best practices related to risk management and governance for the safety of the elements at risk. The crucial point is the mapping of the landslide and flood hazard areas and the identification of the elements at risk.

- **Users of the document**

The users of the documents are administrative offices that work on land and urban planning.

- **Type of the document**

The PAI is organized into three different parts, which are:

Report: It contains a general description of the Arno basin (geology, geomorphology, drainage system, land use) and the description of the methodology used for hazard mapping related to landslides and floods. Eventually the plan of the mitigation measures and the related financial needs are defined.

Cartography: The PAI is equipped with maps, which are:

- Flood hazard map (1:25,000)
- Flood hazard map (1:10,000)
- Map of the elements at risk located inside the floodplain
- Landslide susceptibility map (1:25,000)
- Landslide inventory map (1:10,000)
- Map of the elements at risk located inside landslides

Policies: This document contains rules, limitations and recommendations defined for different degree of hazard. These regulations have to be adopted by all the public entities located inside the Arno River Basin such regions, provinces and municipalities, which are in charge of land and urban planning. The regulations are legally binding and have to be followed by the public administrations.

- **Scale**

The landslide hazard mapping in the Arno river basin has been carried out at two different scales and with two different approaches:

- Medium scale (1:25,000): A susceptibility mapping is carried out based on a qualitative approach through the analysis of preparatory factors.
- Large scale (1:10,000): A landslide inventory is realized where landslides are classified on the basis of state of activity.

- **Type of hazards. Type and mechanisms of landslides**

Not specified.

- **Basic documents required**

Documents that provide information on geology, lithology, hydrogeology, land use and slope degree and mapped landslides. The landslide inventory has been realized gathering information on landslides from different documents realized by public entities such as municipalities and provinces.

- **Methodology**

In the following, a description of the method used by the Arno River Basin Authority for landslide hazard mapping and assessment is described.

In the following, a description of the method used by the Arno River Basin Authority for landslide hazard mapping and assessment is described. The final hazard map is the result of the combination of two different approaches; a landslide susceptibility assessment at medium scale and a landslide inventory map at large scale.

At the medium scale a susceptibility assessment has been carried out by means of a qualitative approach. In particular, the hazardous areas have been defined on the basis of preparatory factors such as geology, lithology, hydrogeology, land-use and slope degree and according to the information of mapped landslides.

The methodology adopted, based on expert judgment of the operators, is used to estimate landslide potential from data on preparatory variables. Field survey and photo-interpretation have been randomly carried out all over the basin in order to validate the final susceptibility map. No information on the recurrence time and the temporal prediction of landslides is added.

The territory of the basin has been subdivided into three classes of susceptibility, from PF3 with the higher level of hazard to PF1 with the lower level.

- PF3: Unstable areas where a combination of unfavorable preparatory factors causes general slope instability.
- PF2: Stable areas with a combination of preparatory factors which may lead to slope instability.
- PF1: Stable areas with a favorable combination of preparatory factors.

Figure 3-21 a detail of the susceptibility map is reported. Inside each classes of susceptibility, rules and best practices are defined in order to manage and reduce the risk associated to the elements at risk. In particular, in the policies document, the activities allowed and not allowed for each class of susceptibility are reported and especially the construction or enlargement of buildings and infrastructures.

A landslide inventory at the scale of 1:10,000 has been realized. The number of mapped mass movements is 6073 and the 19% of mapped areas are in the class PF2, 62% in the class PF3 and 19% in the class PF4.

According to the state of activity, structural measures for landslide mitigation are defined in order to reduce the hazard level. The PAI defines the priority of the interventions and stabilization measures and the financial needs related. In particular among all mapped landslides 115 have been considered the most risky. For these landslides, both the runout and retrogressive areas, have been identified. Afterwards an estimation of the cost of the elements at risk located inside the risky areas has been carried out. In Figure 3-22 a detail of inventory map of the PAI is reported.

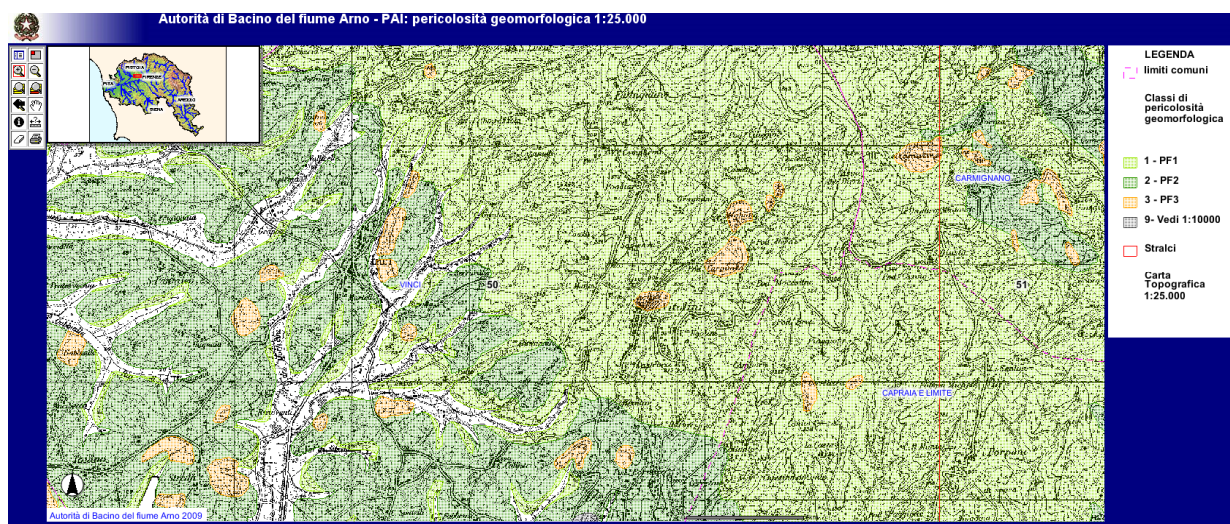


Figure 3-21. A detail of the landslide susceptibility map reported into the PAI : PF3 is the highest level of susceptibility while PF1 is the lowest level. (taken from the online database of the Arno River Basin Authority (<http://www.adbarno.it/cont/testo.php?id=107>)).

- **Hazard matrix**

No hazard matrix is used. The hazard assessment is based on the state of activity (active, dormant, inactive).

- **Hazard level**

Combining the susceptibility map and landslide inventory map the territory of the basin has been subdivided into four classes of hazard, from PF4 with the higher level of hazard to PF1 with the lower level.

•PF4: Active landslides

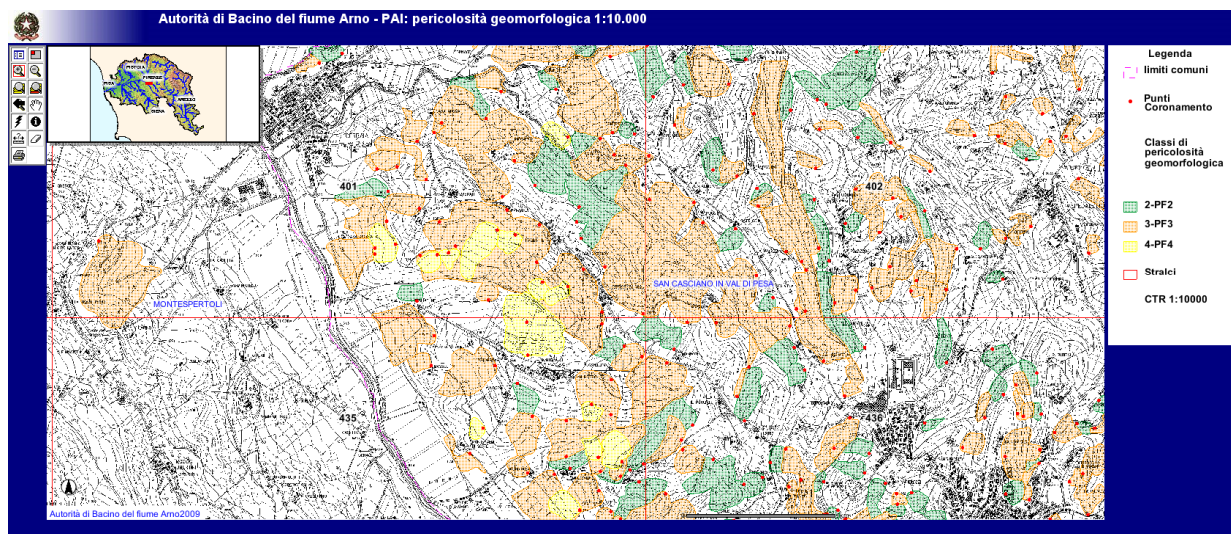


Figure 3-22. A detail of the landslide inventory map reported into the PAI. PF 2 are inactive landslides, PF3 are dormant landslides, PF 4 are the active landslides. (taken from the online database of the Arno River Basin Authority (<http://www.adbarno.it/cont/testo.php?id=107>).

- PF3: Unstable areas where a combination of unfavorable preparatory factors causes general slope instability and dormant landslides
- PF2: Stable areas with a combination of preparatory factors which may lead to slope instability and inactive stabilized landslides.
- PF1: Stable areas with a favorable combination of preparatory factors.

• **Legends**

- Legend used for the landslide susceptibility map (PF3 is the highest level of susceptibility while PF1 is the lowest level):

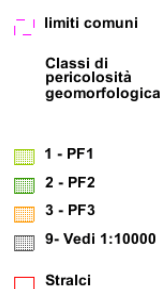


Figure 3-23. Legend used for the landslide susceptibility map in the Arno River Basin

- Legend used for the landslide inventory map (PF 2 are inactive landslides, PF3 are dormant landslides, PF 4 are the active landslides):



Figure 3-24. Legend used for the landslide inventory map in the Arno River Basin

• Zoning, recommendations-restrictions

For each level of hazard the activities allowed and not allowed are defined through a set of recommendations and restrictions. In particular:

PF4: In this hazard class, which represent the highest level of hazard and is constituted by active landslides the constructions or enlargements of new buildings and infrastructures are forbidden with some exceptions regarding interventions on the existing buildings, which may reduce their vulnerability, or concerning public works referring to services which can not be dislocated. Landslide consolidation works are allowed as well as ground investigations and installation of monitoring systems finalized to study of the landslide behaviour for the set up of appropriate mitigation measures.

PF3: In this hazard class the enlargements and small modifications of existing buildings are allowed if preceded by consolidation works, which reduce the general level of hazard.

PF2/PF1: In this class construction of new buildings is allowed provided that the new constructions don't change the geomorphological and geological conditions of the area causing a worsening of the stability conditions.

Refinement of the PAI

B. The PAI described in paragraph A has some weak points, which are:

- The susceptibility assessment has been carried out on a qualitative way and it misses a real evaluation of the preparatory factors. Furthermore the hazard classification has been realized on the basis of the expert judgment of the operator.
- The landslide inventory map has been realized gathering information from former landslide inventories and it lacks standardization both of procedures and classification nomenclature.

For this reason a project between the Arno River Basin Authority and the Department of Earth Sciences of the University of Firenze has been carried out in order to realize a landslide inventory at the basin scale by means of conventional and non- conventional methods and in order to perform a landslide susceptibility evaluation through a statistical approach.

The landslide inventory of the Arno river basin, carried out between 2003 and 2005, counts more than 27,500 events. The inventory has been organized following the approach proposed by Soeters and van Westen (1996) which consists in i) Acquisition of literature and ancillary

data such as existent inventories, ii) mapping from aerial photographs at 1:13,000 and 1:33,000 scale (years from 1993 to 2000), iii) field survey and validation, which represented a key source especially for assessment of state of activity and validation of hazard. The inventory was then updated with the PSI (Persistent Scatterers Interferometry) technique, which allowed to redefine the state of activity and the perimeter of the former landslides, and detect new movements (Farina et al. 2006).

For each landslide, information regarding the typology, state of activity, perimeter and area has been recorded. The classification adopted is the one of Cruden & Varnes (1996) both for the typology and the state of activity.

Statistics on landslide types show that the most represented surface processes are slides (74.8%) and solifluctions (17.4%), followed by shallow landslides (6,6%) and flows (4.5%). Regarding the state of activity 60% of the phenomena are in a dormant state, 38% in an active state and just 2% are in inactive, stabilized state. The single landslide surface area ranges from 100 m² to 5x10⁶ m².

The method adopted for the susceptibility analysis has been the setting up of suitable statistical estimators defined with the help of a set of artificial neural networks (ANN). Neural networks were chosen because they require loose hypotheses on the variable distribution and allow for the use of mixed-type parameters (e.g. categorical and cardinal units) (Ermini et al. 2005; Gomez and Kavzoglu 2005). The computation was carried out through a discrete pixel basis analysis followed by the definition of unique condition units (Bonham-Carter 1994; Chung et al. 1995) for the application of statistical analysis within a GIS environment.

On the basis of the most common landslides in the Arno river basin and the results of the univariate statistical analysis five preparatory factors were selected: slope angle, lithology, profile curvature, land cover and upslope contributing area. All the morphometrical parameters have been derived from a DTM of the Arno basin, produced by the cartographic service of the Tuscany Region Administration and released in 2002, with a resolution of 10 m × 10 m.

The output of the model has been classified in order to define four levels of susceptibility, from S0 with the lowest level of susceptibility to the S3 with highest level of susceptibility.

The hazard map based on this susceptibility map is described in the following:

- **Name of the document**

Hazard map of the Arno river basin

- **Purpose of the document**

To refine the hazard map provided by the PAI.

- **Users of the document**

The Arno River Basin Authority.

- **Type of the document**

The methodology described will be adopted as an official procedure for hazard assessment within the PAI. At the moment the methodology is undergoing a process of validation and is not legally binding.

- **Scale**

1:10,000.

- **Type and mechanisms of landslides**

The most represented surface processes in the area which are:

- slides
- solifluctions
- shallow landslides
- flows
-

- **Basic documents required**

Susceptibility map, inventory map and state of activity for the mapped landslides.

- **Methodology**

Temporal prediction was obtained through the combination of the model results with the information regarding the state of activity for the mapped landslides. State of activity has been used to assign average recurrence intervals to the susceptibility classes and to active landslides. In such a way, five classes of recurrence time were selected and associated to five classes of temporal hazard (10,000 years for H0; 1000 years for H1; 100 years for H2; 10 years for H3 and 1 year for H4), the latter directly assigned only to active mapped mass movements (Catani et al. 2005). Recurrence time was then translated into probability by the computation of the absolute hazard $H(N)$ in a given time span N using the binomial distribution so that $H(N) = 1 - (1 - 1/T)^N$ (see e.g. Canuti and Casagli 1996). Computations were carried out for $N=2, 5, 10, 20$ and 30 years, respectively. Absolute hazard is thus characterized by five classes (from H0 to H4) with probabilities ranging from 0 (class H0) to 1 (class H4) for each time span (Figure 3-25).

- **Hazard matrix**

Quantitative.

- **Zoning, recommendations/restrictions**

This document doesn't provide any further additions to the recommendations and restrictions described in section A.

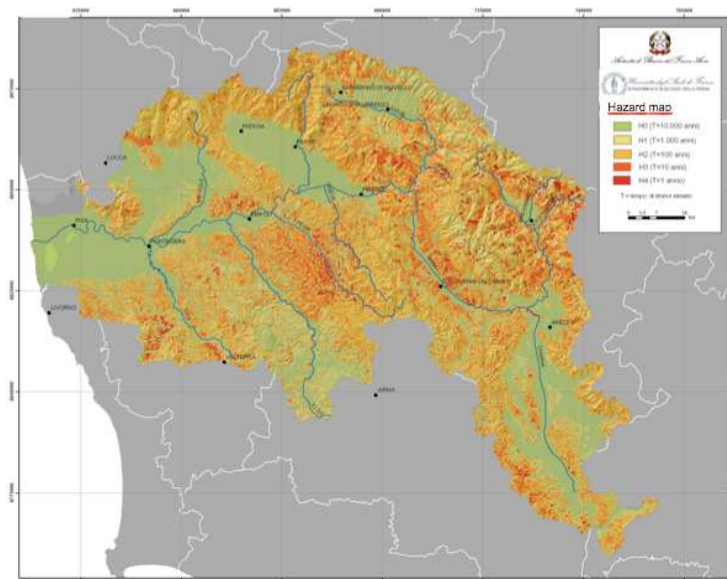


Figure 3-25. Landslide hazard map of the Arno River Basin.
The level of hazard range from H0, lowest hazard to H4 the highest hazard.

- **Legends**

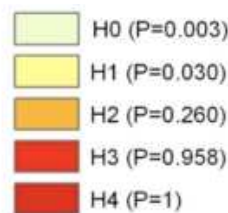


Figure 3-26. Legend used for hazard maps at the Arno River Basin

- **Hazard levels**

Five hazard levels as noted in the legend.

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- website: <http://www.adbarno.it> (Arno River Basin Authority)

3.4.4 Northern Italy

(contributor: UNIMIB)

The Italian alpine region is among the areas most affected by landslides at the European scale, due to the combination of high-relief topography, related to the rise of a young orogen, and a variety of active geomorphic processes (i.e. glacial, paraglacial, fluvial, gravity-related) resulting in high erosion rates and the mass wasting or transport of huge amount of sediments. The considered area includes six main administrative subdivisions (i.e. Regions), namely: Piemonte, Valle d’Aosta, Lombardia, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia. Trentino-Alto Adige is made of two self-governing provinces, i.e. Trentino and Alto Adige/Sudtirolo.

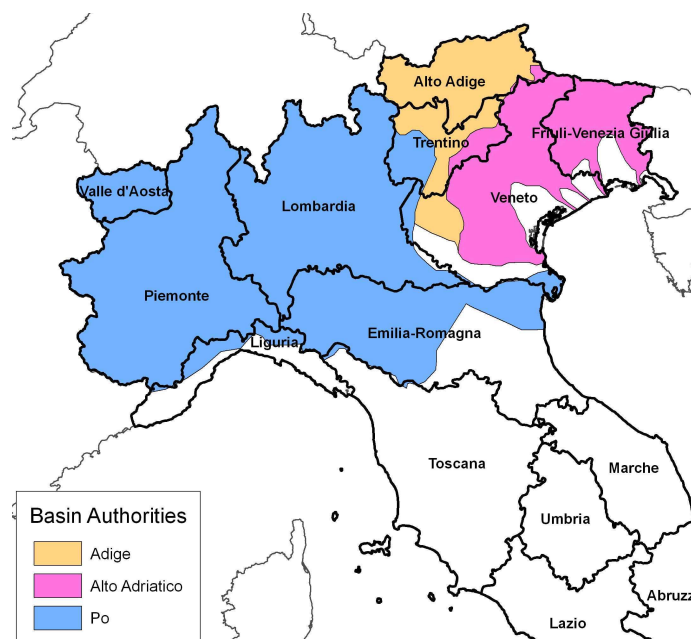


Figure 3-27. General procedure adopted for the Landslides susceptibility Map
Overview of the Italian alpine region and related basin authority extents.

A national-scale overview of the landslide problem in the Italian alpine region was provided by the outcomes of the IFFI project (Trigila et al., 2007), coordinated by the Geological Survey of Italy and aimed at building a national landslide inventory for Italy. Although the completeness of landslide inventories is not homogeneous across different regions (Table 3 7), the IFFI database clearly shows that the considered regions are affected by high number and density of landslides in soil (mainly soil slips/slumps, debris flows, and debris slides; Cruden and Varnes, 1996) and rock, including rockfalls, topples, rockslides/avalanches, complex landslides (Cruden and Varnes, 1996), plus a number of Deep-Seated Gravitational Slope Deformations involving large slopes (Crosta et al., 2008).

Table 3-7. The landslide problem in the Italian alpine region (Trigila et al., 2007).

Region	Mapped landslides #	Total landslide area Km ²	Landslide density (total area) %	Landslide density (mountain area only) %
Piemonte	35023	2540	9.1	15.0
Valle d'Aosta	4359	520	16.0	16.0
Lombardia	130538	3308	13.9	29.9
Alto Adige	1995	463	6.2	6.3
Trentino	9385	879	14.2	14.7
Veneto	9476	223	1.2	3.1
Friuli-Venezia Giulia	5253	511	6.5	14.8

The above mentioned regions belong to three main Basin Authorities (i.e. Po river basin, Adige river basin, Alto Adriatico river basins; (Figure 3-27). Here we review briefly the approaches followed in the Po river basin and Alto Adriatico river basins Master Plans.

Table 3-8 Basin scale Hydrogeological Plans relevant to the Italian alpine regions.

Basin Authority	Hydrogeological Plan	Main reference	Involved Regions
Po river	Piano Stralcio per l'Assetto Idrogeologico	DPCM 24 maggio 2001	Piemonte, Valle d'Aosta, Lombardia, Trentino
Adige river	Piano stralcio per l'Assetto Idrogeologico del bacino idrografico del fiume Adige – Regione del Veneto	DPCM 27 aprile 2006	Veneto
Alto Adriatico rivers	Piano Stralcio per l'Assetto Idrogeologico dei bacini idrografici dei fiumi Isonzo, Tagliamento, Piave, Brenta-Bacchiglione	Delibera Comitato Istituzionale 4/2007, 19 giugno 2007	Trentino, Alto Adige, Veneto, Friuli-Venezia Giulia

The lower level of landslide susceptibility assessment and zoning in Italy is usually included in the framework of urban landplanning. Since 1942 (Legge Urbanistica Nazionale 1150/1942), urban landplanning is carried out by drafting the Land Management Master Plan (Piano Regolatore Generale, P.R.G.), which is aimed at regulating building activities and land use within each Municipality. Since 1968 (D.M. 1444/1968) the concept of zoning was introduced in the Plans through the identification of homogeneous areas subjected to specific, legally-binding regulations and/or land-use limitations. Among the zones envisaged by the law, zone “G” represented areas with limitations due exposure to floods, landslides or snow avalanches.

Following their establishment in 1970, the Regional Authorities were charged from the national Authority of land planning responsibilities. Since that, a number of Regional Laws have been published to rule land planning procedures at Regional, Provincial and Municipality scale. At Municipality level, the Land Management Master Plan was maintained, with some differences in methodologies and procedures. The Plan needs to be accompanied by a geological study aimed at characterizing the geological constraints to land use, including an implicit evaluation of geological hazards (Table 3-9). These constraints must be consistent with the basin-scale Hydrogeological Master Plan (PAI), and are generally defined on the basis of geomorphologic mapping of dangerous phenomena.

Table 3-9. Summary of the current, legally-binding municipality-scale landslide hazard assessment practices used in different Regions.

Region	Level	Approach	Landslide type	Zoning	Ref. #
Piemonte	Susceptibility	Geomorphological	All	?	L.R. 56/77 Circ. P.G.R. 7/96/LAP
Valle d’Aosta	Susceptibility	Geomorphological	All	Yes	L.R. 11/98
Lombardia	Susceptibility	Geomorphological Heuristic / Modelling	Rockfalls, debris flows slides	Yes	L.R. 12/05
Alto Adige / Sudtirol	Susceptibility	Geomorphological	All	Yes	L.P. 13/97
Trentino	Susceptibility	Geomorphological	All	Yes	L.P. 01/08 L.P. 05/08
Veneto	Susceptibility Hazard	Geomorphological / Modelling (adopted from basin-scale zoning)	All	Yes	L.R. 11/04
Friuli-Venezia Giulia	Susceptibility	Geomorphological/ Modelling (adopted from basin-scale zoning)	All	Yes	L.R. 27/88 L.R. 16/09

Some example case studies are reported in the following pages to illustrate current levels of landslide susceptibility or hazard assessment performed (or required) by regional authorities through legally-binding standard procedures. Rockfalls are considered as example landslide type (Cruden and Varnes, 1996) due to their spatial distribution and frequency in the Italian alpine area, as well to the complexity of related hazard assessment.

3.4.4.1 Basin Authority of Po River

(contributor:UNIMIB)

In the Po basin Hydrogeological Master Plan (PAI - Piano Stralcio per l'Assetto Idrogeologico), a simplified assessment of hazard and risk at 1:50,000 scale is provided for flood and landslide hazard, using municipality polygons as reference land units.

Given the scarce availability and statistical significance of datasets of landslide frequency and intensity, for the risk evaluation (see Section 4.2.4), the hazard, i.e. the probability of occurrence of a given dangerous process in a given area and time interval, is expressed in a simplified form and combined according to a simple heuristic (matrix) approach, in terms of susceptibility.

Landslide distribution was obtained by drafting a landslide inventory map at 1:25,000 scale based on historical data (available from local authorities) and reconnaissance aerial photo interpretation. A landslide susceptibility indicator (Landslide Hazard Index) was obtained for each land unit by summing two terms, namely: a Landslide index, I_f (i.e. landslide density, the percent of total land unit area mapped as landslide), and a Landslide Potential Index. The latter depends on the percent outcrop area of specific lithologies weighted by the landslide density computed for each lithology. Susceptibility values were then classified into four discrete classes (i.e. low, moderate, high, very high).

- **Name of the document**

Po basin Hydrogeological Master Plan (Piano Stralcio per l'Assetto Idrogeologico-main reference: DPCM 24 maggio 2001).

- **Purpose of the document**

The main purpose of the document is to use the produced hazard and risk maps for basin-scale land planning in order to prevent further disaster through the management of hydrogeological risk. Additionally, the output maps are used for support national regulations implicitly affecting landslide hazard assessment practices include Civil Protection regulations (Law 225/1992 and following acts) and building codes (D.M. 11/03/1988; Norme Tecniche per le Costruzioni, D.M. 14/01/2008).

- **Users of the document**

The Po River Basin authority.

- **Type of the document**

The provided documents are "hazard" and risk maps, which are legally binding documents. The definition of "hazard" that used here is incorrect according to the suggested terminology of Chapter 1. The produced maps rather correspond to susceptibility maps (e.g. it does not account for landslide intensity).

- **Scale**

1:50,000

- **Type of hazards. Type and mechanisms of landslides**

The included landslides are rockfalls, rock avalanches, deep-seated rockslides, soil slips/slumps, translational and rotational debris slides, earth/mud flows, and debris flows.

- **Basic documents required**

Landslide inventory and information related to landslide density and lithology.

- **Methodology**

Two methodologies are described here:

A. *Methodology for the development of landslide susceptibility maps to be used for the risk assessment (see Section 4.2.4),.*

B. *Methodology for the rockfall susceptibility assessment for “high-risk” classed sites: Rockfall Hazard Assessment Procedure (RHAP) procedure.*

A. *Methodology for the development of landslide susceptibility maps to be used for the risk assessment*

Landslide distribution was obtained by drafting a landslide inventory map at 1:25.000 scale based on historical data (available from local authorities) and reconnaissance aerial photo interpretation. A landslide susceptibility indicator (Landslide Hazard Index) was obtained for each land unit by summing two terms, namely: a Landslide index, If (i.e. landslide density, the percent of total land unit area mapped as landslide), and a Landslide Potential Index, is. The latter depends on the percent outcrop area of specific lithologies weighted by the landslide density computed for each lithology. Susceptibility values were then classified into four discrete classes (i.e. low, moderate, high, very high) (Figure 3-28). The risk assessment based on these maps is described in (see Section 4.2.4).

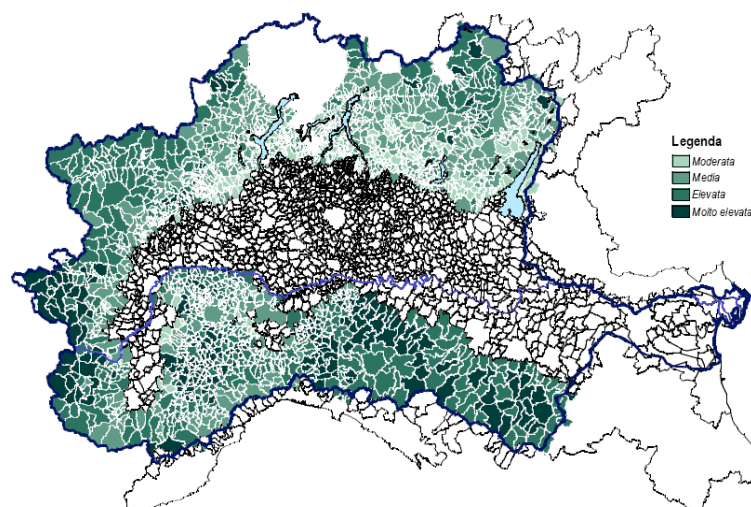


Figure 3-28. General procedure adopted for the Landslides susceptibility Map

Basin-scale landslide hazard map reported in the Hydrogeological Master Plan (PAI) drafted by the Po river basin Authority. Municipalities are considered as land units.

Except for specific long-lived landslides such as earth flows with available historical data, the state of activity of landslides was only estimated by geomorphological criteria. Although the definition of “hazard” used here is formally incorrect (e.g. it does not account for landslide intensity), the use of the inventory map as a starting reference in landplanning studies at the municipality scale is mandatory. In this way, the inventory map is progressively updated and refined by incorporating the outcomes of more detailed field studies (1:2,000-1:5,000 scale). Mapped landslide areas and the related “hazard” classifications are legally binding and must be taken in account in defining urban land planning zones and regulations.

The Po Basin Authority also used the above mentioned landslide inventory to test a local scale heuristic susceptibility and qualitative risk assessment procedure. This procedure, to be applied to single mapped landslides, is aimed at including in the landslide susceptibility assessment different indicators in order to modify an initial value of “hazard” (P0...P4) through the sequential use of heuristic matrices (Table 3-10), accounting for the landslide style of activity (Table 3-11), and the effects of countermeasures (i.e. actions favourable to stability; Table 3-12) and unfavourable actions (e.g. external loads, toe erosion; Table 3-13).

Table 3-10. Preliminary landslide susceptibility matrix (Po basin Authority, 1999).

Magnitude	M1	M2	M3	M4
State of activity				
Dormant	P0	P0	P0	P1
Recently active	P0	P1	P2	P3
Active - reactivated	P1	P2	P3	P4

Table 3-11. –Landslide susceptibility matrix including activity style (Po basin Authority, 1999).

P	P0	P1	P2	P3	P4
Style of activity					
Reducing	D0	D0	D1	D2	D3
Constant	D0	D1	D2	D3	D4
Progressive, retrogressive, widening	D1	D2	D3	D4	D4

Table 3-12. Landslide susceptibility including countermeasures (Po basin Authority, 1999).

D	D0	D1	D2	D3	D4
Countermeasure					
Effective	H0	H0	H0	H0	H1
Partly effective	H0	H0	H1	H2	H3

Ineffective - Absent	H0	H1	H2	H3	H4
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Table 3-13. Landslide susceptibility including unfavourable actions (Po basin Authority, 1999).

H	H0	H1	H2	H3	H4
Unfavourable actions					
Absent	Z0	Z1	Z2	Z3	Z4
Unfavourable	Z1	Z1	Z3	Z3	Z4
Very unfavourable	Z1	Z2	Z3	Z4	Z4

B. Methodology for the rockfall susceptibility assessment for “high-risk” classed sites: RHAP procedure.

According to Region Lombardia regulations, the assessment of rockfall susceptibility at specific sites characterized by high expected hazard or risk should be performed using a methodology called RHAP (Rockfall Hazard Assessment Procedure; Mazzoccola and Sciesa, 2000). Although the methodology is supposed to result in the evaluation of “hazard” zoning, it does not explicitly include frequency in the analysis, and therefore it must be considered as a rockfall susceptibility assessment procedure.

The methodology applies to rockfalls ranging from single blocks to rock mass volumes up to 1,000 m³, and it is suitable for local-scale studies. The method allows to rank the susceptibility level with respect to a specific site. For this reason, susceptibility ranking from different sites are not comparable in absolute value.

The first step in the procedure consists of the identification of homogeneous sub-areas of the rocky cliff / rockfall source zone and affected slope sector, according to a preliminary characterisation of rock mass properties and slope morphology in the source and the runout zone (Figure 3-29). Such identification is usually performed through field surveys, with the help of appropriate check lists and field charts.

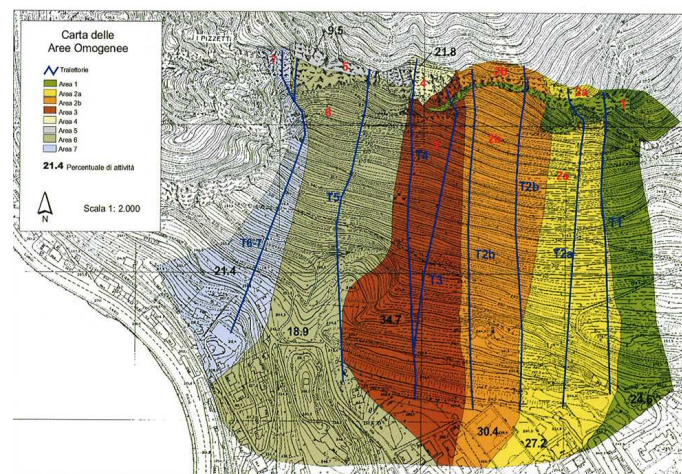


Figure 3-29. General procedure adopted for the Landslides susceptibility Map Mt. San Martino cliff (Lecco, Lombardia). Homogeneous areas and simulated trajectories (from Interreg IIC Project “Falaises”; Carere et al., 2001)

From each defined homogeneous sub-area, 2D rockfall stochastic simulation is performed along specific, representative fall paths in order to perform a preliminary longitudinal zonation of rockfall propagation frequency, depending on the arrests point distribution along the slope. The simulations are performed considering modal (or specific “design”) block volumes and shape, and calibrating restitution coefficients using available field, historical and geomorphological data (e.g. single blocks, scree slope extent). Depending on the percentage of block exceeding a given runout, the slope is zoned in 4 zones (Figure 3-30) with different preliminary susceptibility level: 4 (runout encompassing 75% of the blocks), 3 (90%), 2 (100%), 1 (extent of “extreme runout” blocks).

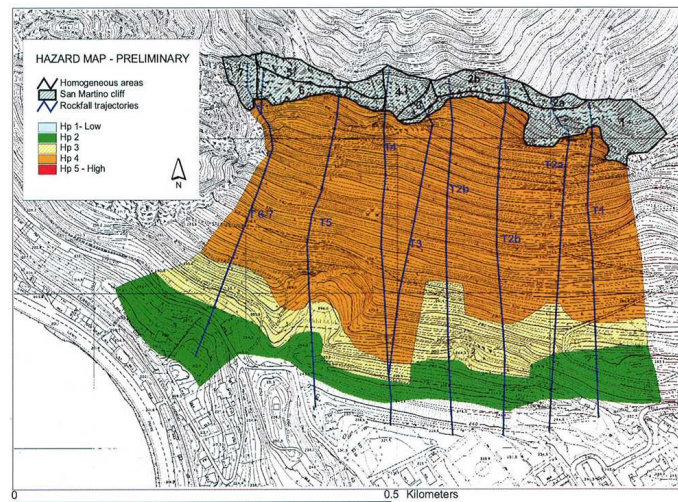


Figure 3-30. General procedure adopted for the Landslides susceptibility Map Mt. San Martino cliff (Lecco, Lombardia). Preliminary susceptibility map based on rockfall simulations along representative trajectories (Interreg IIC Project “Falaises”).

homogeneous zone 1			homogeneous zone 2				homogeneous zone 3			
number of unstable elements, <i>n</i>			number of unstable elements, <i>n</i>				number of unstable elements, <i>n</i>			
1	2	1	1	0	0	0	0	1	0	1
0	3	0	0	1	1	1	0	0	0	0
2	4	2	2	3	0	0	0	1	2	0
3	2	1	1	1	2	1	0	1	2	0
1	2	0	0	0	0	1	0	2	0	0
relative susceptibility, <i>n/5</i>			relative susceptibility, <i>n/5</i>				relative susceptibility, <i>n/5</i>			
0.2	0.4	0.2	0.2	0	0	0	0	0.2	0	0.2
0	0.6	0	0	0.2	0.2	0.2	0	0	0	0
0.4	0.8	0.4	0.4	0.6	0	0	0	0.2	0.4	0
0.6	0.4	0.2	0.2	0.2	0.4	0.2	0	0.2	0.4	0
0.2	0.4	0	0	0	0	0.2	0	0.4	0	0
onset susceptibility, <i>mean(rel. susc.)</i>			onset susceptibility, <i>mean(rel. susc.)</i>				onset susceptibility, <i>mean(rel. susc.)</i>			
0.32			0.15				0.1			

Figure 3-31. General procedure adopted for the Landslides susceptibility Map Example of onset susceptibility calculation from relative susceptibility of regular squares (Interreg IIC Project “Falaises”).

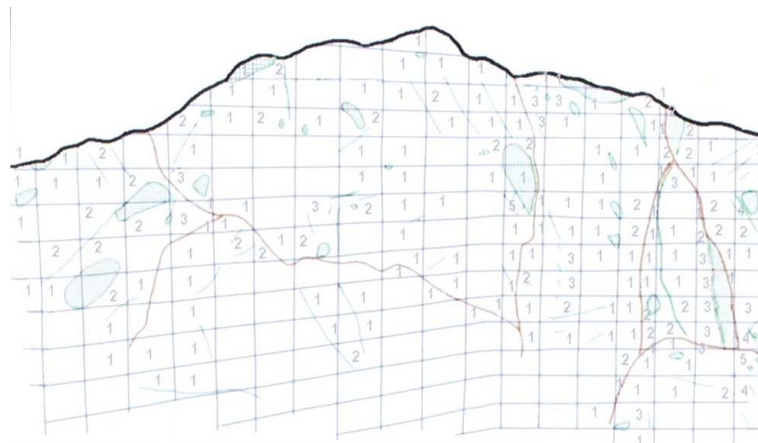


Figure 3-32. General procedure adopted for the Landslides susceptibility Map Mt. San Martino cliff (Lecco, Lombardia). Subdivision of rocky cliff in areas with different number of potentially unstable elements (Interreg IIC Project “Falaises”).

Homogeneous area	n. of squares	n. of unstable element	onset susceptibility
1	730	180	24,6
2a	235	64	27,2
2b	230	70	30,4
3	95	33	34,7
4	280	61	21,8
5	275	26	9,5
6	360	68	18,9
7	140	30	21,4

Figure 3-33. General procedure adopted for the Landslides susceptibility Map San Martino example (Lecco, Northern Italy). Onset susceptibility of homogeneous areas (from Interreg IIC Project “Falaises”; Carere et al., 2001)

The rocky cliff is then characterised by geomechanical surveys and analysis of aerial and terrestrial photos in order to attribute different onset susceptibility levels to each homogeneous sub-area. First, the cliff is discretised into regular squares. For each square, the number of detected “instability indicators” is assessed, and a relative susceptibility index is calculated as the number of detected instability indicators normalized by the maximum number, assumed to be 5. Then, the onset susceptibility of each homogeneous area is calculated as the mean susceptibility of all the inner squares (Figure 3-31 to Figure 3-33).

Then, homogeneous sub-areas are classified into classes of activity (low, medium, high) depending on their estimated onset susceptibility. Finally, the latter classification is used to modify the preliminary susceptibility map by incrementing (high onset activity) or decrementing (low onset activity) the hazard level of one class (Figure 3-34).

- **Hazard matrix**

The hazard matrices that are used for the “hazard” mapping (methodology A for landslide susceptibility) at the River Basin of Po are those shown on Table 3-10 to Table 3-13. They include the state and style of the activity, the countermeasures, and the possible existence of unfavourable actions.

- **Hazard levels**

There are four “hazard” classes: low, moderate, high and very high, as shown in Table 7 (Z1-Z4, Z0 corresponds to no hazard).

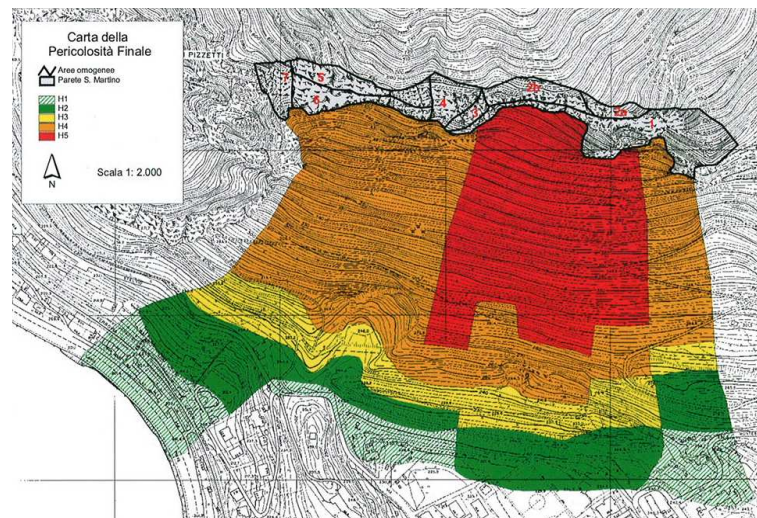


Figure 3-34. General procedure adopted for the Landslides susceptibility Map San Martino example (Lecco, Northern Italy). Final rockfall susceptibility map produced using the RHAP methodology (from Interreg IIC Project “Falaises”; Carere et al., 2001)

- **Legends**



Figure 3-35. Legend for the “hazard” map of Po River Basin

- **Zoning, recommendations-restrictions**

In the Lombardia region, the Land Management Plan structure has been recently revised according to the prescriptions of the Regional Law (L.R.) 12/2005, paying greater attention to the geological component of the landplanning process. In particular, a set of guidelines have been defined at the regional level which are aimed at:

- defining, mapping and summarising the geological, geomorphological, hydrogeological, and seismic aspects of each Municipality with a consistent approach;
- assessing flood, landslide, snow avalanche, and seismic hazards at the Municipality scale, and defining suitable, legally-binding land use limitations and regulations;
- applying the Hydrogeological Master Plan regulations in municipality-scale urban land planning;
- continuously implementing and updating the datasets needed to ensure the consistency of land planning performed at different scale (i.e. basin, Region, Municipality).

In this framework, the assessment of hydrogeological and seismic hazards is an important step of the overall land planning process. These are evaluated in terms of susceptibility by using a geomorphological approach. All the relevant basic informations (i.e. topography, geology, geomorphology, hydrogeology/hydraulics) are mapped and overlaid to obtain a “map of geological constraints”, where geomorphological land units are classified in four classes, with particular subclasses defined according to the main contributing hazard (see Figure 3-37):

- Class 1: no particular limitations;
- Class 2: slight limitations;
- Class 3: significant limitations;
- Class 4: severe limitations.

A first example of municipal scale zoning is extracted from the Territorial Management Plan of Gardone Val Trompia, which is a small city located in middle Valle Trompia, 18 km North of Brescia, Lombardia Region, Northern Italy (Figure 3-36). The Municipality is highly urbanized, with important industrial activities. Due to limits in available building areas, structures and infrastructures are located close to both the main river (Mella river) and the slopes, giving a significant vulnerability.

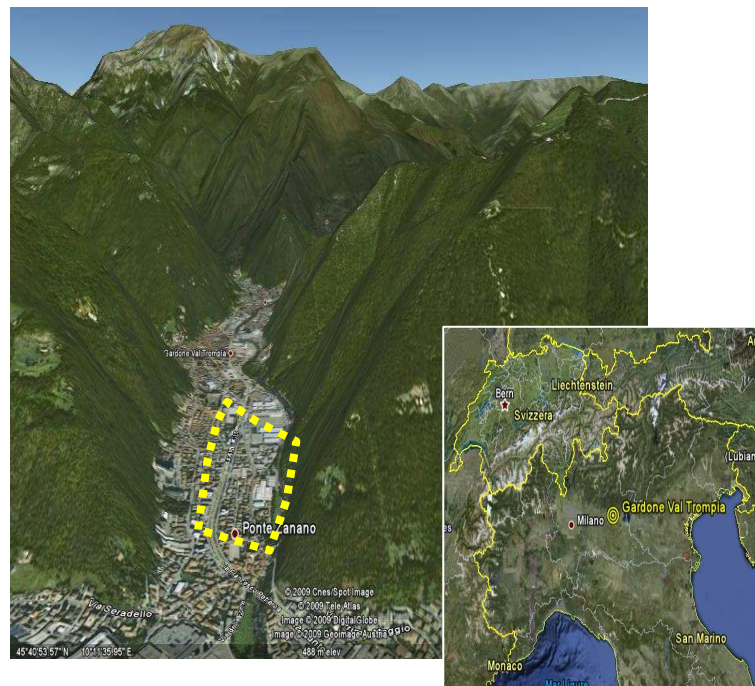


Figure 3-36. Aerial view of Gardone Val Trompia showing the significant exposure of the Municipality to landslide risk.

For this area, the map of geological constraints of the Land Management Plan (Figure 3-36) accounts for several different typologies of geological limitations, including:

- river floodplain potentially interested by exceptional floods (class 3a);
- steep slopes potentially interested by erosion and shallow landslides (class 3b);
- steep slopes potentially affected by rockfalls (class 3c);
- dormant landslide areas (class 3d);
- areas close to scarps (class 3f);

- areas potentially affected by debris flows (class 3g);
- streams potentially interested by ordinary floods (class 4a);
- active landslide areas (class 4b).

A further example is reported for the area impended by the Mt. San Martino – Corno Medale rocky cliffs, in the urban area of the Municipality of Lecco (Lombardia Region; Figure 3-38 and Figure 3-39). This example will be also exploited as case study in the following section. In the map of geological constraints (Figure 3-40), the area is zoned into four classes (1 to 4) represented by four colours, corresponding to different degrees of landuse limitations. In this case, rockfall is the main process contributing to such limitations, especially in the northern part of the area impended by Mt. San Martino and Medale rocky cliffs.

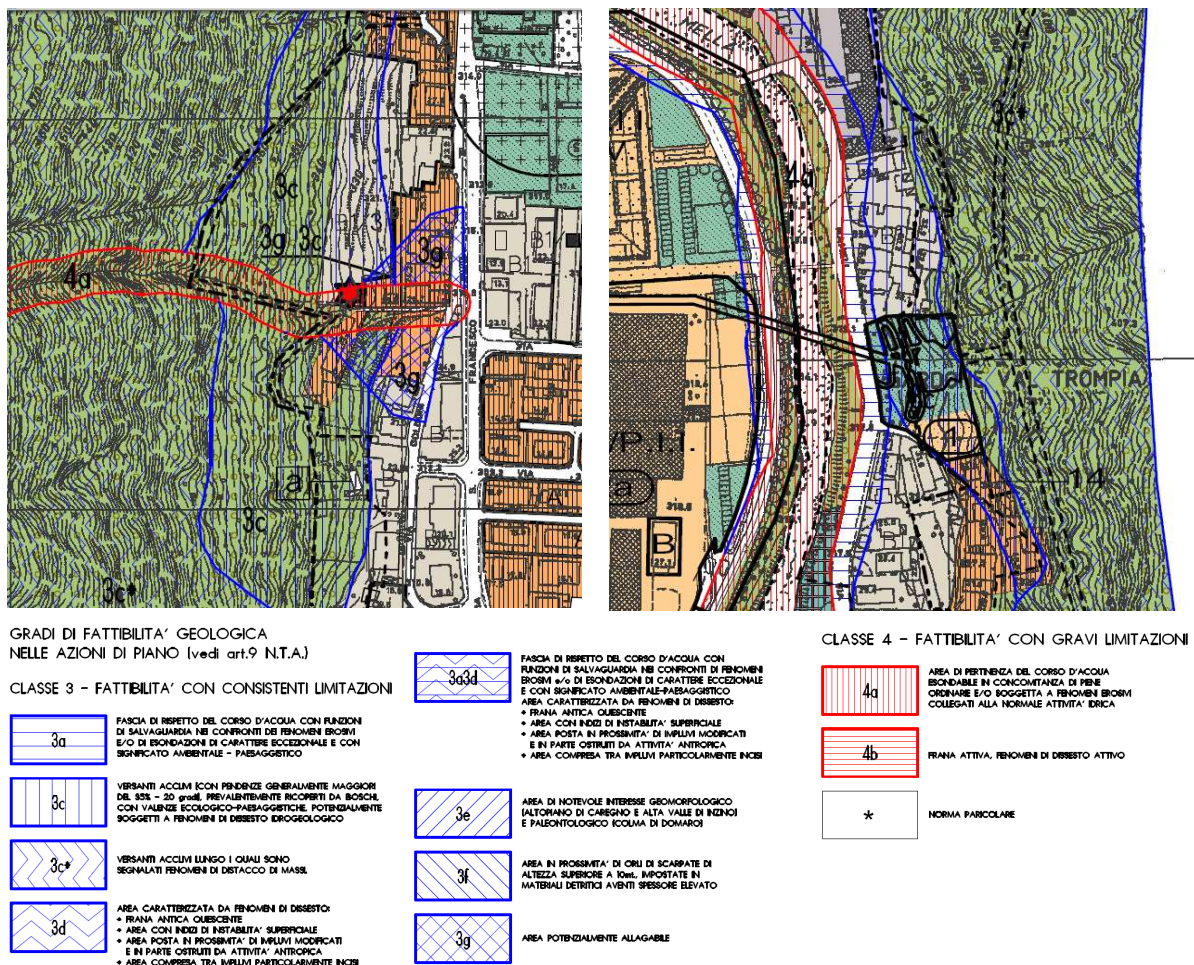


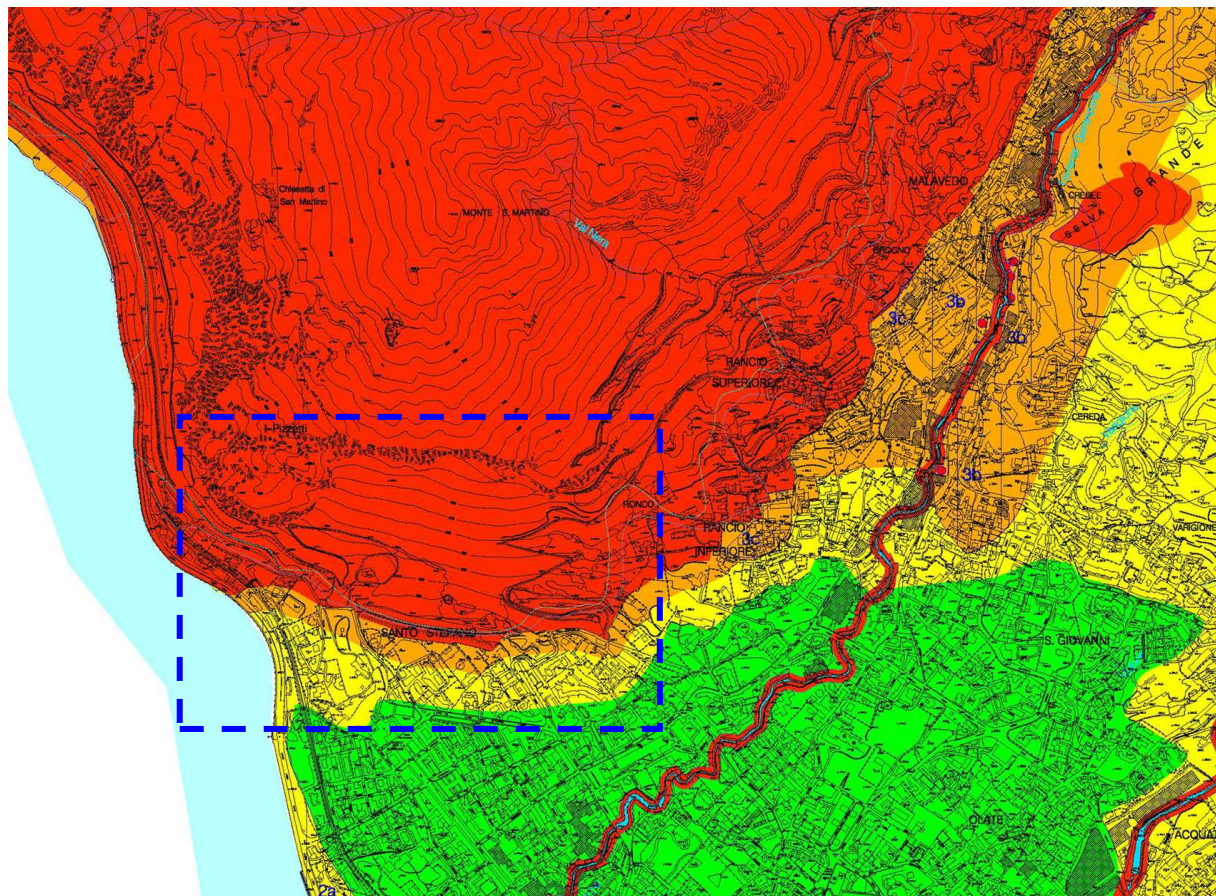
Figure 3-37. General procedure adopted for the Landslides susceptibility Map
Example of Land Management Plan of Gardone Val Trompia.



Figure 3-38. General procedure adopted for the Landslides susceptibility Map
Aerial view of the Lecco showing the study area (S flank of Mt. San Martino).



Figure 3-39. General procedure adopted for the Landslides susceptibility Map
South view of the Mt. San Martino – Medale cliffs



<p>CLASSE " 1 " Fattibilità senza particolari limitazioni</p>		<p>Aree pianeggianti e/o subpianeggianti con BUONE caratteristiche geotecniche dei terreni superficiali. Non vi sono particolari prescrizioni di natura geologico-applicativa. Per tutta la Classe vige la Normativa del DM 11.03.88</p>
<p>CLASSE " 2 " Fattibilità con modeste limitazioni</p>		<p>Aree pianeggianti, subpianeggianti e/o debolmente acclivi con caratteristiche geotecniche dei terreni superficiali da SCADENTI a DISCRETE e geomecaniche del substrato rocioso DISCRETE (III). Per tutta la Classe vige la Normativa del D.M. 11.03.88 con particolare riguardo a verifiche di natura geotecnica e di stabilità dei versanti più acclivi. Per l'area vedi nota in calce.</p>
<p>Sottoclasse "2a"</p>		<p>Per tutta la Sottoclasse vige la normativa del DM 11.03.88 con particolare riguardo a verifiche di natura idrogeologica per la presenza di falda a bassa soggiacenza.</p>
<p>Sottoclasse "2b"</p>		<p>Per tutta la Sottoclasse vige la normativa del DM 11.03.88 con particolare riguardo a verifiche di natura idraulica per tutte le nuove edificazioni e per interventi di sostanziale modifica strutturale e/o cambio di destinazione d'uso che interessino i piani terra di edifici esistenti.</p>
<p>Sottoclasse "2c"</p>		<p>Per tutta la Sottoclasse vige la normativa del DM 11.03.88, per opere di nuova progettazione occorre considerare il livello di massimo innalzamento delle acque dei laghi e del fiume Adda.</p>
<p>CLASSE " 3 " Fattibilità con consistenti limitazioni</p>		<p>Aree generalmente acclivi comprendenti tutta la fascia pedemontana e parte della conca dei Piani d'Enna. L'utilizzo di queste zone e' subordinata alla realizzazione di supplementi d'indagine di natura geologico-tecnica ed idrogeologica/idraulica mediante campagne geognostiche specifiche al fine di precisare le idonee tipologie costruttive, nonché le opere di sistemazione e bonifica.</p>
<p>Sottoclasse "3a"</p>		<p>Aree che presentano rischi consistenti di natura geologica, con caratteristiche topografiche, areali e logistiche tali da permettere l'esecuzione d'interventi di messa in sicurezza e/o bonifica radicale dei siti; sono ricompresi gli ambiti di cava dismessi o di futura chiusura e localizzate aree franose. L'utilizzo di queste zone e' subordinato all'esecuzione d'indagini specifiche di natura geologico-tecnica con redazione di un progetto di bonifica - messa in sicurezza e/o recupero ambientale.</p>
<p>Sottoclasse "3b"</p>		<p>Aree ricomprese nella fascia di rispetto delle captazioni idriche interessanti la zona di ricarica della falda e soggette ad una elevata vulnerabilità della stessa. L'utilizzo di queste aree e' subordinato all'esecuzione di natura idrogeologica e con l'adozione di adeguate tecnologie costruttive nell'esecuzione delle opere di smaltimento dei reflui.</p>
<p>Sottoclasse "3c"</p>		<p>Aree al limite della zona di pericolosità (CLASSE 3H-4I) in cui sono da limitarsi nuove edificazioni e comunque da valutarle singolarmente in funzione della vulnerabilità dell'area specifica. Per quanto riguarda i supplementi d'indagine si confermano quelle previste per la Classe 3.</p>
<p>Sottoclasse "3d"</p>		<p>Per tutta la Sottoclasse vige la normativa del DM 11.03.88 con particolare riguardo a verifiche di natura idraulica per tutte le nuove edificazioni e per interventi di sostanziale modifica strutturale e/o cambio di destinazione d'uso che interessino i piani terra di edifici esistenti.</p>
<p>CLASSE " 4 " Fattibilità con gravi limitazioni</p>		<p>Aree con grado di rischio geologico elevato, estensione areale consistente, diffusione di fenomeni di dissesto generalizzata o concentrata, inaccessibilità dei luoghi per l'esecuzione di opere di protezione e/o bonifica con metodi tradizionali e che comunque non garantiscono una totale riduzione del rischio; inoltre tutte le zone di pertinenza fluviale (fascia di 10 m) e tutela assoluta pozzi e sorgenti (raggio 10 m). All'interno di queste aree e' da escludersi qualsiasi nuova edificazione; e' consentita l'esecuzione di opere per la messa in sicurezza o mitigazione del rischio. Sono da prevedersi una rete di monitoraggio geologico ed idrogeologico.</p> <p>Indicazione della fascia di rispetto dei corsi d'acqua del reticolo minore individuabili dalla topografia esistente - distanza pari a 10 m dall'arginatura artificiale o del ciglio superiore della scarpata fluviale</p>

Figure 3-40. General procedure adopted for the Landslides susceptibility Map
Map of the geological constraints of the Land Management Plan of the Municipality of Lecco. The sub-area considered in the following section is outlined in blue.

3.4.4.2 Basin Authorities of Alto Adriatico

(contributor: UNIMIB)

In the Hydrogeological Master Plan drafted by the Alto Adriatico Basin Authority, landslide hazard has been assessed at the basin scale following a modified version of the Swiss Federal Guidelines methodology by the Swiss Ministry of the Environment (Bundesamt für Umwelt, Wald, und Landschaft; BUWAL, 1998), which is consistent with the guidelines provided by the D.P.C.M. 29/09/1998 for Italy. Details are given in the following.

- **Name of the document**

The Alto Adriatico Hydrogeological Master Plan (Piano Stralcio per l'Assetto Idrogeologico dei bacini idrografici dei fiumi Isonzo, Tagliamento, Piave, Brenta-Bacchiglione - Main Reference: Delibera Comitato Istituzionale 4/2007, 19 giugno 2007).

- **Purpose of the document**

The main purpose of the document is to use the produced hazard and risk maps for basin-scale land planning in order to prevent further disaster through the management of hydrogeological risk. Additionally, the output maps are used for support national regulations implicitly affecting landslide hazard assessment practices include Civil Protection regulations (Law 225/1992 and following acts) and building codes (D.M. 11/03/1988; Norme Tecniche per le Costruzioni, D.M. 14/01/2008).

- **Users of the document**

The Alto Adriatico River Basin authority.

- **Type of the document**

Hazard maps, legally binding.

- **Basic documents required**

Landslide inventory and geomorphological data

- **Methodology**

The methodology that is used is a modified version of the Swiss Federal Guidelines methodology by the Swiss Ministry of the Environment (Bundesamt für Umwelt, Wald, und Landschaft; BUWAL, 1998), which is consistent with the guidelines provided by the D.P.C.M. 29/09/1998 for Italy.

The adopted procedure is based on a matrix approach aimed at a heuristic, qualitative evaluation of landslide hazard based on a simplified assessment of:

- spatial distribution of occurred landslides based on a landslide inventory (e.g. IFFI project);
- type, velocity, size of mapped landslides;
- estimated frequency or recurrence of landslide events.

Although the procedure accounts for both landslide frequency and intensity, it exploits purely geomorphological data. In fact, landslide velocity (Table 3-14) geometric intensity (Table 3-15) and frequency (

Table 3-16) are indirectly estimated using geomorphological indicators derived by inventory maps. Thus, the methodology is able to produce a map of qualitative landslide susceptibility. In detail, the heuristic combination of landslide velocity classes and geometrical severity classes allows to define magnitude (intensity) classes (Table 3-17). The combination of intensity (or velocity) classes with estimated frequency classes allows to reclassify the areas affected by mapped landslides into four “hazard” (susceptibility) classes, from P1 (low hazard) to P4 (high hazard; Table 3-18 and Table 3-19. An additional “undefined hazard” class is attributed to areas with paleo-landslides or landslided with estimated return period exceeding 300 years.

Table 3-14. Definition of velocity classes.

Description	Typical velocity	Velocity class
Extremely fast	5 m/s	3
Very fast	3 m/min	
Fast	1.8 m/hr	2
Moderately fast	13 m/month	
Slow	1.6 m/yr	
Very slow	16 mm/yr	
Extremely slow	< 16 mm/yr	1

Table 3-15. Definition of severity (geometric intensity) classes.

Rockfalls: block diameter	Slides and flows: thickness	Severity class
> 2m	> 15m	3
0.5-2 m	2-15m	2
< 0.5m	< 2m	1

Table 3-16. Definition of landslide frequency (recurrence).

Estimated return period (yr)	Description
1-30	Active landslides, dormant landslides with high reactivation frequency
30-100	Dormant landslides with moderate reactivation frequency
100-300	Dormant landslides with low reactivation frequency
> 300	Relict landslides, low reactivation frequency

Table 3-17. Hazard matrix (for use when landslide severity estimates are not available).

Return period (yr)	1-30	30-100	100-300	>300
Velocity class				
3	P4	P4	P3	undefined
2	P3	P3	P2	undefined
1	P2	P1	P1	undefined

Table 3-18. Magnitude matrix.

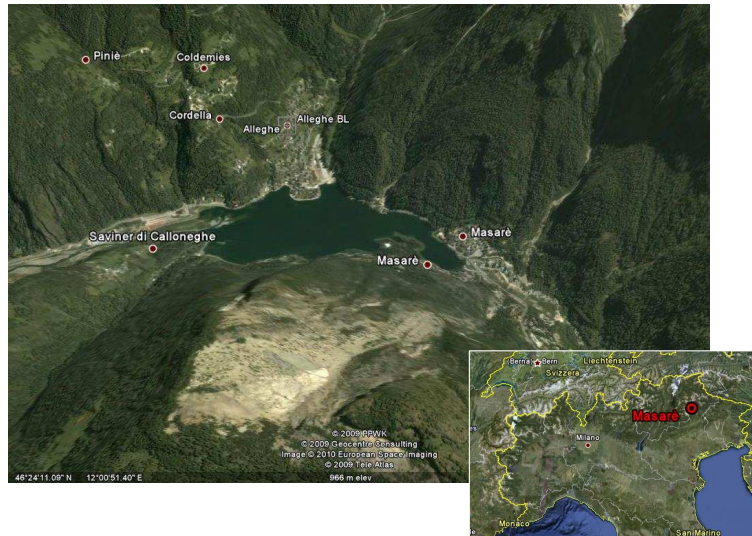
Velocity classe	1	2	3
Severity class			
1	1	2	3
2	2	4	6
3	3	6	9

Table 3-19. Hazard matrix (for use with magnitude classes).

Return period (yr)	1-30	30-100	100-300	>300
Magnitude class				
6-9	P4	P4	P3	undefined
3-4	P3	P3	P2	undefined
1-2	P2	P1	P1	undefined

In order to show the local-scale application of the cited procedure, the recent zonation of rockfall hazard in the village of Masarè (municipality of Alleghe, Veneto Region; (Figure 3-41 and Figure 3-42) is presented.

This example is extracted from a geological report attached to the Regional Resolution (Deliberazione della Giunta Regionale, DGR 2251/2008) which passed the zonation as legally binding in 2008. The zonation was performed taking into account the presence of 3 mitigation structures (barriers) which are considered effective in reducing the actual hazard. In Table 3-20, hazard and residual hazard after mitigation are compared.



*Figure 3-41. General procedure adopted for the Landslides susceptibility Map
Aerial photo of Alleghe showing the study area located in the village Masarè. In front
of Masarè it is possible to recognize the evidence of a large historical rock avalanche
which dammed the valley in 1771 forming the lake of Alleghe.*



*Figure 3-42 General procedure adopted for the Landslides susceptibility Map
Masarè example (Alleghe, Northern Italy). Photo of the village with indication
of the rockfall mitigation works (from Deliberazione della Giunta Regionale, DGR 2251/2008)*

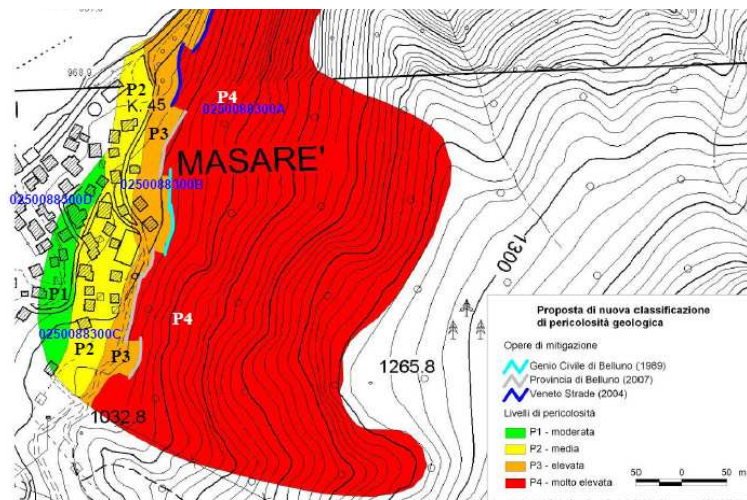


Figure 3-43. General procedure adopted for the Landslides susceptibility Map Masarè example (Alleghe, Northern Italy). Final rockfall hazard map produced using the modified BUWAL methodology (from DGR 2251/2008)

Table 3-20. Parameters and results of the analysis for each zone.

PAI code	0250088300A	0250088300B	0250088300C	0250088300D
Velocity	3	3	3	3
Geometric severity	2	2	2	2
magnitude	6	6	6	6
Frequency	1-30	1-30	1-30	100-300
Initial Hazard	P4	P4	P4	P4
Mitigation		yes	yes	yes
Arrest zone			yes	yes
Final Hazard	P4	P3	P2	P1

- **Hazard matrices**

Two hazard matrices are used.

The first one (Table 3-17) is used when landslide severity estimates are not available) and it is based on the velocity and the return period.

The second one (Table 3-18) is used when magnitude classes are taken into account and it is based on the magnitude class and the return period.

- **Hazard levels**

Four “hazard” (susceptibility) classes, from P1 (low hazard) to P4 (high hazard; Tables 12 and 13). An additional “undefined hazard” class is attributed to areas with paleo-landslides or landslided with estimated return period exceeding 300 years.

- **Legends**



Figure 3-44. Legend indicating the “hazard” levels

- **Zoning, recommendations-restrictions**

The zoning is made according to the hazard levels. An example of the resulting zoning is reported in Figure 3-45.

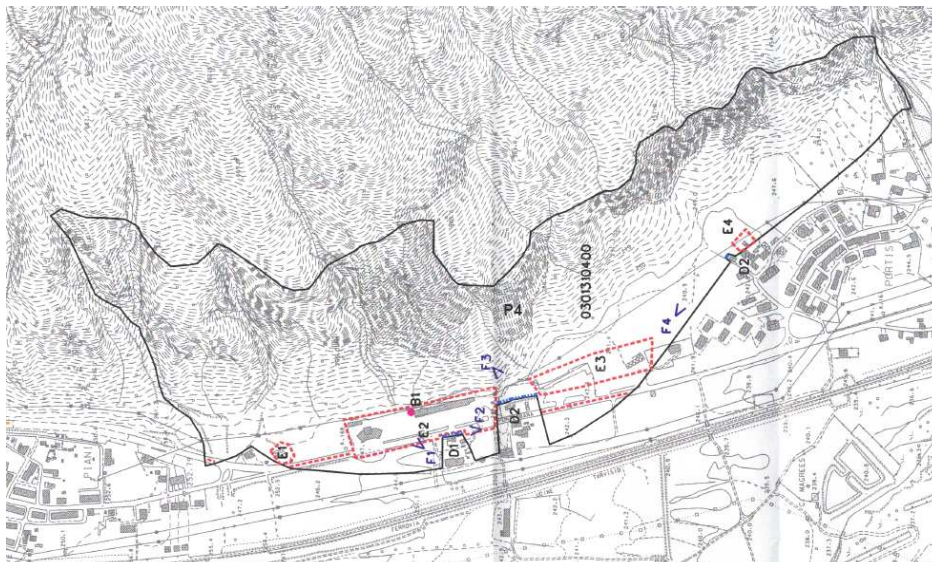


Figure 3-45. Example hazard zoning according to the modified BUWAL procedure (area: Venzone, Friuli-Venezia Giulia; landslide type: rockfall; rockfall class: P4)

References

- Autorità di Bacino dei fiumi Isonzo, Tagliamento, Livenza, Piave, Brenta-Bacchiglione (2007). Progetto di Piano Stralcio per l’Assetto Idrogeologico dei bacini idrografici dei fiumi Isonzo, Tagliamento, Piave, Brenta-Bacchiglione. Relazione Tecnica. Venezia, 248 pp. (in Italian, available at www.adbve.it).
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3.5 NORWAY

(contributor: ICG)

As part of work for The Norwegian Water Resources and Energy Directorate (NVE), Gregersen (2001) developed a simple method to classify and map the risk posed by potential

quick clay slides. The hazard assessment methodology forms part of the risk assessment, and it is described in section 4.3. In the following paragraphs a brief description is only given:

- **Name of the document**

Risk assessment for quick clay slopes (including hazards assessment).

- **Purpose of the document**

The purpose of the document is its use by administrative authorities for the prioritisation of slopes requiring remediation measures.

- **Users of the document**

The users of the documents are administrative offices.

- **Type of the document**

The provided documents are susceptibility/hazard and risk maps.

- **Scale**

1:10,000

- **Type of hazards. Type and mechanisms of landslides.**

Only landslides in slopes containing quick clay are considered.

- **Basic documents required**

The required documents are the landslide inventory and any other document containing information on geometry, lithology, slope angle and human activity.

- **Methodology**

The methodology for the hazard assessment is qualitative. Potential slide areas are given "engineering scores" based on an evaluation of the geotechnical parameters, local conditions, persons or properties exposed and engineering judgement.

- **Hazard levels**

The hazard classes are:

Low: Favourable topography and soil conditions; extensive site investigations; no erosion; no earlier sliding; no planned changes, or changes will improve stability.

Medium: Less favourable topography and soil conditions; limited site investigations; active erosion; important earlier sliding in area; planned changes give little or no improvement of stability.

High: Unfavourable topography and soil characteristics; limited site investigations; active erosion; extensive earlier sliding in area; planned changes will reduce stability.

The zones with weighted score between 0 and 17 (up to 33% of maximum score) are mapped as "low hazard" and have low probability of failure by sliding. The zones with weighted score between 18 and 25 (up to 50% of maximum score) are mapped as "medium hazard" and have a higher, though not critical, probability of failure. The zones with weighted score between 26 and 51 are mapped as "high hazard" and have a relatively high probability of failure.

- **Zoning, recommendations-restrictions**

The zoning for the prioritisation of slopes requiring remediation measures is made based on the risk levels that are outlined at Table 4-5 of Section 4.3.

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3.6 ROMANIA

(contributor: GIR)

According to 575/2001 Law - "Law regarding the approval of the National Territory Plan improvement- Section V- Natural risk areas", natural risk areas are geographically bounded limits, inside which potential destructive natural phenomena occurrence exists, that can affect the population, human activities, environment and generate human and economic losses (the present law refers to natural risk triggered by earthquakes, floods and landslides).

In natural risk areas specific measures for risk mitigation and prevention are being performed, including zoning plans.

According to this law, in 2001, 987 administrative – territorial units (towns and townships) from 37 counties (from a total of 41) were registered with landslide probability and potential between medium and very high.

In these circumstances, in order to establish the potential and the probability of an area to be affected by soil instability phenomenon (caused by natural or anthropic factors), in accordance with the COM 232/2006, Chapter 2, Section 1, Article 6, the first step that has to be made in this direction is to identify and classify the risk areas in the prone region. The region will then be surveyed every 10 years and the investigation program will then be made public and revised every 5 years.

Presently, there is no coherence and cohesion in decisions and actions taken by the research institutes and government institutions involved, at local or regional scale in systematic investigation, or a strategy for inventorying and monitoring of landslide affected areas, at

national scale. Moreover, although a general trend of unification between the Romanian and the international terminology regarding landslide susceptibility, hazard and risk has been observed in recent years, the present methodological requirements underlying the legal framework are not updated. Therefore, the terminology used here is the one used specifically in the legal document (HG No. 447 from 10/04/2003).

Within the Geological Survey of Romania studies were elaborated regarding the assessment of landslide hazard, triggering factors and their effect on slope stability in site territories, were detailed geophysical and geological engineering investigations (seismic, geo-electric, bio-geophysics) were performed (Gorj, Valcea, Prahova, Arges, Buzau and Dambovitza counties).

The methodological requirements for the development of landslide natural risk maps and the content of the relative official documents are described in the following.

- **Name of the document**

The methodological requirements referring to the elaboration and the content of landslides natural risk maps (No.447 from 10/04/2003).

- **Purpose of the document**

To establish the probability of an area to be affected by soil instability phenomena (caused by natural or anthropic factors), in order to be used for the application of risk mitigation and prevention measures, including zoning planning.

- **Users of the document**

Administrative authorities

- **Type of the documents**

The document consists of a report describing the methodology which is used by the Geological Institute of Romania for the development of hazard maps. The document is legally binding.

- **Scale**

Using the methodology, the landslides hazard map was produced at a scale 1:25,000 for regional territory and a hazard map at a scale of 1:5,000 for local areas (towns, villages).

- **Type of hazards. Type and mechanisms of landslides**

There is no information regarding the differentiation between landslide types in the present methodology.

- **Basic documents required**

All documents containing lithological, geomorphological, structural/tectonic, hydrologic and climatic, hydrogeologic, forested, seismic and anthropic impact related information.

- **Methodology**

The methodology used for the elaboration of landslide hazard maps is illustrated in Figure 3-46.

It is based on the following principles:

- the analysis criteria are based on eight factors or criterion (see Table 3-21);
- three degrees of landslides occurrence potential are considered (low, medium, high) and the corresponding probabilities of landslides to occur (from practically zero to very high);
- the risk coefficients K (a - h) are calculated depending on the potential and the probability of landslide occurrence;
- among the triggering landslide factors lithology and geomorphology are considered the most important;
- in order to delimitate an area of the slope, with a specific landslide potential, the average hazard coefficient is calculated, using the following relation:

$$K(m) = \sqrt{\frac{K(a) \times K(b)}{6} \times [K(c) + K(d) + K(e) + K(f) + K(g) + K(h)]}$$

The mentioned relation is used to calculate the average hazard coefficient based on the value of the “risk coefficients K (a - h)” depending on the criterion presented in Table 3-21. As specified, the used terminology is rather unclear.

- the territory for which the hazard map is elaborated is divided into polygonal areas as homogeneous as possible with respect to the factors used for the landslide hazard assessment;
- for each polygonal area the hazard coefficient (K) is evaluated, according to the criteria adopted for analyses;
- finally, using relation (1) the average hazard coefficient of each polygonal area is determined, and the landslide risk map is drawn.

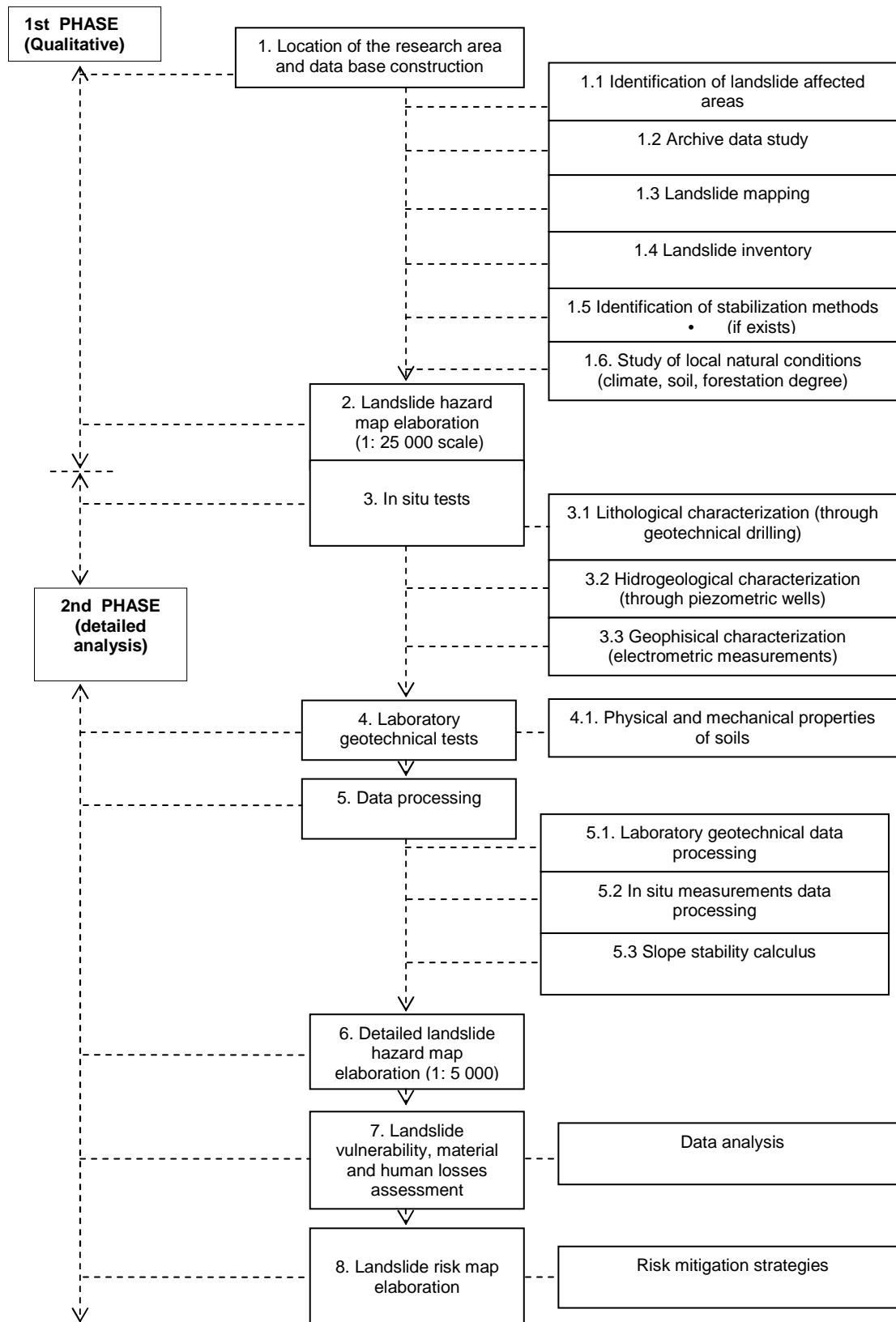


Figure 3-46. Landslide Risk Map Elaboration Phases

Table 3-21. Criterion for landslide potential and probability occurrence assessment

Crt. No.	Symbol	Criterion	Landslide occurrence potential (p)					
			Low		Medium		High	
			Landslide probability occurrence (p) and the corresponding risk coefficient (K)					
			Practically zero	Low	Medium	Medium-high	High	Very high
			0	< 0,1	0,1-0,3	0,31-0,5	0,51-0,8	> 0,8
0	1	2	3	4	5	6	7	8
1	a	Lithologic	Solid, massive, compacted or fissured unweathered rocks	Sedimentary rocks of overlaying formations (deluvial, coluvial and proluvial deposits) and pelitic stratified rocks (clay slate, marls, calcareous marl, chalk); metamorphic rocks (especially epizone and less mesozone schists, highly weathered and exfoliated); some weathered igneous rocks	Detrital sedimentary rocks (unconsolidated – saturated, plastic clays, with high expansive and contractile capacity); montmorillonitic clays; small or medium grain sized loose silt and sand; salt breccia			
2	b	Geomorphologic	Plain relief (hydrographic network integrates mature valleys)	Hilly relief representative for piedmont and plateau areas, edged by medium height slopes with, generally, medium and high declivity	Hilly and mountainous relief, highly fragmented by a dense network of young valleys (most of them, subsequent valleys) with steep and height slopes			
3	c	Structural	Massive igneous rocks; stratified sedimentary rocks with horizontal bedding; metamorphic rocks with horizontal schistosity planes	Most of folded and faulted geological structures affected by cleavage and fissuring; diapir structures; overthrust sheet forehead	Geological structures representative for geosynclines areas in flysch facies and molasse formations from marginal depressions; stratified geological structures highly folded and dislocated, affected by a dense cleavage, fissuring and stratification network			
4	d	Hydrologic and climatic	Generally dry areas with reduced average annual rainfall; the debit flow is strictly conditioned on the precipitation amount; on the river bed, deposition exceeds erosion (lateral erosion only on floods)	Moderate amount of rainfall; the hydrographic network is composed by mature primary valleys, meanwhile, the tributaries are young valleys. During floods, lateral and linear erosion along with important transport and solid discharge are being observed	Long slow rainfall conducive to water infiltration; heavy rainfall with important overflows and solid discharge transport; predominant process: linear erosion			
5	e	Hydrogeologic	Ground water flow at low hydraulic gradients; filtration forces are negligible; confined ground water at great depths	Moderate hydraulic gradients; the equilibrium state of the slope responds to the filtration forces values; phreatic water is situated above 5 m depth	Ground water flow at high hydraulic gradients; water sources are located at the base of the slopes; ground water flow direction is outwards; filtration forces can act as a landslide trigger			
6	f	Seismic	Seismic intensity on M.S.K* scale < 6 th degree	6 – 7 th degree of seismic intensity	Seismic intensity on M.S.K scale > 7 th degree			
7	g	Forestry	Timbering covering > 80%; extended deciduous forests	Timbering covering between 20% – 80%; deciduous and coniferous forests of various age and width	Timbering covering < 20%			
8	h	Anthropic	No important constructions on the slopes; water reservoirs are absent	A number of construction works (road platforms and railroads, coast channels, quarries etc) with limited extension with adequate slope protective measures	Overloaded slopes (dense water supply network and sewerage, roads, railroads, coast channels, quarries, dumps etc; water reservoirs.			

*Medvedev – Sponheuer – Karnik seismic intensity scale (MSK 64)

The synthesis results will be materialized in digital maps of susceptibility to land instability, all data being processed in a Geographical Information System.

At the Geological Institute of Romania studies were developed also at regional and local scale, starting with landslide zoning and the elaboration of landslide hazard maps.

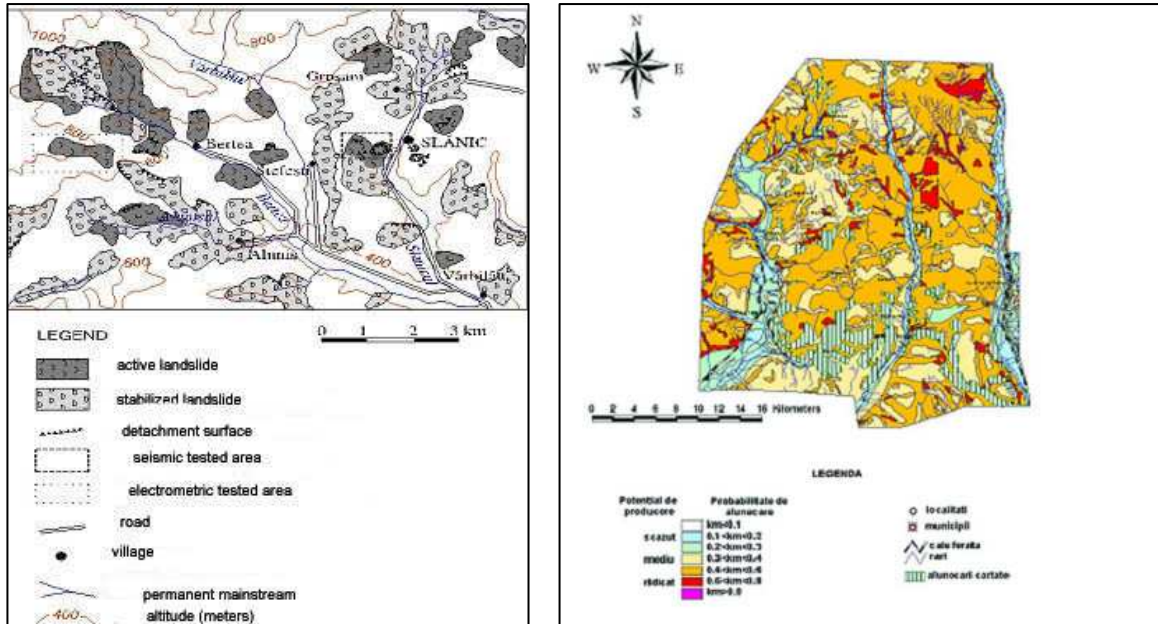


Figure 3-47. Landslide inventory maps and hazard maps at regional scale - 1:25,000 (Getic Subcarpathians, 2004)

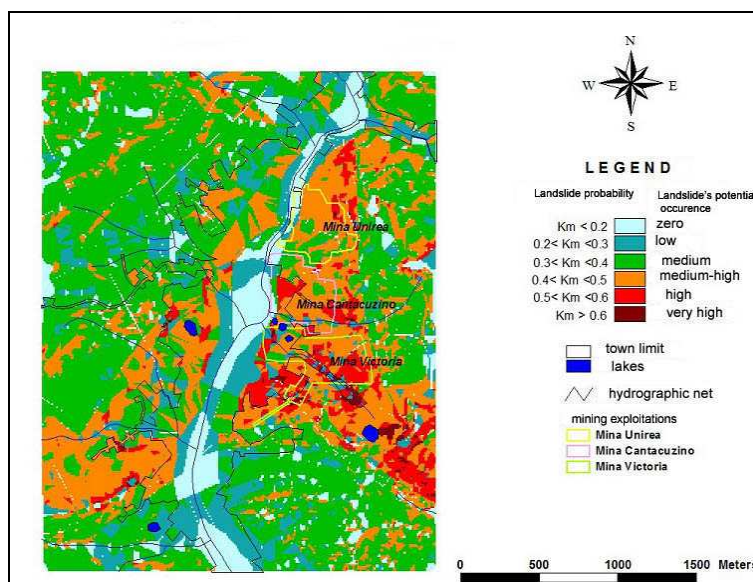


Figure 3-48. Hazard Map (according to HG No. 447/2003) at local scale – 1:5000 (Prahovei Subcarpathians, 2007)

The Romanian legislation which standardizes the means of elaboration of hazard and risk maps assigns eight triggering factors: lithological (Ka), morphological (Kb), tectonic (Kc), hydro-climatic (Kd), hydro-geologic (Ke), forester (Kf), seismic (Kg) and anthropic (Kh).

They are grouped into 3 - 6 classes, according to a standard scale of 0 - 1. The probability of landslide occurrence is calculated by a mathematical relation (1). The thematic maps of the triggering factors, based on the values of the already mentioned factors, grouped into standard intervals (0 - 0,01; 0,01 - 0,1; 0,1 - 0,3; 0,3 - 0,5; 0,5 - 0,8; 0,8 - 1), is meant to create a probability image, at an ideally scale of work (scales larger than 1:25,000 are recommended and the most recent cartographical sources possible).

Using this methodology, the landslides hazard map (scale 1: 25,000) for regional territory, or hazard and risk maps (scale 1: 5,000) for local areas (towns, villages), have been performed. The risk maps represent a standard model to be extended at national level.

Comparing the hazard maps performed on these bases with the active or fossil landslides of the target areas, an overlapping of more than 75% of the last categories over the areas with medium-high, high and very high probability of landslides occurrence is emphasized

Methodological norms

***) Terminology**

*)According to the International Standard Terms Glossary for disaster management, edited by the Humanitary Business Department Geneva 1992, 1993, 1996 under ONU aegis and endorsed by the UE members legislation.

Natural disasters are destructive natural phenomena, which have as a result human and material losses (heavy rainfall, floods, landslides, earthquakes, massive deposits of ice and snow).

A natural hazard is a threat of a naturally occurring event that will have a negative effect on people or the environment. The measure for natural hazard represents the probability of exceeding the characteristically size of one phenomenon in a restricted area and in a given period of time.

The anthropic hazard refers to a certain phenomena, usually natural disasters, which state was affected by the human activities. This phenomenon has a large scale of development; it grows from climate changes, regarding the modification of the rainfall regime (slightly influenced by human actions), to nuclear explosions (total anthropic influence).

The areas that are exposed to natural hazard are geographical limited. In this regions the intensity of the values that feature the natural phenomenon is highly raised, however the risk to produce excessive damages is small.

The areas exposed to landslides are regions with high values to slide probability.

The areas exposed to natural risk or *natural risk zone* are geographical delimited regions in which the intensity of the values, that characterize the naturals destructive phenomena, is high, leading to material and human lives losses.

The elements that run a risk to natural hazard represent all the material and persons that can be affected by the natural phenomenon that can occur.

The elements that run a risk to landslides represent all the material goods and persons that can be affected by the landslide that can occur.

The destructive features of a natural phenomenon that engender losses is represented by that specific magnitude of the phenomenon which produces losses when interacting with the constructions structures. As an example we take the floods that have two destructive characteristics: the height of water spout and also the velocity field; the landslides that develop slowly have distinctive movements.

The destructive features of a landslide represents that specific magnitude of the phenomenon which produces losses when interacting with the constructions structures: the distinctive field movement for landslides that develop slowly, subsidence shift for regressive development, the kinetics energy of the sliding masses for fast landslide.

The vulnerability represents the damage degree (from 0% to 100%) caused by a susceptible phenomenon that generates human and material losses.

The vulnerability of the elements exposed to different destructive features represents the amount of elements affected by the natural phenomenon that causes damage. Vulnerability is a sub-unit value, noted with 0 if the elements are unaffected or with 1 if the elements are entirely damaged (lost lives and ruined constructions).

The vulnerability to landslide represents the degree of affected elements exposed to landslide action.

The risk represents the mathematical estimation of the probability to produce human and material loss for a given region and period of time lied to a certain disaster. The definition of the risk applied to a certain phenomenon is the product between the probability to cause human and material losses and the value of those losses.

The associated risk to landslides represents both the material and potential human loss caused by the appearance of these natural phenomena.

1. When the material and human loss are directly associated with landslides the risk is the product between the probability to slide and the value of human and material losses:

$$R(m) = P(al) \times \sum PM \text{ (RON/year)}$$
$$R(u) = P(al) \times \sum PM \text{ (human losses/year)}$$

where:

Pal = probability to landslide

V= vulnerability of the exposed elements

PM = maximum material losses caused by total destruction of exposed elements

PU = human losses

Rm = annual rate of material losses

Ru = annual rate of human losses

RON = national currency.

When it concerns primary slow development of landslides, or reactivated landslides, the damages both material and human are not maximum. The vulnerability of the affected structures by this type of landslide can be expressed according to the intensity of the destructive characteristics. Having in mind that vulnerability is a random variable that depends on the variation of stress (S) and resistance (R) of the affected slope, it will result the probability and vulnerability curve of destructive characteristics. In this case the mathematic relations are:

$$R_m = P_{dep} \times \sum V_j \times PM$$

$$R_u = P_{dep} \times \sum_{j=1} V_j \times PU_j$$

where:

P_{dep} = probability of outrunning of destructive characteristics

PM = maximum material losses caused by total destruction of exposed elements

PU = human losses

R_m = annual rate of material losses

R_u = annual rate of human losses

The sum refers to the total amount of the exposed elements to landslide hazard.

The natural risk maps represents contour lines regarding the geographical plane distribution of the probability values to produce human and material losses caused by the appearance of natural phenomena which generate loss, value specific to each natural phenomena and each destructive characteristics.

The natural risk maps represents contour lines regarding the geographical plane distribution of the probability values to produce human and material losses caused by the appearance of natural phenomena which generate loss. For areas which are simultaneously exposed to many natural destructive phenomena the risk values can assemble.

The hazard landslide maps represents contour lines regarding the geographical plane distribution of the probability sliding values or the probability to outrun the specific destructive characteristics, generating losses.

The landslide associated risk maps represents the plane distribution of the potential annual values of material and human losses, caused by the landslides.

- **Hazard matrix**

No hazard matrix is used.

- **Hazard levels**

They exist 3 - 6 classes, according to a standard scale of 0 – 1 (see legend).

- **Legends**

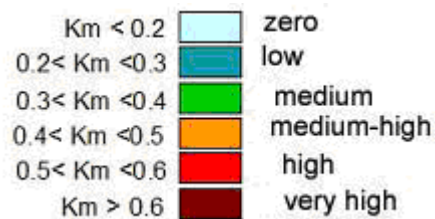


Figure 3-49. Legend used for (susceptibility? or hazard?) maps in Romania

3.7 SPAIN - CATALONIA

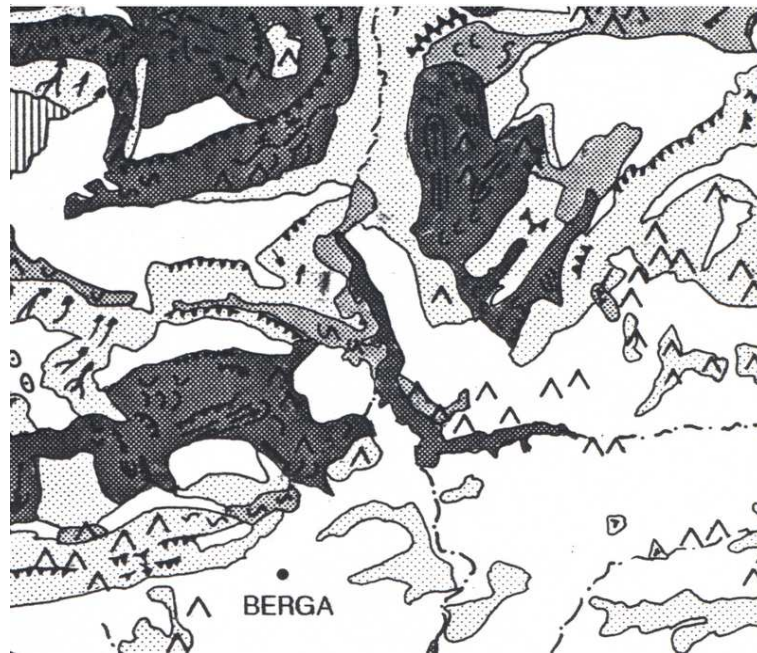
(contributor: UPC)

Spain is organized in autonomous regions. The region of Catalonia has authority over regional planning and land development, and on civil protection. In what concerns the landslide risk management, the Catalanian autonomous administration has followed a different strategy. These strategies have been conditioned by the availability of land, the pressure for development and the socioeconomic impact of the previous landsliding events.

An indispensable requisite for the appropriate landslide risk management is the availability of both landslide inventories and maps. Catalonia region have promoted landslide hazard maps. In 1985, the Department of Public Works and Urban Planning of the Catalanian government commissioned the preparation of natural hazard maps for the Eastern Pyrenees. Ten counties were mapped at 1:50,000 scale (Corominas, 1985). The phenomena analyzed were landslides, snow avalanches, floods and sinkholes and the methodology followed a heuristic approach. The different hazardous phenomena were identified and located using aerial photographs, and checked with field work. Concerning to the landslides, four hazard levels were established based on the presence of large active movements, large dormant movements, shallow landslides, and areas where instability processes have not been identified (Figure 3-50). Due to the working scale only large landslides or long landslide tracks were represented with their real boundaries. Most of the landslide phenomena were plotted with areal symbols (i.e. area affected by shallow landsliding).

In 2002 the Catalanian Geological Institute (CGI) started updating these maps, which have been renamed as county maps for the prevention of the geological hazards. The new generation of maps include the same processes plus the basic seismic acceleration. At present, 13 counties have been completed.

In Catalonia, the Geologic Institute of Catalonia (Institut Geològic de Catalunya - IGC) has the responsibility of studying and evaluating the geological and associated risks, including the risk due to avalanches. More specifically, there exist various norms that, for their application, they make reference to the presence of geologic and other natural hazards: i.e. the Urban Law (Text Refós de la Llei d'Urbanisme -TRLU), approved by decree in 2005 and modified in 2007 and the Regulation of the Urban Law, approved by decree in 2006.



*Figure 3-50. Fragment of the Natural Hazard Map at 1:50,000 scale (Corominas, 1985).
Hazard levels increase with the density of the hachure.*

To this purpose the creation of Prevention Maps from the Geological Risks of Catalonia in the scale of 1:25,000 (Mapa de Prevenció de Riscos Geològics de Catalunya (1:25,000)) and the development of the related Information System was assigned to the IGC.

The Prevention from Geological Risks Map of Catalonia (MPRGC) was conceived as a multi-risk map that outlines all the geological risks at the territory and identifies the areas that are susceptible to hazardous events that may generate risk situations. The project initiated on 2007 and will be completed by 2011. Since it is a recent project the intention has been to integrate new technologies and concepts for the production of the maps.

The term “Prevention from Geologic Risks” is used as indicator of the qualitative rating of the hazard levels for various hazards. A detailed study is recommended for the areas that are identified as of high hazard and that coincide with the presence or the future planning of infrastructures.

A description of the hazard evaluation in Catalonia is following.

- **Name of the document**

The Geological Risk Prevention Map of Catalonia.
(Mapa de Prevenció de Riscos Geològics de Catalunya-MPRGC)

- **Purpose of the document**

The purpose of the document is to support the urban and land planning.

- **Users of the document**

The document is intended to be used by administrative authorities, companies and professionals as a support tool for the planning of the territory of public works. Given that it is an on-going project, the documents are not yet available to the authorities and the public.

- **Type of the document**

For the project, Catalonia was divided into 304 sectors and the hazard maps for each one will be created. The maps provide a qualitative rating of the hazard levels, for different kinds of hazards. A detailed study is recommended for the areas that are identified as of high hazard and that coincide with the presence or the future planning of infrastructures. The character of the document is recommending and not legally binding.

- **Scale**

The scale of the maps is 1:25000. The areas where a detailed study of scale 1:10000 is needed will be indicated on the maps.

- **Type of hazards. Type and mechanisms of landslides**

Types of hazards:

- A. Slope movements
- B. Torrents
- C. Settlements
- D. Avalanches
- E. Floods
- F. Earthquake

Types and mechanisms for landslides:

- 1) Rockfalls
- 2) Landslides
 - Rotational
 - Translational
- 3) Flows
 - Debris flow or rockflows or earthflows
 - Creep
 - Liquefaction
- 4) Complex movements
 - Rotation and flow
- 5) Others
 - Lateral spreading

- **Basic documents required**

- Topographic maps at scale 1:25,000
-

- Topographic maps at scale 1:10,000
- Aerial photos. 1957 (1:33,000), 1977 (1:17,000) and 1985 (1:22,000).
- Orthophotomaps at scale 1:5,000
- Geologic map at scale 1:25,000
- Digital Elevation Model 5x5
- Seismicity map for an average soil
- Geo-anthropologic map at scale 1:25,000
- Existing information on the Document Management System of the IGC (information of geological risks, flood studies, technical notes on concrete incidents, studies on geological hazard, reports of technical and investigation projects).
- Information provided by historical documents
- Other bibliographic sources.

• **Methodology**

The general methodology for all hazards includes the following steps:

- a. Bibliographic and cartographic research
- b. Photo-interpretation study
- c. Survey
- d. Field work
- e. Phenomena inventory and evidences (Inventari de fenòmens i indicis)
- f. Susceptibility analysis
- g. Hazard analysis
- h. Digitalization
- i. Reporting (memòria)

Detailed step-by-step instructions are provided for the evaluation of the hazard for each one of the hazard phenomena and landslide mechanism separately.

• **Hazard matrix**

The hazard matrix is the following:

Table 3-22. Hazard Matrix for Catalonia

		Frequency		
		low	moderate	high
Magnitud	low	low hazard	low hazard	low hazard
	moderate	low hazard	moderate hazard	moderate hazard
	high	moderate hazard	high hazard	high hazard

For the superposition of hazards due to different phenomena in the same zone, a graphical representation was established for the identification of the zones where there superposition was made and for the indication of the greatest hazard:

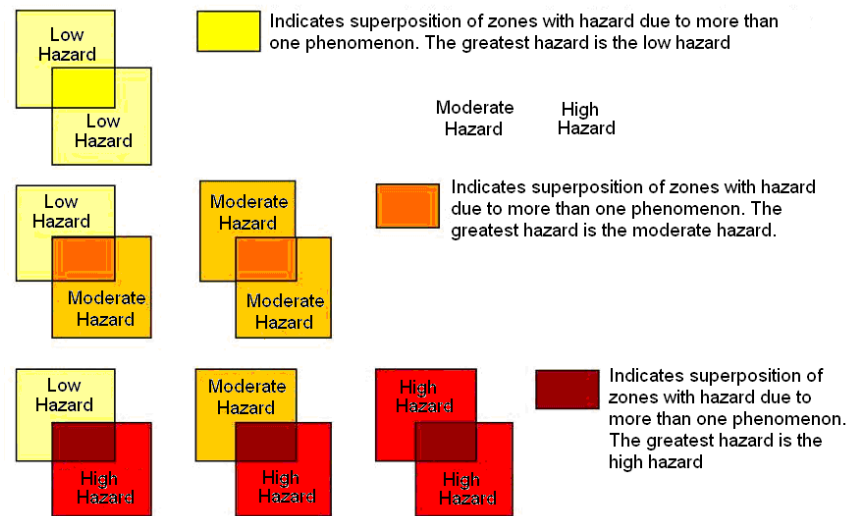


Figure 3-51. Superposition of zones with hazard due to more than one phenomenon

- Hazard level**

Three different levels:

- Red: High hazard
- Orange: Moderate hazard
- Yellow: Low hazard

The thresholds for differentiate one level from the other depend on the landslide type.

- Legends**

For the slope movements, the legend indicating the phenomena which are attributed with a hazard level:

-  Esllavissades (Landslides)
-  Esllavissades superficiales (Shallow landslides)
-  Despreniments (Rockfalls)
-  Allaus (Avalanches)
-  Fluxos torrencials (Torrents)
-  Esfondraments (Collapses)
-  Inundabilitat (Floods)

3-52. Legend used for hazard maps in Catalonia

- Zoning, recommendations-restrictions**

Zoning levels are used to indicate whether activities are allowed or not. A detailed study is recommended for the areas that are identified as of high hazard and that coincide with the presence or the future planning of infrastructures.

References

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3.8 SWITZERLAND

(contributor: ETHZ)

Background and objectives

In the Swiss political system, the community level administrations that exist below the cantonal level bear the first direct responsibility for risk management of events associated with natural hazards (except earthquakes). The basic structure, legal frameworks and recommendations for prevention/protection actions as well as financial support and subsidies for all associated activities are provided by the higher cantonal or federal authorities (Leroi et al., 2005). This involvement of the higher cantonal or federal authorities ensures a certain level of homogeneity in the consideration of natural hazards; at the same time, it also gives the local communities the necessary independence and space to plan, design and implement measures appropriate for their regions.

The procedures, guidelines and recommendations for hazard assessment of landslides and other hazards characterised by mass movements are provided in a federal/national document in German titled “Empfehlungen 1997 : Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten” (Recommendations 1997 : Consideration of mass movement hazards in spatial planning and development activities) (BRP, BWW and BUWAL, 1997) jointly published by the Bundesamt für Raumplanung (now known as the Bundesamt für Raumentwicklung (ARE) – Federal Office for Spatial Development), Bundesamt für Wasserwirtschaft (now part of the Bundesamt für Umwelt (BAFU) – Federal Office for the Environment) and the Bundesamt für Umwelt, Wald und Landschaft (now part of the Bundesamt für Umwelt (BAFU) – Federal Office for the Environment). This document is available in German and French.

Further, the structure of a uniform register of landslide events has been developed, including special datasheets for each phenomenon (slides, rock falls, debris flows) and each canton is currently compiling the data for its own register. These databases, called “StorMe”, are transferred to the Swiss Agency for the Environment, Forests and Landscape to allow an overview of the different natural disasters and potential associated damage in Switzerland (Lateltin et al., 2005).

In Switzerland, the responsibility for developing landslide hazard maps rests with the cantonal authorities. Some cantons (for example – Fribourg (<http://www.geo.fr.ch/>), Schaffhausen (<http://www.sh.ch/GIS-Karten-und-Plaene.663.0.html>)) have made these maps available online in .pdf or .svg formats on their administration portals. However not all the cantons in Switzerland are yet to publish these maps online.

- **Name of the document**

“Empfehlungen 1997 : Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten” (Recommendations 1997 : Consideration of mass movement hazards in spatial planning and development activities) (BRP, BWB and BUWAL, 1997) jointly published by the Bundesamt für Raumplanung (now known as the Bundesamt für Raumentwicklung (ARE) – Federal Office for Spatial Development), Bundesamt für Wasserwirtschaft (now part of the Bundesamt für Umwelt (BAFU) – Federal Office for the Environment) and the Bundesamt für Umwelt, Wald und Landschaft (now part of the Bundesamt für Umwelt (BAFU) – Federal Office for the Environment).

- **Purpose of the document**

The four main elements of the natural hazard risk management strategy in Switzerland can be identified as hazard assessment, definition of protection requirements, planning of measures and emergency planning (Lateltin et al., 2005). The underlying basis of Swiss national/federal laws on forest and flood protection is to ensure the protection of people, assets, infrastructure and lifelines as well as the environment from different natural hazards. This is translated into implementable form in additional federal ordinances on flood and forest protection which stipulate the establishment of hazard maps by the cantonal or regional level authorities; these hazard maps are also required to be incorporated in regional master plans and local development plans.

- **Users of the document**

Administrative national and local authorities and public.

- **Type of the documents**

In Switzerland, the landslide hazard and zoning maps are not legally binding documents in themselves. However when used in conjunction with land use planning and applications for construction / building permits, they acquire a legal character consistent with the laws and regulations governing land use planning and development activities.

The following paragraph has been adapted from (Leroi et al., 2005). Since 1991, federal regulations require the 26 cantons in Switzerland to establish hazard maps and zoning for mass movements so as to restrict development on hazard-prone land. Mapping work is still in progress; the consideration of landslide hazard maps is carried out at the community level through the mandatory ten year revision process of the local land management plan. All proposed revisions need to be voted in the communal council so as to receive a popular

approval. These approved local land management plans are then submitted for approval to the cantonal authorities. Following this approval, the actions laid out in the revised local land management plan (in the form of inclusion of hazard zones and/or inclusion of specific rules) are required to be followed for any development activity in the community.

- **Scale**

The scale used for the maps is, in general, 1:25,000. In a few specific locations, maps of smaller scales (for instance, 1:100,000) also exist.

- **Type of hazards. Type and mechanisms of landslides**

The classification of landslides is made in the Swiss recommendations BRP, BWW and BUWAL (1997) on the basis of different parameters. According to the estimated depth of the slip surface, slides can be classified as shallow if the depth is less than 2 m, intermediate if the depth is between 2 m and 10 m and deep if the depth is greater than 10 m. If the long-term mean velocity of the movements is used as the parameter for classification, the three categories are sub-stabilized (less than 2 cm/year), slow (2–10 cm/year) and active (greater than 10 cm/year).

Rock falls are characterized by their speed (between 10 and 40 m/s), the volumes involved (between 100 and 100,000 m³) and the size of their elements (stone diameter if less than 0.5 m, block diameter if greater than 0.5 m). Rock avalanches are defined as events with huge volumes (greater than 1,000,000 m³) and rapid velocity (greater than 40 m/s).

- **Basic documents required**

Landslide phenomena maps, register of slope instability events, topographic and geological maps, digital elevation models.

- **Methodology**

Hazard quantification and development of hazard maps

The hazard quantification process involves the determination of the magnitude or intensity of the hazard event over time. This is usually done by modeling the involved processes using a mathematical, physical and/or empirical model which is calibrated using historical information.

The results obtained from the hazard quantification process are classified into an appropriate hazard class. A hazard map is then obtained by depicting the hazard class for different locations on a geographical map. Such a map is used for the planning of the necessary emergency, protection and/or prevention measures against the considered natural hazards. An example of an intensity map and hazard map is shown in Figure 3-53; this figure has been taken from Loup and Raetzo (2009).

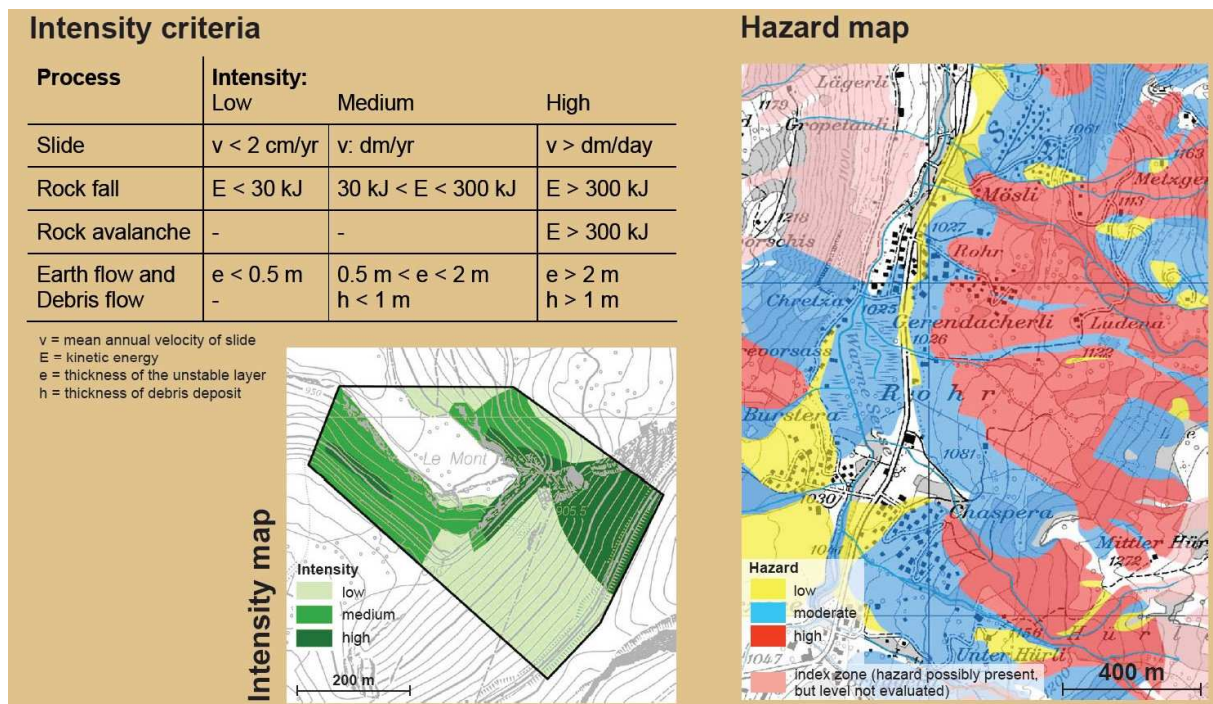


Figure 3-53. Example of an intensity map and hazard map (Source : Loup and Raetzo, 2009)

• **Hazard matrix**

The significant criteria used in the case of slides are the mean annual velocity and/or the horizontal displacement whereas the kinetic energy on impact is used for rockfall events. The criteria for the intensity of different landslide hazards and the corresponding magnitudes as suggested in the Swiss recommendations BRP, BWW and BUWAL (1997) are given in Figure 3-54; this figure has been taken from Lateltin et al. (2005).

Process	Intensity		
	Low	Medium	High
Rock falls			
Kinetic energy	<30 kJ	30 - 300 kJ	>300 kJ
Slides			
Mean annual velocity	<2 cm/year	2 - 10 cm/year	>0.1 m/day
Displacement	-	-	>1 m/event
Debris flow			
Debris front thickness	-	<1 m	>1 m
Debris flow velocity	-	<1 m/s	>1 m/s
Depth of soil material (potential debris flows)	0.5 m	0.5 - 2 m	>2 m

Figure 3-54. Criteria for intensity and magnitudes for different landslide hazards (Source: Lateltin et al., 2005)

Corresponding to three ranges of return periods 1 – 30, 30 – 100 and 100 – 300 years, three levels of probability of occurrence are considered and denoted as high, medium and low

respectively. For a given reference period n (values of 30 or 50 years are suggested in the Swiss recommendations BRP, BWB and BUWAL (1997)), the relationship between the probability or occurrence p and the return period T can be expressed as:

$$p = 1 - \left(1 - \frac{1}{T}\right)^n$$

For the different landslide hazards, the standard levels for the intensity and return period are combined in a matrix diagram to yield five hazard classes (as identified in the Swiss recommendations BRP, BWB and BUWAL (1997)) – high hazard (red), moderate hazard (blue), low hazard (yellow), residual hazard (yellow-white hatching) and no known hazard (white). This is shown in

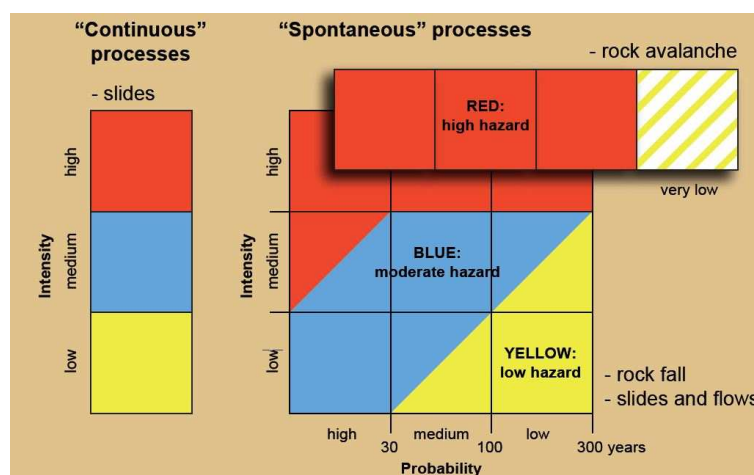


Figure 3-55. Matrix diagram combining intensity and probability of occurrence (Source: Loup and Raetzo, 2009)

• **Hazard levels**

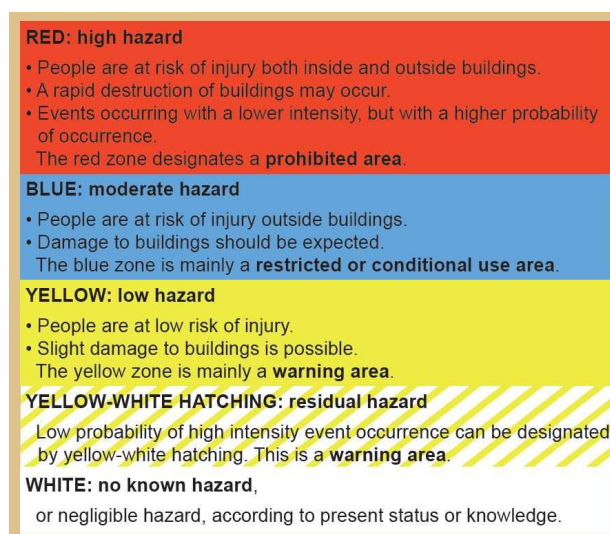


Figure 3-56. Description of hazard classes (Source: Loup and Raetzo, 2009)

The intensity of a hazard is categorised into one of three different levels – high, medium or low. This classification is based on the selection of an appropriate criterion or parameter that is identified to be the most significant for the hazard under consideration, usually based on the physical considerations associated with the process.

Two more classes are used to express residual and not known hazard. The five hazard classes correspond to different degrees of danger to people, assets, and infrastructure which are described in the following figure; this figure has been taken from Loup and Raetzo (2009).

- **Legends**

The following legend is used for the hazard maps.

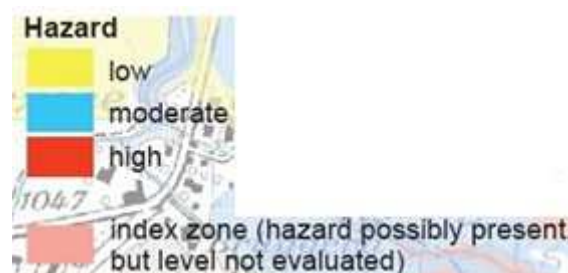


Figure 3-57. Legend used for Switzerland hazard maps

- **Zoning**

Zoning is related to the hazard classes or levels described in Figure 3-53. In the red zone or the prohibition zone, no construction or installation activity is allowed. In the blue zone or the restricted zone, buildings are allowed only under certain conditions depending on the nature of the hazard. The yellow zone is the warning zone where land development and construction is possible but landowners need to be informed of the existing hazards.

References

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3.9 UNITED KINGDOM

(contributor: TRL)

Introduction

National landslide database and landslide hazard assessment for Great Britain

In the UK there is no legal requirement or regulation for the production of landslide hazard maps. However, the British Geological Survey (BGS) have developed the National Landslide Database and the Landslide Hazard Assessment for Great Britain.

National Landslide Database

The National Landslide Database covers Great Britain (Scotland, England, and Wales but not Northern Ireland) and is maintained by the BGS to document landslides across this area. The primary source of information is the National Digital Geological Map (DiGMap) at 1:10,000 scale (DiGMap10) and 1:50,000 scale (DiGMap50). This has been supplemented by other data collected through media reports, site investigations, journal articles, information from the public, and some regional databases which were inherited or compiled by the BGS since the 1970s, and new direct field mapping. (Foster et al., 2008).

Each landslide within the database is documented as fully as possible with information on location, name, size and dimensions, landslide type, trigger, damage caused, movement date, age and with full bibliographic reference. BGS geologists are required to complete a pro-forma on which to record data on any landslide mapped; however, it is appreciated that time constraints can sometimes mean that only some of the relevant attributes are collected. Up to 70 different types of spatial, temporal, physical and environmental data (also, where available information on socio-economic impacts) are stored within the database. The database is the linked to a GIS which displays the landslides as point data. (Foster et al., 2008).

Since the data is stored within a fully relational ORACLE database it can be accessed through typological (Microsoft Access) or geographical (ArcGIS) interfaces. Operation of the database complies with regulations that govern national archive databases in UK whereby each data table is linked to a history table that records all changes made to the database (allowing for auditing of all information within the database). (Foster et al., 2008).

The National Landslide Database uses BGS standard dictionaries for lithological and stratigraphical nomenclature, and nationally and internationally recognised dictionaries used for other data tables (eg location, damage type). Where possible, details of each landslide are recorded using terminology from the World Landslide Inventory. (Foster et al., 2008).

Landslide Hazard Assessment for Great Britain

- **Name of the document**

Using the National Landslide Database the BGS have undertaken a Landslide Hazard Assessment for Great Britain, which is presented as GeoSure.

- **Purpose of the document**

To identify areas which are susceptible to landslides and other geohazards across Great Britain.

- **Users of the document**

GeoSure is used by Government planners, insurance companies, and utility operators, and is available to citizens through online “resellers”. For the most part GeoSure is accessed through automatically generated reports for a given location (BGS GeoReports). (Foster et al, 2008)

- **Type of document**

GeoSure is a GIS based model. The results of the model are stated to be purely for information and as having no legal implications.

- **Scale**

The GeoSure model has a 1:50,000 working scale. The multi-criterion analysis was completed using grids which were then converted to a polygon file for distribution and use. Polygons have a pixilated form inherited from the grid which is considered helpful in enforcing the resolution of the data (i.e. when a user zooms beyond 1:50,000 it will have a very blocky appearance) (Foster et al., 2008).

- **Type of hazards. Type and mechanisms of landslides**

GeoSure covers the following geohazards:

- Collapsible deposits;
- Compressible ground;
- Landslides (slope instability);
- Running sand;
- Shrink swell; and,
- Soluble rocks (dissolution) (BGS, n.d. a).

In the case of landslides failures in earth, rock, and debris are included. It encompasses the following mechanisms:

- Falls
- Topples
- Rotational slide (slumps)
- Translational (planar) slides
- Spreads
- Flows
- Complex slides (BGS, n.d. a).

- **Basic documents required**

The key causative factors which have been used in the model are:

- Slope angle: Derived directly from NEXTMap digital terrain model of Britain (original resolution of 5m, which was resampled to 25m for use in GeoSure as it was too memory intensive);
- Geology: Digital geological polygons assigned a score based on potential of that material to fail (taking strength, permeability, and known susceptibility of lithologies into account along with slope angle); and,
- Discontinuities: Detailed information is not consistently available for most rock types across Great Britain. Categories defined in accordance with British Standard 5930: Field Description of Rocks and Soils (BSI, 1990) and Bieniawski's Engineering Rock Mass Classifications (1989) (Foster et al., 2008).

As such the documents that are required include NEXTMap digital terrain information, geological information, and discontinuity information either site specific or inferred.

- **Methodology**

Landslide hazard in GeoSure was developed by the BGS (Foster et al., 2008) using elements of both deterministic and heuristic approaches:

- Heuristic: Expert judgements were used to assess and classify the hazard and determine likely causative factors of landsliding.
- Deterministic: The presence of causative factors is assessed in the GeoSure model and rated according to its relative importance (in causing slope instability). Although described by the authors as 'deterministic' this clearly contains elements of heuristic judgement and might be better described as 'Deterministic/heuristic' or 'Semi-deterministic'.

The factors listed above were then combined using a multi-criterion technique which applies a series of rules against the available data to provide a hazard 'score' for each location in Britain where high scores indicates that the conditions mean there is a potential for future sliding (and does not define whether sliding has happened in the past or will occur in the future). Problems were encountered with slope modelling due to tree stands and man-made embankments although the issue with trees has been largely rectified. (Foster et al., 2008)

- **Hazard matrix**

No information has been found to be publicly available regarding the combination and weighting of the factors within the hazard matrix.

- **Hazard levels**

For landslides GeoSure has 5 hazard levels ranging from A (low) to E (high) (BGS, n.d. b).

- **Legends**

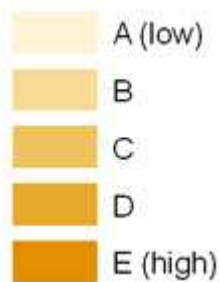


Figure 3-58. Legend used for hazard mapping

- **Zoning**

The results of GeoSure are not used for the purposes of zoning areas for development. Instead, this matter is covered by Planning Policy Guidance (PPG) 14.

Planning policy guidance: development on unstable land

In the United Kingdom the issue of development on unstable land is covered by Planning Policy Guidance (PPG) 14: Development on Unstable Land (DoE, 1990), with landsliding considered in more detail in the supporting document Annex 1: Landslide and Planning (DoE, 1996).

PPG 14 relates to the three main causes of ground instability:

- Underground cavities;
- Unstable slopes; and,
- Ground compression.

Both natural and man-made causes are considered (DoE, 1990). Ground instability has been recognised as a hazard due to its potential direct risks to humans and buildings/services, and associated indirect risks. It is acknowledged in the Guidelines that development itself may trigger instability in locations where it has not previously been reported.

Landslide classification as used in the Guidelines is based primarily on the type of movement ie mode of failure and landslides have been divided into:

- Falls;
- Slides; and,
- Flows.

It is recognised that a landslide can contain a combination of these movements. A further sub-division is cognisant of the importance of the slide material itself which is divided in the Guidelines into:

- Rock (bedrock) ,
- Debris (coarse engineering soils), and
- Soil (fine engineering soils).

The Guidelines provide advice to local authorities, landowners and developers on the way in which UK planning controls can be exercised where development is proposed on land which

is known to be unstable, or which is considered potentially unstable. They place responsibility for determining whether or not the land is stable with the developer, who is required to undertake appropriate investigation in order to determine whether or not it is stable. Local authorities are not responsible for investigating ground conditions at a development site although they have the power to control most developments, and they are responsible for controlling certain aspects of development through the Building Regulations and Housing Acts. Should it be determined that the land is potentially unstable the onus is on the developer to ensure that this is overcome within the scope of the proposed development by either appropriate remedial or preventative measures being implemented, or in the extreme by avoiding development altogether. (DoE, 1990).

Planning control in the UK is exercised by granting or withholding planning permission for a development. One of three outcomes can be set down by planners as detailed in the Guidelines:

- Planning permission granted without conditions: The development is not adversely affected by instability, nor will it adversely impact the stability of neighbouring ground.
- Planning permission refused: Instability cannot be overcome.
- Planning permission granted subject to conditions: The conditions are those measures that would be required in order to make the otherwise potentially unstable ground safe for development.

PPG 14 Annex 1: Landslides and Planning (DoE, 1996) relates specifically to landslides and unstable slopes in the context of the UK planning system, and in conjunction with PPG 14 are in place to advise local authorities, landowners and developers on land use and development planning controls for sites that are on or adjacent to unstable and potentially unstable slopes. They provide supplementary information on the hazard and the way in which it can be dealt with.

In the UK, Building Regulations and the planning system are the main strategy in ensuring the risk of slope instability is dealt with appropriately. However, the Building Regulations alone do not cover all relevant aspects of slope stability largely because some buildings are exempt from the Regulations, and many activities which are pertinent in slope stability do not require approval under Building Regulations. As such, the planning process comes into its own in ensuring that slope stability is addressed in development. (DoE, 1996)

Annex 1 (DoE, 1996) also provides guidance for local planning authorities who are keen to, or for whom it would be pertinent to, assess landsliding within their area of jurisdiction. A phased approach which has been implemented successfully in the South Wales Coalfield and at Ventnor, Isle of Wight is described as summarised below:

1. Preparation of a landslide inventory;
2. Consultation of BGS maps and records as well as other bodies and information sources;
3. Use of aerial photography interpretation, with field inspection and reconnaissance geomorphological mapping to supplement as necessary;
4. Trial trenching within the development site in areas which have previously been affected by periglacial solifluction where numerous shear surfaces may be present at relatively shallow depths;

5. Consideration of other key slope stability factors: e.g. slope angle (DoE, 1996).

Development on unstable land, including that which is designated as unstable due to landsliding, is therefore prevented by a combination of Building Regulations and local authority Planning Controls. PPG 14 has only been in place since 1990 therefore it is implied that developments prior to this date may not satisfy current requirements. Even now a small number of developers do not operate fully within what is required of them. Furthermore, developers, planners, and all others involved in the decision making process are reliant on being provided with robust information gathered from reliable sources.

Example: Scottish road network landslide study: Hazard assessment

The methodology used to create GeoSure and that described in PPG 14 do not define how landslide hazard is assessed in the UK. Landslide hazard assessment can be tailored to specific requirements, a good example of which is the Scottish road network landslides study.

The Scottish Road Network Landslides Study (SRNLS): Implementation (Winter et al., 2008a) report presented the methodology utilised for a Scotland wide debris flow hazard assessment. The study was implemented following a series of debris flows in 2004 which impacted the Scottish trunk road network.

The hazard assessment was initially undertaken by the BGS and the study's working party using a GIS-based assessment to identify areas with the potential for triggering debris flows using three data sources were used during this stage:

- BGS DiGMap;
- NEXTMap Britain; and,
- CEH (Centre of Ecology and Hydrology) land use data (Harrison et al., 2008).

The five key components that contribute to debris flow hazard in Scotland were focussed on and included:

- Availability of debris material;
- Hydrogeological conditions;
- Land use;
- Proximity of stream channels; and,
- Slope angle (Harrison et al., 2008).

Utilising the knowledge and experience of the working party each of the 5 factors listed above were weighed such that the relative importance of each could be expressed. Different scenarios could then be modelled, which were validated by real-world examples known to members. (Harrison et al., 2008)

The five factors above were combined in a GIS such that their distribution could be analysed, and in order to spatially combine their contributing hazard scores, using grids with 25m cells. The result was a 1:50,000 scale model with a legend which summarised the data into 5 classes ranging from A (least potential to initiate debris flow landslides) to E (highest potential to initiate debris flow landslides). The model was considered a success as it identified the areas of the 2004 events as being of high potential to initiate debris flows. (Harrison et al., 2008)

Intrinsic to the study was the need to relate the hazard assessment to the 3,200km trunk road network. The GIS-based model therefore provided a starting point for more detailed hazard assessment along the road network. This desk based study comprised the inspection of the entire road network using:

- The GIS output layer from the hazard assessment;
- 1:50,000 scale Ordnance Survey digital mapping; and,
- Low resolution aerial photographs where available (Winter et al., 2008b).

In doing so the spatially distributed potential for debris flow triggering conditions could be linked to on-the-ground factors such as flow paths to the section of road in question (Winter et al., 2008b). For areas in which the GIS study showed a potential hazard an assessment of whether the hazard could reach the road network could therefore be made from which sections of road could be categorised as:

- Main study: Lengths of route where significant potential hazard was identified;
- Opportunistic: Sections of road where the hazard was too low to justify a main detailed study within the project, but which should be considered and reassessed if and when any major works are proposed; and,
- Other: Assessment determined that no potential hazard was present and, in terms of the road network, the site was benign (Winter et al., 2008b).

The main study sites were then further assessed for the severity of the potential hazard and were ranked accordingly (1: most severe to 4: lesser severity). This allowed sites that required further, specific study to be identified (Winter et al., 2008b).

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4 RISK ASSESSMENT PRACTICES

In comparison with the landslide hazard assessment reviewed in section 3, the official risk assessment practices are scarce in the European area. This is due to the relatively less information on vulnerability issues. In this section the risk assessment practices that have been adapted by National authorities (France, River Basins of Arno, Liri-Garigliano and Volturno River Basins in Italy) are presented.

4.1 FRANCE

In France, the PPRN (“Plans de Prévention des Risques Naturels” or risk prevention plans) that is described in section, besides the hazard map, include the elaboration of the Map of major asset, which permits the landslide risk assessment. At section 3, there is provided information concerning the risk prevention at local and regional level.

Map of major asset

The inventory of the stakes consists in analyzing the landuse characteristics considering both the existent and the future developments.



Figure 4-1. Example of Risk map with the PPRN RAM.

This analysis allows identifying the major assets such as establishments receiving public (hospital, schools, campsites, etc), strategic buildings (fireman's barracks, water drinkable tanks, etc), and areas of major economic activities (industrial buildings, etc) as well as the communication capabilities (roads, railways, power roads, etc) which threatening may aggravate the risks during a major event.

The cross-correlation of the hazard map and the map of major assets allows identifying qualitatively the main risk areas to be protected. The risk zoning consists in three risk classes (red, blue, white) and delineates zones in which prevention measures have to be taken.

Thus, red zones can concern zones where the measures of prevention are impossible or too costly, so no construction will be authorized.

Risk prevention plan at local level

In France, the PPRN (“Plans de Prévention des Risques Naturels” or risk prevention plans) are the reference tools of the State for the regulation of zones subject to natural hazards, and notably to landslide hazards.

The administrative division level in charge of the implementation of PPRN is the “département” (territory around 6,000 km² in average that includes around an undred of townships). The State is represented at this level by a “préfet” who is responsible for all decision involving the state at “department” level. He is supported and technically advised on PPRN issues by the departmental division of public works designated as DDE (“direction départementale de l'équipement”).

It is the "préfet" who can prescribe a PPRN for a township of his "département" if he judges it necessary (for example if an important event occurred in the past in the town territory, or if an evaluation of the landslide hazard at a coarse scale underlined high hazard zones within the town area). These plans are financed by the State. However, even if the town is not involved in the financing of PPRN studies, a PPRN is not necessarily considered very advantageous by the town representatives: the PPRN zoning could imply the depreciation of some areas if declared not suitable for construction by the study. Consequently, the town representatives are also part of the decision of prescribing a PPRN in an area at risk, not by the law, because they can set many administrative obstacles that will prevent the PPR for being realized.

Contrary to the seismic risk PPRN, whose realization is quite codified, there no official procedures for the realization of landslide risk PPRN. The only document that standardizes in some way the content of those studies is the “Guide méthodologique plans de prévention des risques de mouvements de terrain”, (guidelines for the landslides PPRN), which is a document edited by the MEDDM (“Ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer”, Ministry of Ecology, Energy, Sustainable Development and Sea). This guide exposes the main steps of the realization of a well-structured PPR and illustrates them with examples.

According to the different studies carried out in France in the last decades, a PPRN can be divided in 2 parts: the realization of a technical study and the establishment of regulation actions from analyses of the technical study results.

The technical study

The technical study can be performed by any qualified engineering office. An agreement between such office and the State can be met after an invitation to tender, or directly over the counter. The public institutes, such as the BRGM, can be employed to realize such studies; in practice they are often excluded of the invitation to tender, because the State is interested in the possibility of using their expertise to evaluate the quality of the technical study delivered.

The result of this study consists mainly of 3 maps: a map making the inventory of the land instabilities occurred in the past, a hazard map and a map locating the elements at stake. Usually, the scale is specified by the State in the study specification. It is often set to 1:25,000 for the inventory maps, and 1:10,000 for hazard and risk maps. In some cases maps at 1:5,000 scale are produced in densely populated areas or in mountain environments. At first, the perimeter of the study is settled: the areas prone to land-moves, where detailed studies should be carried out are listed. Sectors which could be considered geologically homogenous are also underlined, so that more data about each landslide type could be considered.

Then, an inventory of the events that occurred in that area is performed. The data used in most of cases is the BDMVT database (www.bdmvt.net , “Base de Données Nationale sur les Mouvements de Terrain”, managed by the BRGM), which lists the land moves that occurred in the past over the French territory, aerial photographs, images taken directly from the investigated sites, available maps and the BDSS database (“Banque de Données du Sous-Sol”, managed by the BRGM), which makes an inventory of geological and geotechnical boreholes realized for different kinds of studies. Finally, the dataset is completed by the examination of representative sites by an expert (new soil samplings are not usually done). From this information, the types of land moves that should be considered in the PPRN are defined by expert analysis.

Afterwards, adapted hazard zoning is performed. For this purpose, GIS processing and computing are most of the time used to elaborate maps of predisposition factors, such as topography, geology, land-use... that are crossed each others to identify zones featured by highest hazards. These systems allow a better homogeneity in the risk zoning. Sometimes, studies are only based on expert judgements, but an increasing number of more quantitative studies have been carried out recently. In such studies, the method for crossing factors is based on weights attributed to each predisposition factor. In a few studies, the weighting is totally empirically based, and the results have to be very cautiously interpreted. The studies are more reliable when the weighting is based on a physical background (equation of stability, etc).

Most of the time, the hydrology is not studied. It is only considered if previous study already exists because such investigations are often expensive and phenomena are complex.

Finally, a map of the elements at stake, locating urban areas, public infrastructures and roads is created. Ideally, areas in construction or planned to be urbanized have also to be listed. However, the economic consequences of reference events (for example intense rainfall that could trigger landslides) are most of the time not calculated in detail. The vulnerability function of constructions is most of the time restricted to binary (intact or destroyed), and no classified states of damage are estimated. Sometimes, an emergency plan can be joined with the technical study, but it is very exceptional.



Figure 4-2. Map making an inventory of the past land moves in Sievoz (Isère) (Source: guide méthodologique)

Risk Levels

The inventory of the stakes consists in analyzing the land-use characteristics considering both the existent and the future developments. This analysis allows identifying the major assets such as establishments receiving public (hospital, schools, campsites, etc), strategic buildings (fireman's barracks, water drinkable tanks, etc), and areas of major economic activities (industrial buildings, etc) as well as the communication capabilities (roads, railways, power roads, etc) which threatening may aggravate the risks during a major event.

The cross-correlation of the hazard map and the map of major assets allows identifying qualitatively the main risk areas to be protected. The risk zoning consists in three risk classes (red, blue, white) and delineates zones in which prevention measures have to be taken.

The regulation

The regulation is usually taken in charge from the technical study results by the DDE. However, in some cases, the engineering office which made the technical study can propose a regulation, but the State always decides at the end of the regulation that should be enforced.

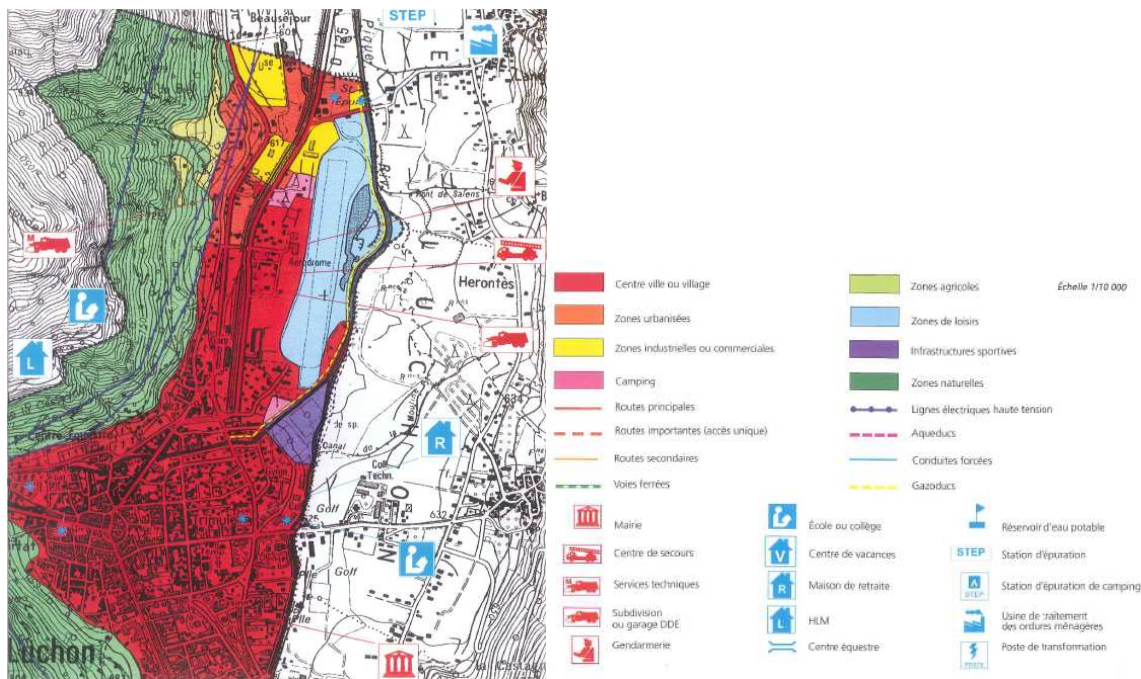


Figure 4-3. Map locating elements at stake in the town of Luchon (Haute Garonne) (Source: guide méthodologique)

At this step of the PPRN, the town area is classified in 3 zones depending on the level of hazard calculated in the technical study: a high hazard zone where new constructions are not permitted (red zone), an area where constructions are allowed but conditions have to be fulfilled (blue zone) and an area with no restrictions (white zone). The difficulty of such work is notably due to the fact that the land plots of the town land registry don't fit perfectly with the hazard zoning of the technical study, and so the regulator has to adapt the zoning on an individual case basis. Moreover, the conditions that must be fulfilled in the blue zone must be adapted to the type of hazard pending on each land plot, and must also be set on an individual case basis. Finally, a regulation impacting the houses within the red zone must be set (for example, if the house is destroyed by a fire, would the owner be allowed to build it again? And if the house is destroyed by a landslide would it be the same rule?).

Landslide hazard and landslide risk at medium scale level (departmental or regional)

Recently, a few studies at coarser scales than the PPRN have been performed: a good illustration is the “department” scaled study realized by the BRGM in the Jura in 2009. Depending on the scale, such studies could have only an informal interest: that was the case for a study of the landslide hazard in the “région” PACA (Provence-Alpes-Côte d'Azur) that has been realized by the BRGM in 1999. However, these studies could also have more practical uses: for instance, helping the State authorities to decide where PPRN have to be performed, or harmonizing PPRN plans inside a whole “department”.

The processes employed for the realization of such studies is quite similar to the ones performed in the PPRN, but some major differences could be raised:

<i>Localisation</i>	<i>N° de la zone réglementaire</i>	<i>Type de règlement</i>	<i>N° de la zone d'aléa correspondante</i>
Bois de la Joux, Corne à Bouc	212	H	200
Torrent des Cheserys	213	X	196
Les Cantellières	214	J-F	198
Secteur des Tines au Col des Montets	215	H-I	197
La Joux	216	C	193
La Joux	216bis	C-E	193
Les Cordays, Plans Dessous	217	D	195
Plans Dessous, Les Grosses Pierres, Les Glières	218	X	102
Ruisseau des Plans	219	X	194
Les Pormoins	220	X	192
La Chauffriaz	221	X	190
Ravin de la Trappe	222	X	187
Torrent de la Trappe	223	X	189
La Chauffriaz	224	I-C	188
Raverettaz	225	H-I	186

*Figure 4-4. Extract from the regulation of the PPRN of Chamonix (Haute Savoie): rules are applied for each land plot depending on the hazard zoning.
(Source: révision partielle du PPRN, commune de Chamonix Mont-Blanc, règlement).*

- As the level of details required is lower, less on site investigations could be performed;
- The event inventory is obviously less exhaustive;
- Information about all physical proprieties influencing the stability of slopes that are usually considered in PPRN may not be available everywhere in such important areas: consequently, the models employed are often simpler, i.e. less instability predisposition factors are crossed with the GIS tools;
- A risk evaluation on the investigated area may be performed, but the results of such a study would be at a macro level. (For instance, only the percentage of buildings destroyed in each town will be computed).

In France not all regulatory zonation maps of PPRN are available online. The Departments (e.g. Prefecture) are incitated to develop an online access through WebGIS procedures in order to give information to a possible buyer of a land or a building to know beforehand the regulations applicable (Information Acquéreur Locataire, IAL), but it depends. For instance, on-line maps are available for the PPRN of Département "Alpes-de-Haute-Provence" at <http://www.alpes-de-haute-provence.pref.gouv.fr/pages/IAL/> then selection of the Municipality (eg. Commune) and selection of the PPRN Map.

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- Collectif, 1999, Plans de prévention des risques naturels (PPRN) : risques de mouvements de terrain. Guide méthodologique. Ministère de l'Aménagement du Territoire et de l'Environnement (Direction de la prévention des pollutions et des risques) et Ministère de l'Équipement, des Transports et du Logement (Direction générale de l'urbanisme, de l'habitat et de la construction). La Documentation Française, Paris, 71p.

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4.2 ITALY

4.2.1 Legal framework

In Italy, the landslide risk zoning is in charge of the River Basin Authorities (3.4.1) within the Hydrogeological Setting Plan – Landslide Risk project (L. 183/1989; L. 365/2000). In compliance with Governmental requirements (D.P.C.M. 29/09/98), four risk classes are identified according to the expected consequences to landslides. In particular the risk level is considered to be:

- Very high (R4), where human life loss and destruction of buildings, infrastructures and the environment as well as the interruption of economic activities are expected;
- High (R3), where victims, functional damage to buildings and infrastructures, as well as partial interruption of economic activities are possible;
- Medium (R2), where limited damage to buildings, infrastructure and the environment may occur;
- Low (R1), where social, economic and environmental damage are of marginal relevance.

4.2.2 Southern Italy

Two indicative risk assessment practices that have been followed by the River Basin authorities in Southern Italy are reported here: the National Basin Authority of Liri-Garigliano and Volturno Rivers and the Regional Basin Authority of the “North-western” Basin of Campania Region.

4.2.2.1 *National Basin Authority of Liri-Garigliano and Volturno Rivers*

(contributor: UNISA)

All over the towns (450) located in the territory of the National Basin Authority of Liri-Garigliano and Volturno rivers, the PsAI-Rf Project zones the landslide risk (R) at 1:25,000 scale together with areas which are not urbanized yet and are considered as expansion areas in the urban-planning scheme. Risk (R) is evaluated according to the Varnes and IAEG (1984) formula which calls for the separate estimation of hazard (H), elements at risk (E) and vulnerability (V).

As highlighted in 3.4.2.1, the hazard (H) is related to the landslide intensity (i.e., the maximum expected velocity) and its state of activity. The term E is assumed equal to 1, but critical buildings (e.g. hospitals, barracks, schools) are identified and located on the map. The vulnerability V is estimated taking into account the landslide intensity and the typology of the element at risk; the presence of landslide-induced damages is also considered when buildings for civil use, roads, lifelines and control works interact with landslides classified as “medium”

or “low” intensity (damages were recorded during field surveys and evaluated according to a simple classification system).

The following vulnerability classes are, then, established:

- High: for facilities interacting with landslides of medium intensity, with a severe recorded damage;
- Medium: for facilities interacting with landslides of medium intensity, with a low (or absent) recorded damage;
- Modest: for facilities interacting with landslides of low intensity, with a severe recorded damage;
- Low: for facilities interacting with landslides of low intensity, with a low (or absent) recorded damage.

The vulnerability of the critical elements at risk (hospitals, barracks, schools, etc.), independently from the presence of landslide-induced damages, is assessed as “high” when the element at risk is located inside a landslide classified at “medium” intensity; and “modest” in the case of a landslide having a “low” intensity. Finally, (V) of all the elements at risk in an area threatened by a landslide classified at high intensity is automatically included in the “high” vulnerability class.

Once hazard and vulnerability are estimated, the risk levels are defined using the matrix shown in Figure 4-5.

In this way it was possible to classify the landslide risk over the whole NBA LGV territory with the exception of small areas where further investigations and studies, at a more detailed scale, were considered necessary.

		I		HAZARD		
		HIGH	MEDIUM	LOW		
		H	H	M	H	M
Vulnerability	high	Hh	Hh	Mh		
	medium		Hm	Mm		
	modest				Hm	Mm
	low				Hl	MI

R4	
R3	
R2	
R1	

Figure 4-5. Nominal scale for risk level estimation (Cascini, 2005a; Cascini et al., 2005).

Starting from the results of the landslide risk zoning, the document dealing with “restriction codes and safeguarding measures”, which currently is a significant part of the land-use planning, establishes policies to be followed within the areas where a given landslide risk level is recognised.

In particular, these policies, in very high (R4) and high (R3) risk areas, as well as in high (A4) and medium-high (A3) attention areas (Section 3.4.2.1), impose that building and morphological changes are forbidden, with some exceptions concerning public (or of public interest) works referring to essential services which can not be delocalised. In the medium (R2) and moderate (R1) risk areas, as well as in the medium (A2) and moderate (A1) attention areas (Section 3.4.2.1), the build-up of both public and private works must be preceded by

accurate studies aimed at defining their hydro-geological compatibility with the current status of the territory.

It is worth noting that designs related to the engineering works must be accompanied by the so-called Study of Hydrogeological Compatibility (SCI) commensurate to the importance and size of the works as well as to the type of the landslide phenomenon and risk level of the area.

The SCI must verify that:

- a) the engineering work agrees with the Plan, the restriction codes and the safeguarding measures;
- b) the realisation of the work guarantees [...] the land safety according to the art. 31 of Law 183/89 on the basis of three criteria, namely: population safety, impending damage, harmonious development;

The hydrogeological compatibility of the work must be:

- a) verified on the basis of the instability phenomena involving the areas at landslide risk, as detected by the Plan;
- b) assessed on the basis of the definition and the detailed interferences between the detected hydrogeological instability phenomena and the land-use;
- c) evaluated via the comparison of the proposed engineering work with the estimated landslide risk level as well as to the consequences on the environment.

References

Legal documents:

Italian Law n. 183 of 18 May 1989 dealing with “Norme per il riassetto organizzativo e funzionale della difesa del suolo”;

D.P.C.M. 29/09/98 (Decreto del Presidente del Consiglio dei Ministri 29 settembre 1998). Atto di indirizzo e coordinamento per l'individuazione dei criteri relativi agli adempimenti di cui all'art. 1, commi 1 e 2, del D.L. 11 giugno 1998, n. 180 (published on 5 January 1999).

Italian Law n. 365 of 11 December 2000 dealing with “Conversione in legge, con modificazioni, del decreto legge 12 ottobre 2000, n. 279, recante interventi urgenti per le aree a rischio idrogeologico molto elevato ed in materia di protezione civile nonché a favore delle zone della Regione Calabria danneggiate dalle calamità idrogeologiche di settembre ed ottobre 2000.

Scientific publications:

Cascini L. 2005a. Risk assessment of fast landslide. From theory to practice. General Report. Proceedings of the International Conference on “Fast Slope Movements – Prediction and Prevention for Risk Mitigation”. Picarelli L. (ed.), Vol. 2, pp. 33-52. Pàtron Editore, Bologna. ISBN: 88-555-2833-5

Cascini L. 2005b. La gestione scientifica dell'emergenza idrogeologica del maggio 1998 nella Regione Campania. Rubbettino Editore, 278 pp. ISBN: 88-498-0964-6 (in Italian)

Varnes DJ, IAEG Commission on Landslides. 1984. Landslide hazard zonation – a review of principles and practice. UNESCO, Paris, 63 p

4.2.2.2 Regional Basin Authority of the “North-western” Basin of Campania Region

(contributor: AMRA)

The Landslide Risk Map (Figure 4-6) was prepared according to the four classes defined in current Italian legislation (D.P.C.M. 29/09/98).

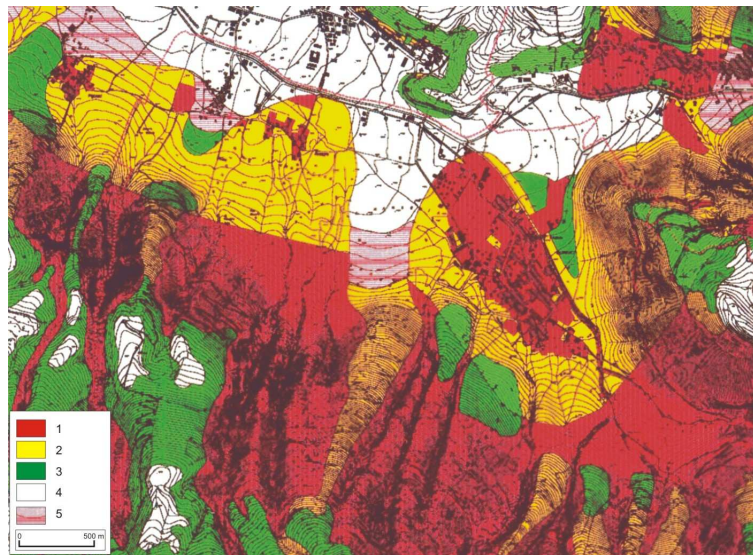


Figure 4-6. Landslide Risk Map. Legend: 1) Very high risk (R4); 2) High risk (R3); 3) medium risk (R2); 4) Moderate (R1); 5) Area whose classification requires more detailed studies.

This map results from the cross-checking of information from the described Landslide Relative Hazard Map with data on the urban layout of the territory, represented in the Exposed Value Map. In particular, it stems from the application of a matrix (Figure 4-7) with three degrees of susceptibility and four levels of Potential Damage. Damage (D) is defined as the expected loss of property and/or human life and is the product of the Exposed Value (E) and Vulnerability (V). Four categories of Elements at Risk were identified (AA. VV., 2002), ranging from very high (E4: urban and industrial areas, protected areas, etc.) to high (E3: main infrastructures, etc.), moderate (E2: agricultural areas, minor infrastructures, etc.) and low or null (E1: uncultivated fields). To ensure safety, considering the high intensity of landslide events, we set $V = 1$ (maximum value); the risk level was therefore calculated through the equation:

$$R = P \cdot D$$

Many mountainous regions (generally belonging to hazard class P3 or P2) are protected areas of high environmental value (E4–E3); even though in these areas no urban settlements and/or important infrastructural networks are present, the matrix (Figure 4-7) attributes them to risk class R3 or R4.

The adopted procedure allowed to evaluate by means of a GIS, the areal extent, for 62 municipalities, of the total area falling in high ($P_3 = 16.5\%$), medium ($P_2 = 6.3\%$) and low ($P_1 = 5.1\%$) hazard classes and in the four risk categories ($R_4 = 16.8\%$; $R_3 = 7.4\%$; $R_2 = 3.1\%$; $R_1 = 1.8\%$). Considering only the areas with settlements-infrastructures classified as R_3 – R_4

(the most important in terms of the safety of inhabitants), hence excluding the protected areas, the relative percentage decreases significantly.

Rk = Pn x Dm		Pn SUSCEPTIBILITY		
		P3	P2	P1
Dm DAMAGE	D4	R4	R4	R3
	D3	R4	R3	R3
	D2	R4	R2	R2
	D1	R3	R1	R1
	D1	R2	R1	R1

Figure 4-7. Risk matrix

References

AA.VV. (2002) - Piano Stralcio per l'Assetto Idrogeologico –Autorità di Bacino Nord Occidentale della Campania. 4 voll, Naples: T.P.S. – SELCA.

4.2.3 Central Italy

The procedure followed for the risk assessment by the Arno river Basin Authority is presented here.

4.2.3.1 Basin Authority of Arno River

(contributor: UNIFI)

In Italy, according to the Hydrological Setting Plan (see section 3), National and Regional River Basin Authorities have to assess the risk related to floods and landslides as the product of hazard, exposure and vulnerability. In particular, as provided for law, they have to map the hazard, to identify the elements at risk and define their vulnerability and eventually to identify and map areas where landslide risk is most severe. The landslide risk ranking occurs on the basis of four different levels (R1=low, R2=medium; R3=high; R4=very high). Inside each class of risk rules, recommendations and mitigation measures are defined.

The landslide risk for the Arno river basin (see Section 3) was computed on the basis of the combination of hazard, vulnerability and exposure as suggested by Varnes and IAEG (1984).

Vulnerability is a function of intensity. In the case of the Arno River basin the definition of intensity and run-out is influenced by the fact that mass movements are deep-seated reactivated slides sometimes evolving into flows. Restricting the analysis to this type of movement introduces a notable simplification, since a limited range of velocities can be adopted for the intensity computation and the expected mobilized volume can be reasonably deemed as equal to the present estimated landslide volume (Catani et al. 2005; DRM 1990; Cruden and Varnes 1996). Two main cases were thus considered: deep-seated rotational

slides and shallow flows or planar slides with virtually constant depth. In the latter case, intensity as a function of volume was set proportional to the area of the mapped phenomenon. In the former case, a geometric model was used to compute the volumes. The volumes range from 10^2 m^3 to 10^8 m^3 . Four classes of intensity have been defined on the basis of the statistical distribution and literature values (Fell 1994).

The assessment of vulnerability and exposure is based on the selection of the relevant information present in digital topographic maps at the scale of 1:10,000 as well as in the updated land cover map at the 1:50,000 scale. For every single object a value of vulnerability and exposure has been given on the basis of typology and main utilization. Vulnerability values are given in percentage of loss for each different class of intensity and for each type of element at risk, while exposure has been given in euro/m² and estimated on the basis of the presumed asset and income values.

The landslide risk was assessed both in a qualitative and quantitative way at the scale of 1:10,000. In the former case contingency matrices were used to intersect hazard classes with vulnerability and exposure classes, thereby classifying the territory of the Arno river basin in five classes of landslide risk (R0, R1, R2, R3, R4). (Figure 4-8). The quantitative assessment of risk was carried out through the application of the risk equation, therefore applying the product of the numerical values of hazard, vulnerability and exposure (Cruden and Fell 1997). The procedure lead to the definition of risk values expressed as economic losses for each terrain units and for different periods of time in the future (2, 5, 10, 20 and 30 years). In the next five years, around 2.5 billion of Euros should be expected as economic losses due to landslides. This value agrees with the data regarding the costs for landslide mitigation measures spent in the Arno river basin in the last five years (Tofani et al., 2008).

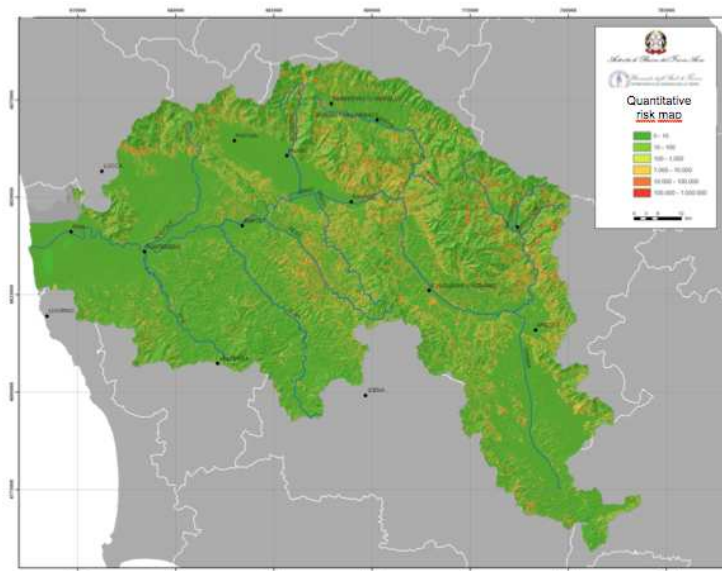


Figure 4-8. Landslide hazard map of the Arno River Basin.
The level of hazard ranges from H0, lowest hazard to H4 the highest hazard.

References

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Cruden DM, Varnes DJ (1996) Landslide types and processes. In: Turner AK, Schuster RL (eds) Landslides investigation and mitigation, Special Report 247. Transportation Research Board, National Research Council, Washington, DC, pp 36–75

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Fell R (1994) Landslide risk assessment and acceptable risk. Canadian Geotechnical Journal 31(2): 261-272

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website: <http://www.adbarno.it> (Arno River Basin Authority)

4.2.4 Northern Italy

The procedure followed for the risk assessment by the Arno river Basin Authority is presented here.

4.2.4.1 Basin Authority of Po River

(contributor: UNIMIB)

The Section 3.4.4, the procedure that is followed by the Po River basin authorities for the production of “hazard” (susceptibility) map, according to the Po basin Hydrogeological Master Plan (PAI - Piano Stralcio per l'Assetto Idrogeologico), is described. The risk assessment is also performed using a simplified procedure. The output maps are provided at 1:50,000 for flood and landslide hazard, using municipality polygons as reference land units. In this analysis, the classical UNESCO definition of risk (Varnes et al., 1984) is adopted:

$$R = H * V * E$$

where:

- H: hazard, i.e. the probability of occurrence of a given dangerous process in a given area and time interval;
- V: vulnerability, i.e. the expected degree of loss to an element at risk due to the occurrence of a given dangerous process;
- E: value (or number) of the elements at risk.

Given the scarce availability and statistical significance of datasets of landslide frequency and intensity, and of vulnerability and value of elements at risk at the basin scale, the above parameters have been expressed in a simplified form and combined according to a simple heuristic (matrix) approach. The following expression is then used:

$$R = S * V * E$$

where:

- S: susceptibility heuristic indicator (different indicators used for floods and landslides);
- V: vulnerability relative class (heuristic);
- E: value relative class (heuristic), based on landuse considerations.

The susceptibility values are obtained and classified into four discrete classes (i.e. low, moderate, high, very high), as described in Section 3.4.4 and they are combined with vulnerability and value matrixes to obtain a relative risk classification according to the D.P.C.M. 29/09/1998 (Table 4-1 and Figure 4-9).

Table 4-1 . Risk ranking according to the DPCM 29/09/1998.

Risk level	Zone	Description
Low	R1	negligible damage to society, property, and environment
Moderate	R2	minor damage to structures and infrastructures, no loss of life
High	R3	severe damage to property and activities, possible injury to people
Very high	R4	possible loss of lives, major damage to structures and infrastructures

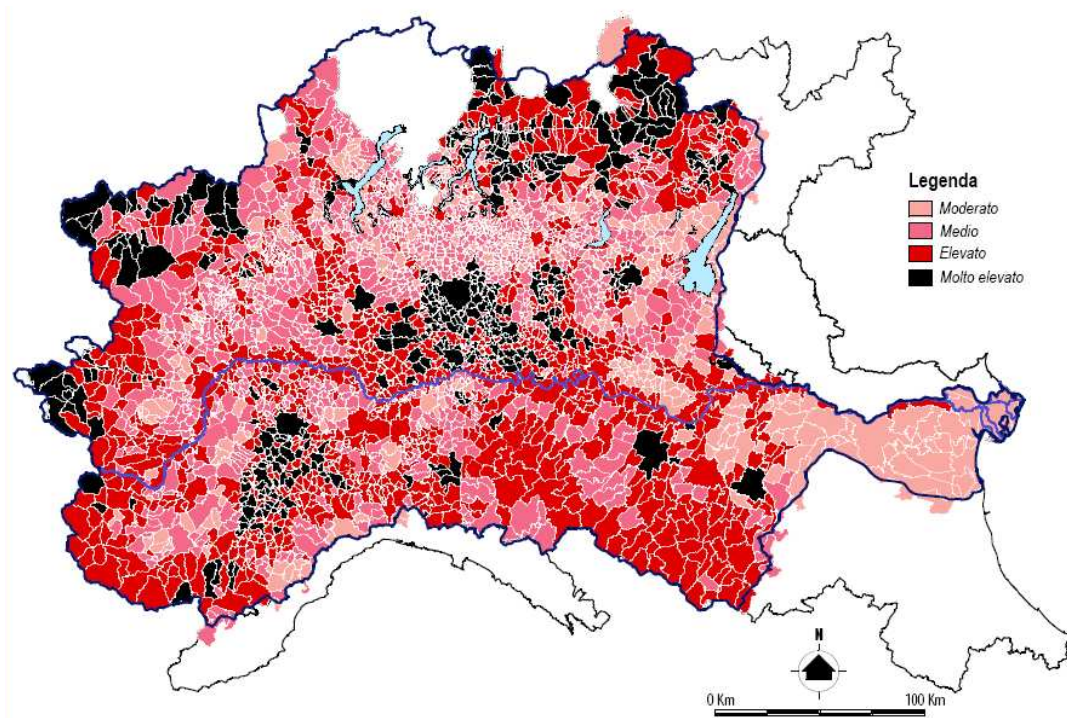


Figure 4-9. Combined hydrogeological risk map (below) reported in the Hydrogeological Master Plan (PAI) drafted by the Po river basin Authority. Municipalities are considered as land units.

References

Varnes, D.J.,1984. Hazard Zonation: A Review of Principal and Practice. Commission of Landslide of IAEG, UNESCO, Natural Hazards, No.3,61 p.

4.3 NORWAY

(contributor: ICG)

Risk zonation for quick clay slopes in Norway

As part of work for The Norwegian Water Resources and Energy Directorate (NVE), Gregersen (2001) developed a simple method to classify and map the risk posed by potential quick clay slides. Potential slide areas are given "engineering scores" based on an evaluation of the geotechnical parameters, local conditions, persons or properties exposed and engineering judgement. Hazard classes are described as low, medium and high. Consequence classes are discussed as not severe, severe and highly severe. The resultant risk, based on engineering evaluation and experience, is divided in five risk classes (Lacasse et al. 2004).

Hazard classes

The hazard level depends on topography, geological and geotechnical conditions, and changes at the site. The evaluation of the hazard is done with the help of Table 4-2. The weight given to each hazard in Table 4-2 (or later, to consequence in Table 4-3) describes its importance relative to the stability of the slope. The hazard classes are:

- Low:* Favourable topography and soil conditions; extensive site investigations; no erosion; no earlier sliding; no planned changes, or changes will improve stability.
- Medium:* Less favourable topography and soil conditions; limited site investigations; active erosion; important earlier sliding in area; planned changes give little or no improvement of stability.
- High:* Unfavourable topography and soil characteristics; limited site investigations; active erosion; extensive earlier sliding in area; planned changes will reduce stability.

The zones with weighted score between 0 and 17 (up to 33% of maximum score) are mapped as "low hazard" and have low probability of failure by sliding. The zones with weighted score between 18 and 25 (up to 50% of maximum score) are mapped as "medium hazard" and have a higher, though not critical, probability of failure. The zones with weighted score between 26 and 51 are mapped as "high hazard" and have a relatively high probability of failure.

Consequence classes

Consequences are commonly evaluated in terms of human life safety, environmental, financial and social effects. The evaluation of the consequences is done with the help of Table 4-4, with consequence classes:

Not severe: No or small danger for loss of human life, costly damage or consequences.

Severe: Danger for loss of life or property or important economical or social loss.

Highly severe: High exposure of human life loss or large economical or social loss.

The zones with weighted score between 0 and 6 (13% of maximum score) are mapped as "not severe". In these zones, there would be very few or no permanent residents. The zones with weighted score between 7 and 22 (up to 50% of maximum score) are mapped as "severe". The zones with weighted score between 23 and 45 are mapped as "highly severe"; they would hold a large number of persons, either as residents or as persons on the premises temporarily.

Table 4-2. Evaluation of hazard for slides in quick clay in Norway

Factor/parameter affecting hazard	Weight	Score for hazard			
		3	2	1	0
TOPOGRAPHY					
Earlier Sliding	1	Frequent	Some	Few	None
Height of slope, H ⁱ⁾	2	>30 m	20-30 m	15-20 m	<15 m
GEOTECHNICAL CHARACTERISTICS					
Overconsolidation ratio (OCR)	2	1.0-1.2	1.2-1.5	1.5-2.0	>2.0
Pore pressures ⁱⁱ⁾					
- In excess (kPa)	3	> + 30	10-30	0-10	Hydrostatic
- Under pressure (kPa)	-3	> - 50	-(20-50)	-(20-0)	Hydrostatic
Thickness of quick clay layer ⁱⁱⁱ⁾	2	>H/2	H/2-H/4	<H/4	Thin layer
Sensitivity, St	1	>100	30-100	20-30	<20
NEW CONDITIONS					
Erosion ^{iv)}	3	Active/sliding	Some	Little	None
Human activity					
- Worsening effect	3	Important	Some	Little	None
- Improving effect	-3	Important	Some	Little	None
TOTAL SCORE					
Maximum weighted score		51	34	16	0
% of max. weighted score		100%	67%	33%	0%

ⁱ⁾ For the quick clays in the study, inclination was identical for all slopes (1:3), and slope inclination was not included as a variable. In a general study, slope inclination should be added in the list of hazards.

ⁱⁱ⁾ Relative to hydrostatic pore pressure

ⁱⁱⁱ⁾ In general, the extent and location of the quick clay are also important.

^{iv)} Erosion at the bottom of a slope reduces stability.

Risk classes

The risk score to classify the mapped zones into a risk class is obtained from:

$$\text{Risk} = \text{Hazard} \times \text{Consequence}$$

$$R_{ws} = H_{ws}(\%) \times C_{ws}(\%)$$

where R_{ws} = Weighted score for risk mapping

$H_{ws}(\%)$ = Hazard weighted score in %

$C_{ws}(\%)$ = Consequence weighted score in %

Table 4-4 gives the risk scores for the five risk classes used for quick clay slides in Norway. Figure 4-10 shows a risk mapping of the area Modum in Norway using the procedure outlined above.

Decision-making on remedial measures

To make decisions on the need for additional soil investigations, stability analyses or other remedial actions, Table 4-5 gives recommendations for quick clay areas in Norway.

The volume of the sliding material is probably the most important factor for the extent of the run-out zone. If several millions of cubic metre is involved, the run-out cannot be evaluated by simple dynamic or topographic models. This is especially important if large rivers are blocked and huge amounts of water are dammed with the possibility of generation of catastrophic flood waves downstream.

Table 4-3 . Evaluation of consequence for slides in quick clay in Norway

Elements at risk / Possible damage	Weight	Score for consequence			
		3	2	1	0
HUMAN LIFE AND HEALTH					
Number of dwellings ⁱ⁾	4	> 5 Closely spaced	> 5 Widely spaced	≤ 5 Widely spaced	0
Persons, industry building	3	> 50	10-50	< 10	0
INFRASTRUCTURE					
Roads (traffic density)	2	High	Medium	Low	None
Railways (importance)	2	Main	Required	Level	None
Power lines	1	Main	Regional	Distrib. network	Local
PROPERTY					
Buildings, value ⁱⁱ⁾	1	High	Significant	Limited	0
Consequence of flooding ⁱⁱⁱ⁾	2	Critical	Medium	Small	None
TOTAL SCORE					
Maximum weighted score		45	30	15	None
% of max. weighted score		100%	67%	33%	0%

i) Permanent residents, in both sliding area and within run-out distance.

ii) Normally no one on premises, but building(s) have historical or cultural value

iii) Slides may cause water blockage or even dam overflow, flooding may cause new slides; there should be time for evacuation; damage depends on a complex interaction of several factors.

Table 4-4 . Risk classes for slides in quick clay in Norway

Risk Class	1 (lowest)	2	3	4	5
Risk Weighted Score (RWS)	0-160	161-350	351-800	801-1600	1601-2295
RWS (% of max RWS)	0-7%	7-15%	15-35%	35-70%	70-100%

Table 4-5 . Activity matrix as a function of risk class

Activity	Risk class			
	1 – 2	3	4	5
Soil investigations	None	Consider additional <i>in situ</i> tests and pore pressure measurements	Require additional <i>in situ</i> tests and pore pressure measurements	Require additional <i>in situ</i> tests and pore pressure measurements
Stability analyses	None	None	Consider doing	Do detailed stability analyses
Remediation ⁱ⁾	None	None	Consider doing	Implement risk-reducing measures

ⁱ⁾ e.g. erosion protection, stabilizing berm, unloading, soil stabilization, moving of residents

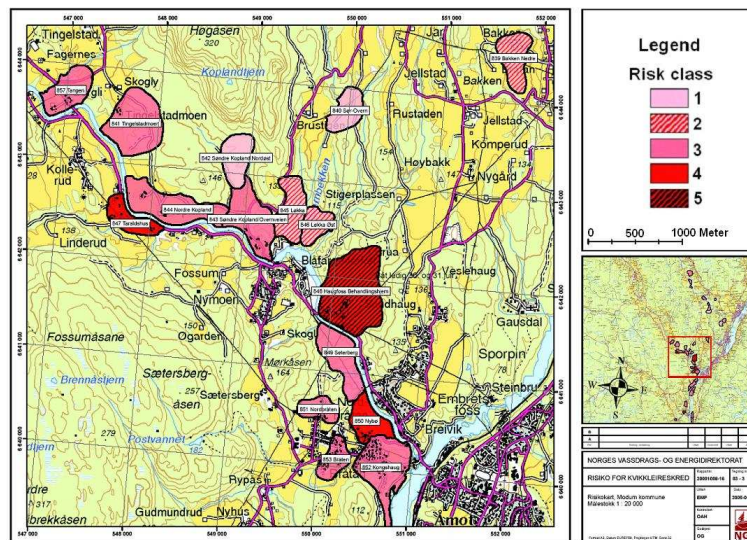


Figure 4-10. Quick clay risk map for Modum, Norway.

References

- Gregersen, O. (2001). "Metode for klassifisering av faresoer, kvikkleire". Norwegian Geotechnical Institute report 20001008-1 (in Norwegian), Oslo, Norway, 24 January 2001.
- Lacasse, S., Nadim, F., Høeg, K. and Gregersen, O. (2004). "Risk Assessment in Geotechnical Engineering: The Importance of Engineering Judgement". The Skempton Conference, Proc. London UK. V 2, pp 856-867.

4.4 SWITZERLAND

(contributor:ETHZ)

Introduction

In Switzerland, the national/federal agency Bundesamt für Umwelt, Wald und Landschaft (now part of the Bundesamt für Umwelt (BAFU) – Federal Office for the Environment) has developed a methodology to perform risk analysis for gravitational natural hazards. This

methodology is explained in a two part document (BUWAL, 1999a; BUWAL, 1999b) in German titled “Risikoanalyse bei gravitativen Naturgefahren – Methode” (Risk analysis for gravitational natural hazards – Methods) and “Risikoanalyse bei gravitativen Naturgefahren – Fallbeispiele und Daten” (Risk analysis for gravitational natural hazards – Case studies and data). The methodology comprises three self contained and independent procedures (or stages) for risk analysis. These procedures can be applied independently or in a combined manner, depending on the level of detail and rigour required of the risk assessment. The entire procedure is illustrated in Figure 4-11; this figure has been taken from BUWAL (1999b).

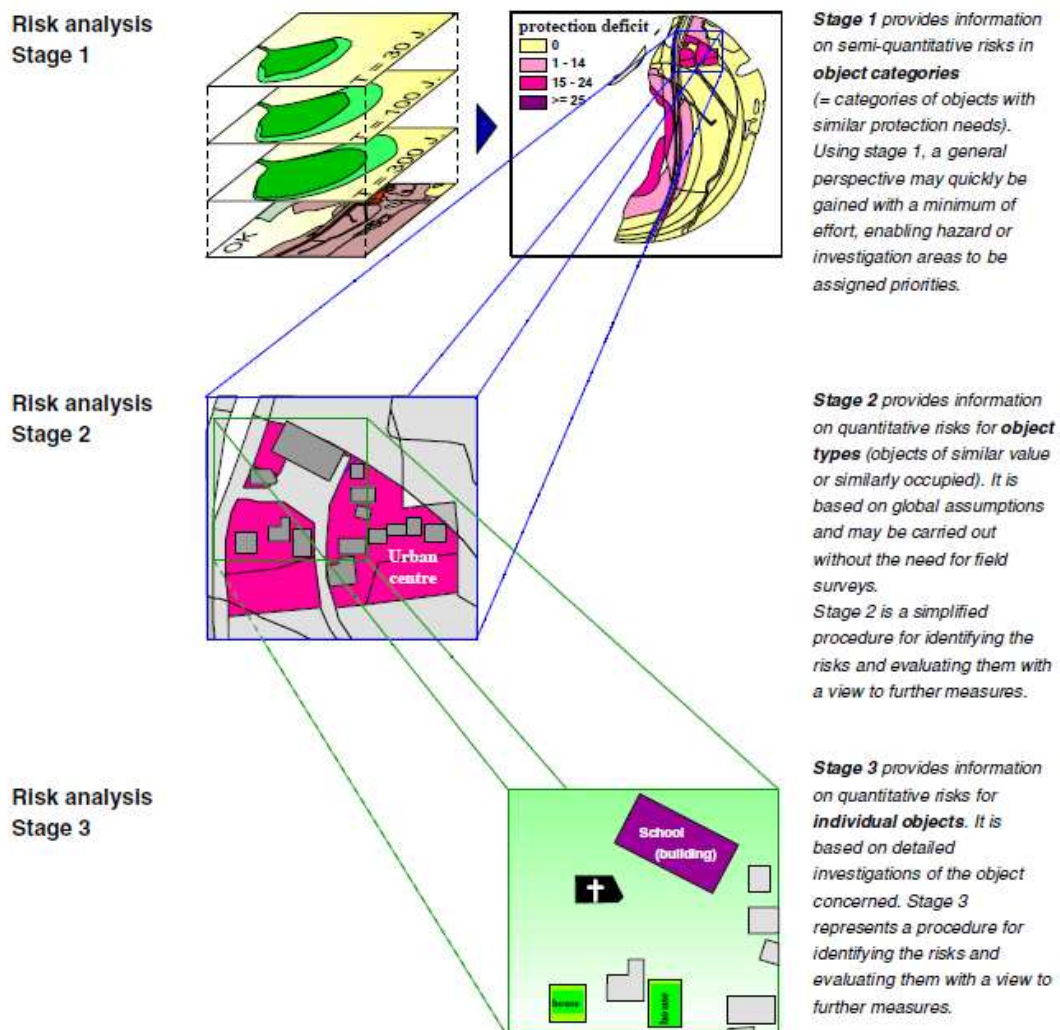


Figure 4-11. Illustration of the three-stage procedure for risk analysis
(Source : BUWAL, 1999b)

Stage 1

The stage 1 procedure is based on the principle of protection deficit or the degree of non-compliance with protection objectives. This involves i) the audit and verification of specified protection objectives in categories of objects or infrastructure having similar protection needs, ii) the determination of protection deficits or the level of non-compliance and iii) identification of conflict areas that would require further attention. The results from a stage 1

procedure can be used to prioritise and identify areas that require attention and consideration in spatial and emergency planning as well as in land use planning measures.

The method to be followed in this analysis stage begins with the digitisation of hazard intensity maps using a Geographical Information System (GIS). Objects or infrastructure with similar protection needs are then grouped together in object categories. The object categories are assigned protection objectives and then digitised and represented in an object category map. The object category map is superimposed on the hazard intensity map. This provides the basis for the determination of protection deficits or the degree of non-compliance with protection objectives; a protection deficit is deemed to occur when the intensity of the hazard is greater than the maximum intensity permissible for the corresponding land use. Depending on the extent and magnitude of the non-compliance, the protection deficits can be categorised into protection deficit classes and assigned suitable weights. The protection deficit or protection deficit classes are finally depicted in protection maps, tables or diagrams.

Stage 2

The stage 2 of the methodology provides a procedure for the quantitative risk analysis of natural hazards in a given area, based on general global assumptions and without the need for any specific field investigations. This involves the determination of quantitative object and collective risks based on data from similar objects/infrastructure types which approximately have the same asset value and/or are occupied by the same number of persons. The risks are usually expressed in relation to persons (number of fatalities) and material assets (property damage in Swiss Francs). The results from a stage 2 procedure provide the basis to i) establish the need for action in the form of protection and emergency planning measures and ii) perform a cost effectiveness study of the various protection measures.

The stage 2 procedure begins with an expanded hazard analysis in which the spatial probability of occurrence of the hazard is estimated. The hazard intensity maps for different disaster scenarios are then digitised using a Geographical Information System (GIS). Objects or infrastructure with similar asset value and/or occupation conditions are grouped under an object type. All the identified object types are displayed and digitised in an object type map. This object type map is then superimposed on the hazard intensity map. For each disaster scenario, the disaster frequency is obtained as the product of the frequency of occurrence and spatial probability of occurrence of the hazardous process and probability of the object being present. Following this, the extent of damage for each disaster scenario is calculated from the product of extent of the area at risk and the specific extent of damage of the object type at risk. The specific extent of damage is represented by an estimated overall value expressed in terms of number of fatalities or property damage in Swiss Francs. Based on experience of previous occurrences and on estimates, guideline values for different hazard processes and intensity classes are provided.

For each disaster scenario, the quantitative object risks (divided into risks to persons and risks to material assets) are then determined as a function of the disaster frequency and the extent of damage. Finally, all the object risks are suitably combined to obtain the collective risk which is then displayed in risk maps, tables or diagrams.

Stage 3

A procedure for the quantitative analysis of natural hazards for individual objects is given in stage 3 of the methodology; this is based on investigations specific to the object. The objective here is to determine the quantitative object risks based on data for individual objects with reference to persons (number of fatalities) and material assets (property damage in Swiss Francs), and also the individual fatality risks. As with stage 2, the results from a stage 3 procedure provide the basis to i) establish the need for action in the form of protection and emergency planning measures and ii) perform a cost effectiveness and cost benefit study of the various protection measures.

The stage 3 procedure commences with an expanded hazard analysis in which the spatial probability of occurrence and the seasonal occurrence of the hazard as well as the advance warning time are estimated. For each hazard scenario, the disaster frequency is obtained as the product of frequency of occurrence and spatial probability of occurrence of the hazard process and the time-dependent probability of coincidence (probability that the events will coincide) of hazard process and exposure of the object or the persons; the probability of evacuation of persons from the danger area is taken into account. Next, the extent of damage for each disaster scenario is calculated from the product of number of persons at risk and lethality or asset value and susceptibility to danger of the object at risk. For lethality and susceptibility to danger, figures for comparative values for standard cases are provided, based on experience of previous occurrences and on estimates.

The object risk for each hazard scenario is then determined as a function of disaster frequency and extent of damage. The object risks investigated for all scenarios are combined to form the total object risk. The individual risk (corresponding to individual fatality risk) is then obtained from the total object risk and the number of persons in the object. Similarly, the collective risk with respect to an object group can be evaluated by adding the total object risks of various objects.

References

- BUWAL (1999a). Risikoanalyse bei gravitativen Naturgefahren – Methode. Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern. Umwelt-Materialien Nr. 107/I. (this document is in German)
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5 COMPARISON OF EUROPEAN EXPERIENCES

5.1 POLICIES FOR HAZARD AND RISK EVALUATION

- **Policies, time and motivation for hazard and risk assessment**

The awareness for the landslide risk and the establishment by law of official practices is usually raised by hazardous events with serious consequences, as for example the destructing rockfall in Andorra (1997); or the Polesini (1951) and the Firenze flooding (1966) and the 1997 and 1998 landslides in Campania, in Italy.

For all the cases of susceptibility, hazard and risk evaluation that have been described in Sections 3 and 4, the official state or local authorities are those to take the initiative for the creation of the relevant documents. The development of the methodologies, on the other hand, is assigned either to administrative authorities (River Basin authorities in the case of Italy, Switzerland), geological surveys (Austria, Catalonia, Romania), or to external consultants, including both private and academia (Andorra). The collaboration among these institutions and organizations is also very common (Andorra, Catalonia, Italy and Scotland).

The main objective of the hazard and risk evaluation is the delimitation of zones to be considered for the urban and land planning (Andorra, Austria, Catalonia, France, Switzerland, Romania and Italian river basins). In some cases the established procedures for the development of hazard maps have a complementary role to existing laws for urban and spatial planning. Examples of this include Catalonia (TRLU), Austria (Tyrolean Act on Spatial Planning), Italy (PAI), and Romania (Law regarding the approval of the National Territory Plan Improvement 575/2001). The planning and optimization of protective structural measures is also a primary objective for the hazard evaluation in the cases of Andorra and the Arno River Basin.

For the countries and the regions that are reported in this deliverable, Austria was the first one to officially start generating susceptibility and hazard maps (in 1975). For the rest of the countries, the landslide hazard mapping and related territory planning experience is more recent. In 1989, Italy established a law according to which the Regional River Basin Authorities were assigned with the duty to prepare the Basin Plan, which contained information regarding the physiographic outline and land planning. Nevertheless the law was not put into practice until the new law of 1998 for the Hydrological Setting Plan (PAI). France established by law the Risk Prevention Plans (PPR) in 1995. For Andorra the hazard mapping initiated in 1989 but mapping of the whole territory was not completed until 2001. Switzerland in 1997 published the national/federal guidelines, procedures and recommendations for hazard and risk assessment. In Catalonia (Spain) the generation of hazard maps is an ongoing process that started in 2007. Although not legally binding, the Geological Survey of Romania uses methodological requirements established in 2003 for the landslides natural risk maps and Great Britain established the GeoSure procedure in 2008, for the same purpose.

Concerning the risk mapping, so far, the risk maps that have been produced within Europe on an official basis are in France, Italy, Norway and Switzerland.

- **Users, availability of and accessibility to the official documents**

On a general basis, the existing hazard and risk evaluation documents are addressed to administrative bodies and local authorities for the urban and spatial planning. In many cases the documents are also accessible by the public (i.e. Andorra, Italy) or it is intended to be in the future (i.e. Romania, Catalonia).

Their type of accessibility and reproducibility differs from region to region depending on the level of digitalization of the information. For Andorra, the original map is available for the public at the Town Hall and online (in .pdf format). No information is available at a Geographical Information System (GIS) platform format (.shp or .gdb). For Catalonia, the provided maps will be in GIS compatible format (.shp or .gdb). However, as their creation is an on-going process which will be completed in twenty years, information is not available so far. In Italy, the accessibility varies according to the local authorities that manage the project. For the Arno Basin River, the hazard information is very well registered and easily accessible online at image (.pdf) and GIS (.shp) format. For the Liri-Garigliano and Volturno Rivers Basins, the information accessible on-line deals with i) the general report; ii) the restriction codes and safeguarding measures; iii) program of risk mitigation. As for base and derived maps they can be requested by filling a form. In Austria Hazard Zone Maps can be consulted freely at the competent communal, district, provincial and regional authorities. By the end of 2010 all maps and associated documents should be available in a digital database. Maps produced by the Geological Survey of Romania are also intended to be digitalized and processed on a GIS platform. In the UK, site specific GeoSure reports can be bought online for a particular property or small area, while maps can be purchased for larger areas (at 1:50,000 scale). In France, the availability of the zonation maps online depends on the willingness of the Department (e.g. Prefecture) to develop the appropriate system. In Switzerland, the responsibility for developing landslide hazard maps rests with the cantonal authorities. Some cantons have made these maps available online in .pdf or .svg formats on their administration portals. However not all the cantons in Switzerland are yet to publish these maps online.

Commonly, the language used is that officially spoken at every region/country.

In all cases, the dissemination of the existing information is promoted by numerous scientific articles and reports.

- **Coverage**

The coverage of the maps mainly depends on the spatial extent of the phenomena, the administrative structure of the state and local authorities and their potential complementary character to other laws or regulations. In Andorra, the coverage of the hazard map at 1:5000 is the whole territory while larger scale maps are restricted to the most conflicted areas. The coverage of the Prevention from Geological Risks Map of Catalonia is intended to cover the whole territory of Catalonia. In Austria, the coverage of the Hazard Zone Plan in Torrent and Avalanche Control is national. In Italy, the initiative was taken by the Central Government and it is expected that maps will cover all the Italian basins. However, the actual coverage depends on the extension of the area controlled by local executive authorities which in the case of the Hydrogeological Setting Plan (PAI) are the River Basin Authorities. In Romania, the coverage is regional or local. Switzerland has a national coverage. In UK the GeoSure Landslide Hazard Assessment has been performed for Great Britain (Northern Ireland data is

understood to be under development) and in France the landslide hazard and risk assessment has been made on a local up to departmental or regional level.

- **Legal framework**

In many of the reported countries the hazard maps have been put into force as official laws. For Andorra and Italy, the documents are legally binding for the public administration and the land users. In Austria, the hazard maps are legally binding only for spatial planning purposes. For land use planners they have a recommendatory instead of ordinance character since the delimitation of hazard zones is not an official statutory regulation. In Switzerland the procedures and the output maps are legally binding. Neither in Catalonia nor in Romania and UK, the procedures for hazard assessment and the output documents are legally binding. On the contrary, the output maps constitute legal information in France.

5.2 DOCUMENTATION AND CONTENTS

- **Type of the existing documentation**

The support material for the hazard and risk mapping, varies from country to country. It may include as in the case of the Arno River Basin a report including the description of the area and the methodologies used for hazard mapping and mitigation measures, maps and policy documents with rules, limitations and recommendations of different degrees of hazards. The Austrian Hazard Zone Plan in Torrent and Avalanche Control contains general and detailed hazard maps, an explanatory document with the results of hazard assessment and documents of the administrative process. The existing documentation in Andorra consists exclusively of general hazard maps with no support material. For Catalonia and the MPRGC, a fully detailed support document with the technical specifications accompanies the hazard maps. In Romania, the methodological requirements are described in a report. The PPRN in France consists of a series of informative documents (a note of presentation, a localization map of the phenomena, a hazard map and some statutory documents).

- **Information content related to landslides**

With reference to the official practices that are reported in this deliverable, the maps produced are landslide inventory maps (Austria and considered Italian River Basins, UK), susceptibility maps (Italian River Basins, Austria and France), and hazard maps (Andorra, Catalonia, Italian River Basins, Austria, Switzerland and France). Risk maps are provided by the majority of the reported Italian River Basins (except the Alto Adriatico River Basin), France, Norway and Switzerland.

All susceptibility and hazard maps provide qualitative or semi-quantitative information which is classified into levels. The exceptions are the quantitative methodologies used at the Arno River Basin and Switzerland. The same applies for risk mapping, where the only quantitative methodologies are the ones for the Arno River Basin and Switzerland, too.

- **Landslide types and mechanisms considered for the hazard and risk assessment**

In relation with the types and mechanisms of landslides represented in the maps, in general they are grouped in few general mechanisms (i.e. rockfalls, slides, flows).

The classification criteria present large diversity even within the same country. As a result in some cases no landslide mechanisms are specified (i.e. France, Romania) and in some others there is an exhaustive list of landslide types (i.e. Spain, Liri-Garigliano & Volturno basin – Italy).

The Director Plan for the Solà d'Andorra is monothematic and focuses only on rockfalls. Accordingly, in Austria and with reference to landslide hazards the mapping is made just for debris flows. Susceptibility maps further include slides and falls. In Arno River Basin the main cases that were considered are slides, solifluction, shallow landslides, flows and falls. The maps for the Liri-Garigliano and Volturno River Basin include a lot of types of mass movements (falls and topples, flowslides, debris flows, fast earth-flows in marl-clayey soils, translational slides, rotational slides, earth flows, superficial and deep creeps, lateral spreads, deep-seated gravitational movements). For the Po River Basin, the included landslides are rockfalls, rock avalanches, deep-seated rockslides, soil slips/slumps, translational and rotational debris slides, earth/mud flows, and debris flows. In the UK the classification of landslides differs between PPG14 (Planning Policy Guidance – PPG- 14: Development on Unstable Land, DoE 1990) and the BGS GeoSure (Foster et al., 2008) database while the Scottish Road Network Landslides Study (Winter et al., 2008) deals exclusively with debris flows. The MPRGC map in Catalonia has a more comprehensive character and includes a complete list of landslide phenomena (rockfalls, rotational and translational landslides, different types of flows, creep, liquefaction, lateral spreading and complex movements). In France the differentiation is not obligatory and only in some cases there is a differentiation between rockfalls, landslides and debris flow. No differentiation is made between landslide types and mechanisms in Romania.

Usually, only the most frequent mechanisms in an area are treated. The types considered are probably ought to the variety of landslides present in the area, to the technique used for their identification (satellite images, aerial photointerpretation, DTM analysis, field work, etc.) and to the scale of the map (for instance, shallow landslides can not be mapped at small scale). Specific mechanisms also are considered according to the special characteristics of the area (e.g. flowslides and lateral spreading and Italy and quick clays in Norway).

- **Scale**

The scale of the maps varies significantly depending on the coverage, the information provided, and the methodology that is used. For the whole Principality of Andorra the scale is 1:5,000 while for the Solà d'Andorra, the scale is 1:1,000 or 1:2,000 on other locations (site-specific). The MPRGC map in Catalonia is developed on a local to regional scale (1:25,000). In Austria the hazard mapping (Hazard Zone Plan in Torrent and Avalanche Control) was prepared at 2 scales: general hazard mapping at 1:10,000-1:150,000 and detailed hazard zone maps at 1:2,000. The susceptibility maps have scales from 1:1,000 to 1:750,000 and the inventory maps from 1:1,000 to 1:30,000. For the Basin Authority of Liri Garigliano and Volturno Rivers, the adopted scale is 1:25,000. For Romania where the coverage is regional the maps are produced at a scale 1:25,000 and where it is local at 1:5,000. For UK (Great

Britain zone) it is 1:50.000 and for France it is 1:10,000 and in some cases 1:5,000 in densely populated areas or in mountain environments.

- **Differentiation between landslide types and/or mechanisms on the maps. Consideration of multi-hazard phenomena.**

The differentiation of landslide types and/or mechanisms on the maps is not always applied. Liri-Garigliano and Volturno hazard maps, Catalonia hazard maps and the Austria susceptibility maps (not hazard maps) are the only to differentiate between them. For the rest of the reported countries, no differentiation is made on the maps according to the landslide type or mechanism.

When more than one landslide type and/or mechanism with different susceptibility or hazard levels apply to an area, their superposition should be taken into account for the final susceptibility or hazard result. This is rarely considered (i.e. Catalonia).

Furthermore, for some regions further natural hazards besides landslides are considered as for example floods (Italy and Austria), subsidence and earthquakes (Catalonia). No reference is made to their synergistic amplification effect on the susceptibility or the hazard. For South Italy and Romania the effect of earthquake excitation to landslides is taken into account for the hazard assessment.

- **Contents of susceptibility and hazard maps**

All susceptibility maps include potential landslide areas. However, the run-out distance is not always taken into account, particularly in regional scale maps. The countries Andorra, France Catalonia, North and South Italy. In most cases the evaluation is made empirically or based on geomorphological criteria (Andorra, France, Catalonia and South Italy), while for the River Basins of North Italy trajectory analysis is used

Hazard assessment are prepared using hazard components (intensity and frequency), however, in many cases, for simplicity reasons or due to lack of necessary data, “susceptibility” maps are used instead. For the production of hazard maps from susceptibility maps, additional information related to the temporal probability of landslide events and the intensity of the landslides are needed. According to the reported hazard assessment methodologies, only in a few cases these parameters are taken into consideration.

5.3 METHODOLOGIES

- **Guidelines**

The guidelines that describe the processes for the development of inventory and susceptibility maps and the evaluation of hazard and risk levels are, in general, available through scientific publications and reports. Only in a few cases there exist accompanying official technical specifications that explain step-by-step the used methodologies (e.g. Switzerland, France and Catalonia and Italy).

Additionally, in many cases no step-by-step methodologies exist and only judgmental/expert criteria are used for the development of landslide inventories and susceptibility maps (especially when the latter are qualitative).

It is worth mentioning that although in most cases on national level, the applied methodologies are common, in Italy the methodologies differentiate strongly from river basin to river basin (different criteria for hazard, thresholds, methodologies etc...), and they are local dependent.

- **Input data**

Some common input data are used for all cases i.e. geologic, geomorphologic and soil cover maps. The techniques to obtain input data for the landslide inventory and susceptibility maps vary from basic to sophisticated (interpretation of aerial photographs, use of laser-scanner images), resulting in various levels of quality and quantity of data.

- **Procedures**

The procedures followed for the hazard and risk assessment can be mainly categorized into the following:

- Analytical procedures supported by computer simulation
- Procedures on the basis of weighted indicators, expert judgment and field survey
- Combination of the above two procedures.

According to the output, the procedures for hazard and risk assessment can also be classified into:

- Qualitative, where the output is the characterization of areas using qualitative classes (i.e. low, moderate, high).
- Quantitative, where the output is the temporal probability of a landslide event for each location on the map.

- **Hazard and risk matrices**

Hazard and risk matrices (or tables) are used only when they are required by the followed procedure (i.e. Andorra, River Basins of North and South Italy and Switzerland). When hazard or risk indices based on weighted indicators are used, hazard matrices are not always necessary (i.e. France).

The hazard matrices that are used for the evaluation of the hazard vary considerably from case to case. The differences refer to:

- a. The parameters that are used to determine the hazard levels. I.e. in Andorra and in Switzerland the hazard is based on the frequency and intensity of the event, while in Austria the frequency parameter is not taken into account. Instead the hazard level is defined using spatial distribution criteria as for example the boundary of debris flow deposits. At Liri-Garigliano and Volturno, the hazard is evaluated as a function of the intensity and the state of activity of the landslide (including active, reactivated and suspended phenomena or quiescent, i.e. dormant phenomena).
 - b. The parameter values that are used as thresholds to establish the hazard / risk levels.
-

c. The number and the interpretation of the risk levels.

- **Vulnerability and risk evaluation**

Risk evaluation requires the vulnerability assessment. The only officially applied practices of risk evaluation exist in Italy, France and Switzerland.

For the Arno River Basin the vulnerability is quantitatively calculated, based on the typology of the elements and on the intensity of the hazard. It expresses the percentage of loss in function of a class of intensity. Exposure is calculated in terms of euro/m². The risk is the calculated qualitatively and quantitatively (using the risk equation), taking into account intensity, vulnerability and exposure. The risk levels are 6 in total.

In the case of the River Basins of South Italy, vulnerability is calculated qualitatively based on both the building use and the landslide-induced damage recorded via field surveys. The risk is calculated as a function of the hazard and the vulnerability and four risk levels are established.

For Northern Italy, vulnerability is taken into consideration only in the case of Po River Basin, using heuristic methods.

In France the vulnerability of the exposed buildings also depends on their use. The risk is calculated qualitatively by superposition of hazard, exposure and vulnerability.

Three stages are used in Switzerland for the quantification of vulnerability. Stage 1 provides as an output the protection deficit or non-compliance with protection objectives (semi-quantitative); stage 2, the collective vulnerability based on global assumption without specific field investigations (quantitative), and stage 3 the individual and collective vulnerability based on individual specific field investigations (quantitative). The risk is calculated by superposition of the hazard and the vulnerability. Using the outputs from the three stages, three types of risk analysis are performed with the following information:

1. semi-quantitative risks in object categories (considering stage 1 vulnerability)
2. quantitative risks on object types (considering stage 2 vulnerability)
3. quantitative risks on individual objects (considering stage 3 vulnerability)

It can be concluded that vulnerability and risk evaluation approaches present fundamental differences thus rendering the risk results not comparable between them.

- **Flexibility of zoning**

In some cases of zoning like in Andorra, Italy and Austria the issue of construction permission in moderate hazard areas is feasible if appropriate protection measures are taken.

5.4 TERMINOLOGY

The terms susceptibility, hazard and risk are interpreted differently from country to country. For instance, the Romanian recommendations call triggering factors what in other countries is

considered as conditioning factors. The latter are named as “criteria” in the Romanian recommendations. Risk in Romanian recommendations corresponds to landslide susceptibility in other countries. In the case of UK and Norway, too, for the development of hazard maps, only susceptibility factors are taken into account.

5.5 MAP SYMBOLS

The map symbols that are used present important differences from document to document with reference to:

- symbols of types and mechanisms of landslides on the maps,
- symbols of susceptibility, hazard and risk levels.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 POLICIES FOR HAZARD AND RISK EVALUATION

In the previous section a comparison was made between the different policies and methodologies that apply to different countries and regions in Europe for landslide hazard and risk evaluation. Based on this comparison, the possibility of harmonization of the policies and the application of common practices to bridge the existing gaps is discussed in this section.

The hazard and risk evaluation for delimitation of zones to be considered for urban and land planning as well as for optimization of protective measures is a common objective for all the reported territories. The collaboration of national, central and local authorities (decision makers) with academic and research institutions and professionals that have proven experience on landslide phenomena at the investigated areas (transfer of knowledge) takes place very often.

The first official hazard maps were produced in 1975 in Austria. For the majority of the European countries that are reported here, hazard mapping has taken place over the last 15 years or it is an on-going process or even it is at a very early not official stage. There are few examples of official risk mapping in Europe (Italy, France, and Switzerland). The collaboration between countries that present common characteristics (i.e. dominant landslide types, relief, hydro-meteorological conditions, seismicity) may promote the official establishment of already validated methodologies. For this reason, some recommendations are necessary. Possible procedures for assessment of key factors are discussed in the following paragraphs.

On a general basis the hazard and risk evaluation documents are intended to be used by administrative bodies. Documents are not always accessible to the public (either free or through resellers). The digitalization of information and its availability online (at the web) will improve their accessibility and reproducibility. For the flexible management of information, the use of GIS compatible formats is recommended.

Only in some of the reported countries the zoning maps are legally binding for public administrators and land users (Andorra, Italy and France). In Switzerland, the landslide hazard and zoning maps are not legally binding documents in themselves. However when used in conjunction with land use planning and applications for construction / building permits, they acquire a legal character consistent with the laws and regulations governing land use planning and development activities. In many cases there exist procedures developed by geological surveys, local authorities and research institutes (i.e. Catalonia, Austria, Romania, UK) which are not official statutory requirements. Methodologies and maps are often legally binding when referring to site-specific or local scales. Methodologies that have been developed to provide maps at a wide regional or national scale are not legally binding in most cases.

6.2 DOCUMENTATION AND CONTENTS

So far, information is mainly provided on landslide susceptibility and hazard. Risk assessment is performed only in a few countries (Italy, France, Norway and Switzerland).

Given the variation in the use of scale between countries, it is suggested the standardization of the use of scales in relation to the extent of the area coverage. This will permit the gradual and homogenous coverage of the European area. The standardization of scales may also be realized in relation to the desired level of detail, permitting the homogenous downscaling into highly hazardous areas.

The classification of landslide types and mechanisms varies from methodology to methodology, as well as the criteria used for it. Quite often, landslides are grouped in wider classes: i.e. in some cases landslides are grouped into flows/rockfall/slides or into flowslides/debris flows/first-failures in brittle materials/sagging/ lateral spreads etc. In order to harmonise the information that is provided by the output maps it is necessary to use common landslide types and mechanisms schemes.

The classification criteria for landslide types and mechanisms present large diversity even within the same country. As a result in some cases no landslide mechanisms are specified (i.e. France, Romania) and in some others there is an exhaustive list (i.e. Spain, Liri-Garigliano & Volturno basin – Italy). Each mechanism requires its own method of assessment. The differentiation of landslide types and mechanisms is recommended particularly for scales larger than 1:25,000. The effect of hazard amplification due to the spatial superposition of different types of instabilities should also be taken into consideration, as well as the synergistic action of other natural phenomena (i.e. earthquake) wherever applicable, regardless of the mapping scale.

In relation with the types and mechanisms of landslides represented in the maps, in general they are grouped in few general mechanisms (i.e. rockfalls, slides, flows).

6.3 METHODOLOGIES

In order to obtain comparable hazard and risk data for the European area, harmonization of methodologies for hazard and risk assessment is necessary. In this context, the possibility of standardization of the input data and methodologies is discussed here.

- The use of **explicit documents** and related reports is suggested, to ensure the repeatability and transparency of the procedures and the correct interpretation of the maps. **The use of step-by-step analytical or data treatment techniques** is recommended, in order to minimize the incorporated uncertainties that relate to judgmental approaches.

A first step is the use of explicit documents and related reports. The lack of explicit documents may result in non-transparent and unrepeatable procedures for hazard and/or risk assessment. In order to ensure the correct interpretation of the maps, their reproducibility and possible update, the edition of accompanying reports and explanatory documents that contain information on the area and its characteristics, the input data, the step-by-step procedures, the interpretation of susceptibility, hazard and risk levels with rules as well as limitations and recommendations about the use of the maps is recommended.

For the standardization of the methodologies and the homogenization of the outputs the following is important:

1. Recommendations for the input data concerning their type, accuracy, precision and the techniques used for their acquisition. In more specific, given that landslide inventories, geological, lithological, DTM and land-use data are commonly prerequisite data for the application of the hazard assessment, it is necessary to define the minimum acceptable quality levels for their use in hazard assessment.
2. Discussion on the significance of landslide susceptibility. The assessment of the susceptibility as a first step of the hazard assessment is not always taken into account in some of the methods reported.
3. Use of step-by-step analytical or weighted factors techniques, in order to minimize the incorporated uncertainties that relate to judgmental approaches.
4. The homogenization of hazard matrices. So far, there is an important disparity between them, in particular on the hazard parameters, levels and thresholds used.
5. Use of quantitative methods in order to reduce subjectivity. With the exception of the Arno River Basin in Italy and Switzerland, for the rest of the reported countries hazard and risk outputs are qualitative. Depending on the mapping scale and given that the quantitative information in probabilistic terms offers an objective insight to hazards and risks, when feasible, it is necessary in order to minimize the uncertainties that derive from expert judgments and qualitative considerations.

Concerning risk assessment, the methodologies used also show disparity in-between them. It is important to identify reliable methods for vulnerability assessment at different scales and to standardize the quantified calculation of risk, based on different scenarios. Given the scarce of risk assessment methodologies, a possible harmonization is still on a premature phase.

No reference is made, for the reported countries, to tolerability and risk acceptability thresholds. The establishment of common tolerable and acceptable threshold values for the whole of Europe remains an open point for discussion.

6.4 TERMINOLOGY

For the standardization of the methodologies for landslide hazard and risk assessment the use of common terminology is necessary. To this purpose the use of the terminology described in Section 1 is proposed.

6.5 MAP SYMBOLS

For the homogenization of hazard and risk maps, the creation of a common symbol and legend library for the European area is recommended. The symbols used should cover a complete range of different types and mechanisms of landslides hazard and risk levels.

7 ANNEX

The annex includes a synthesis of the information on the hazard and risk assessment practices that are applied in the reported countries, using four tables:

1. Table 7.1: Policies for hazard and risk assessment
2. Table 7.2: Input data
3. Table 7.3: Hazard assessment practices
4. Table 7.4: Risk assessment practices

The tables are enclosed to the deliverable in Excel format.