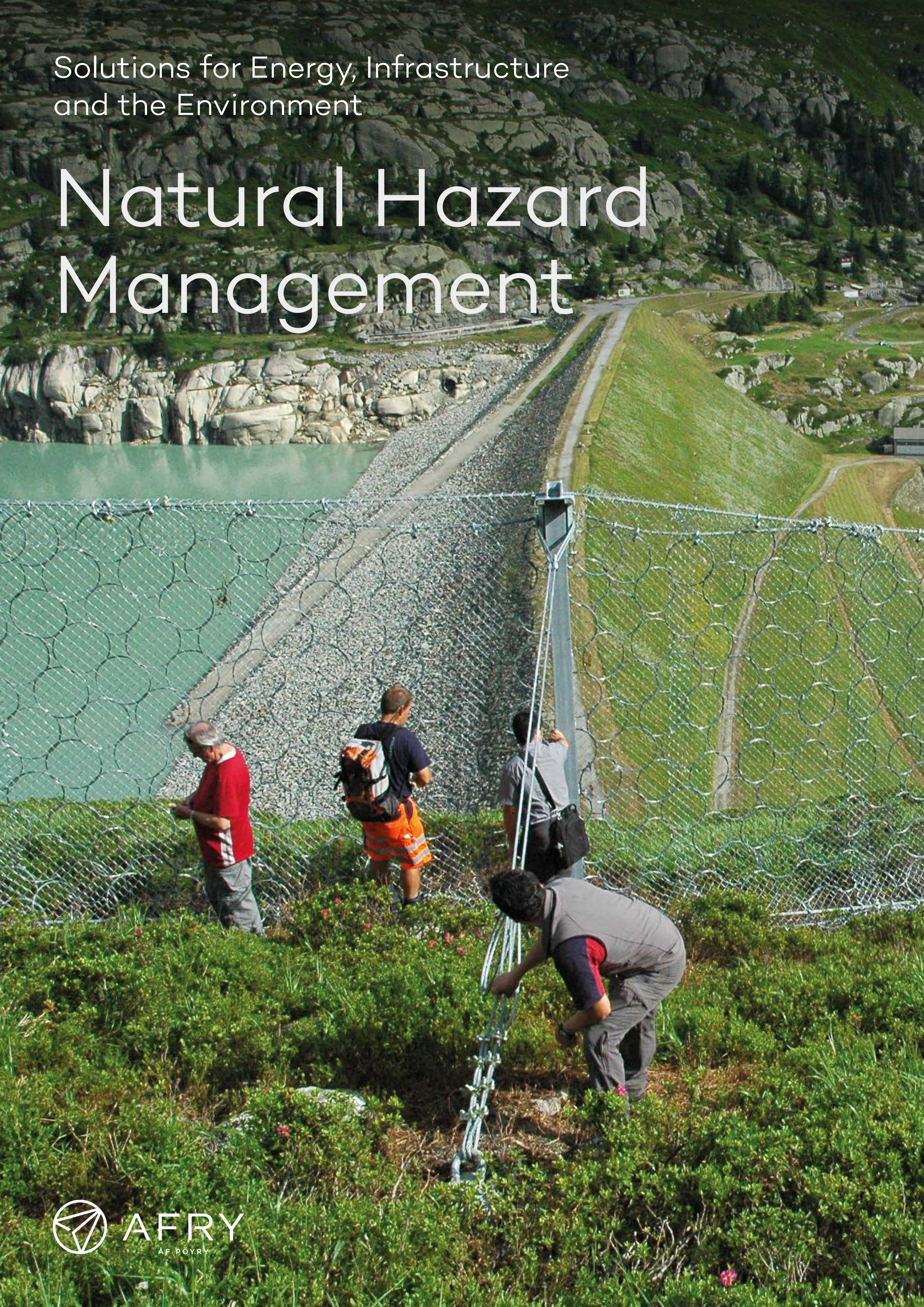
Solutions for Energy, Infrastructure and the Environment

Natural Hazard Management



AFRY
AF PÖYRY

Nature is a living organism that is continuously changing and can never be completely controlled by humans. Events such as floods, rock-falls, landslides, avalanches, and earthquakes influence our living space. Flexible and tailor-made solutions are essential to ensure a safe coexistence between humans, infrastructure, and nature.

AFRY is a leading international engineering, design and consulting company with interdisciplinary expertise in the planning and managing of both small and large projects. Our engineering specialists are here to support you in all related aspects of natural hazard management, from assessment and strategic conception to project planning, approval, construction supervision and management.

The planning of natural hazard management strategies is one of our key services and begins with a detailed assessment of the risk of natural hazards. This is of utmost importance and is the prerequisite for the safe design and safety assessment of all types of infrastructure projects.

AFRY'S EXPERTISE IN ASSESSMENT OF NATURAL HAZARDS

Our experienced engineers, geologists, hydrologists, and scientists execute successful projects all over the world, assessing various types of hazards in a wide range of physical environments.

Slope failure after heavy rainfall, Sri Lanka, 2012

Disaster Risk Reduction

A natural hazard is a potentially damaging physical event, that may cause injury, the loss of life or damage to property, social and economic disruption or environmental degradation. Natural hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, and probability of occurrence.

Such hazards represent a serious threat to human life and assets. Therefore, a thorough assessment of the prevailing hazards and risks in a specific region is imperative for any kind of development activity. This is particularly important in disaster-prone areas, such as floodplains, steep valleys in mountainous regions, areas of higher seismicity, or areas exposed to storms and high precipitation.

Various types of natural hazards can be distinguished, depending on topographic and climatic conditions in the project area.

GEOLOGICAL HAZARDS

- Earthquake
- Landslides and slope failure
- Block/rock-fall and rock avalanche
- Debris flow
- Ground subsidence and liquefaction
- Dissolution of rock, etc.

METEOROLOGICAL AND HYDROLOGICAL HAZARDS

- Heavy rain
- Flash flood
- River flood
- Tsunami
- Strong wind
- Wild fire
- Snow avalanche
- Anomalies of temperatures, etc.

The time-dependence of the different hazards, which plays an increasing role in connection with climatic change, must be addressed. This requires a periodic reassessment of hazards when new information (e.g. melting of permafrost, etc.) becomes available.


Flood with dam overtopping, Palagnedra, Switzerland, 1978


Slope protection above federal road and railway, Austria, 2020


Rock-fall protection barriers above Ova Spin Dam, Switzerland, 2015


Damage to Shih-Kang Dam due to fault movement, Chi-Chi earthquake 1999, Taiwan

Methodology

AFRY's approach in the assessment of natural hazards is based essentially on the methods developed and applied successfully in infrastructure projects located in difficult geological, topographical and climatic environments within Central Europe.

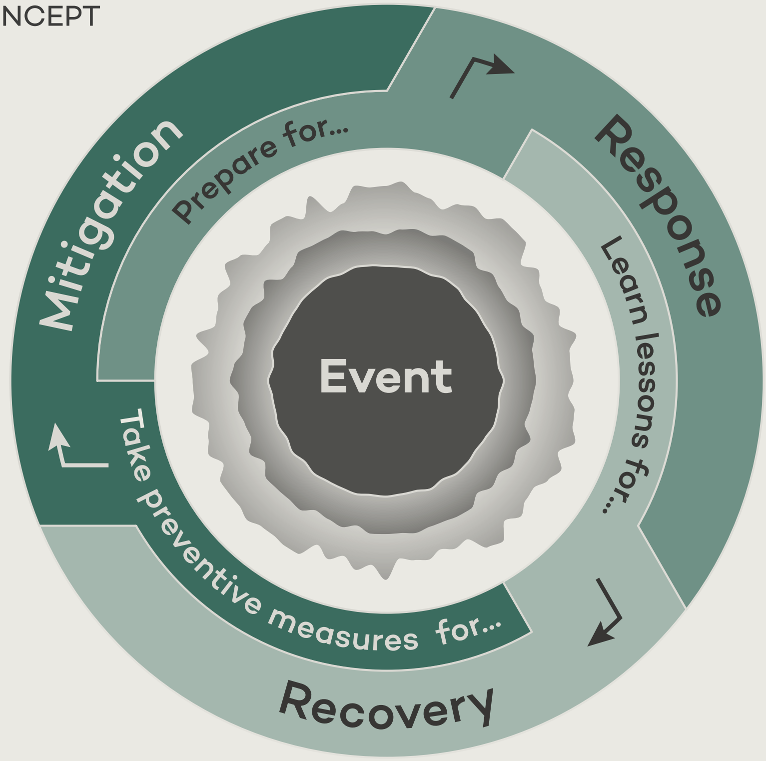
Disaster Risk Reduction (DRR) has a long tradition in Central Europe, starting with the construction of the railways through the Alps and the development of water resources for energy production with run-of-river power plants and large storage schemes. Some of these achievements have been in successful operation for more than a century. Today, risk-based approaches for particular natural hazards, such as rock-fall, floods, and earthquakes, are gaining in importance.

A risk-based approach comprises standardized procedures and clearly defined logical steps of activities to allow for a flexible application of the methodology, dependent on the project's size and complexity, the type of hazards, and their potential impact.

THE PRIMARY GOAL IS TO FIND ANSWERS TO THE FOLLOWING QUESTIONS:

1. **What** can happen (slope failure, rock-fall, flood, earthquake etc.) and **where** will it happen? → Identification of hazards
2. **How often** and **how intense** will it happen, how extensive is the expected **damage**? → Analysis of hazards, vulnerabilities and risk
3. What are the most **efficient ways** to protect people and assets? → Planning of measures

THE APPLIED RISK CONCEPT



VULNERABILITY

A measure of susceptibility of an object or community to being harmed physically or economically by physical, social, economic, and environmental hazards or processes.

The vulnerability is determined by the exposure, the value and the susceptibility to damage.

RISK

The product of the probability of hazard and the impact (probability of harmful consequences, or expected losses resulting from interactions between natural hazards and vulnerable object or system)

Risk is conventionally expressed by the notation:

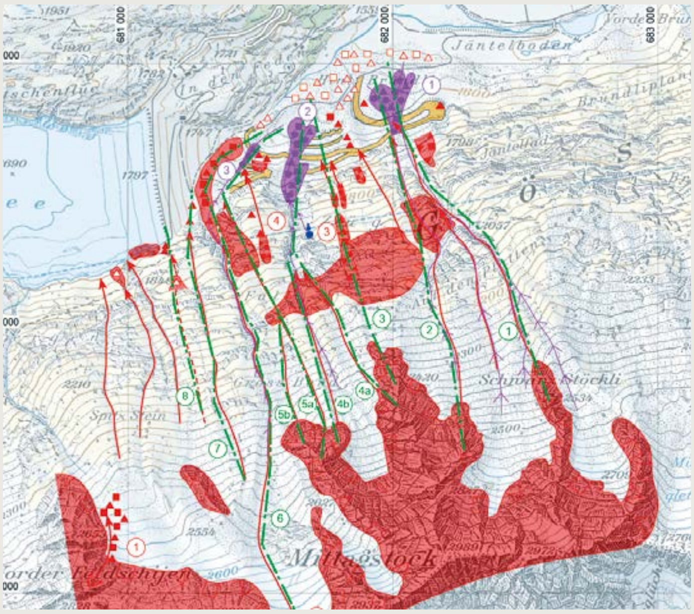
Risk = Probability of Hazard event x Vulnerability

> "An integrated approach for the reduction of risk to hazards, demands well established hazard and risk assessments."
>
> Swiss Agency for Development and Cooperation (SDC), 2005

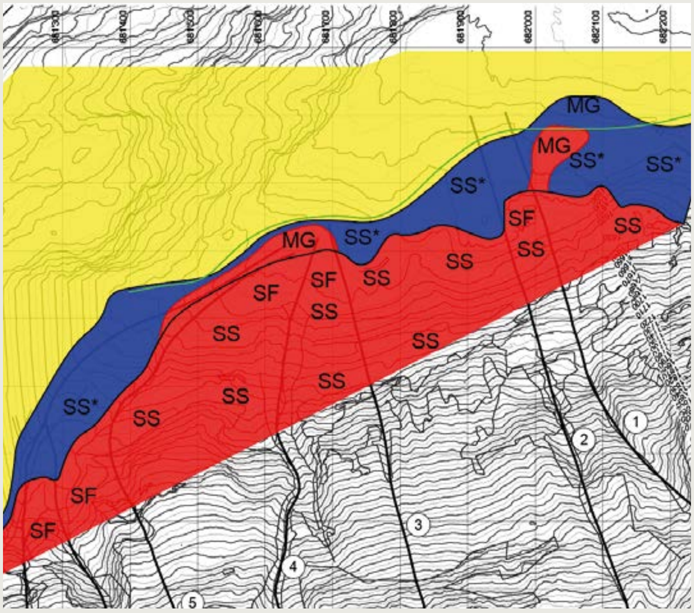
AFRY's approach to assess and quantify the natural hazards, risk and necessary mitigation measures:

1. Hazard/Risk
   - Analysis of all prevailing hazards
   - Analysis of vulnerabilities
   - Use of harmonized and natural hazard-consistent procedures
2. Risk Evaluation and definition of protection goals
3. Definition of design criteria
4. Planning of measures according to sustainability principles
   - Planning of measures, employing an integrated approach by following applicable codes, regulations and recommendations
   - Planning of sustainable solutions
   - Partnership with all project stakeholders and authorities

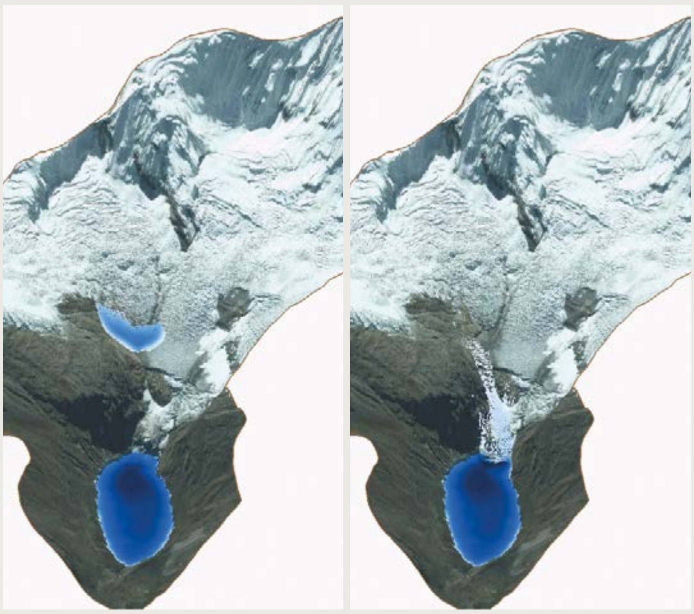
Slope failure, Mindanao, Philippines, 2015



Map of phenomena, Goescheneralp Dam, Swiss Alps



Danger map, Goescheneralp Dam, Swiss Alps



3D modelling of glacier block slide, Laguna Rajucolta, Peru, 2017

The basis for answering the principle questions is a series of map types.

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1. Event Map and Event Register

Display record events that occurred in the past and provide an overview.

2. Map of Phenomena

Documents past events, phenomena, and sources indicating future potential events.

3. Hazard Map

Shows where a hazardous process can occur. Most hazards are distinguished according to the type of hazard, source area, flow path, and impact area.

4. Danger Map

Indicates the intensity and probability of the process. Primary management tool; justification for structural protection measures; basis for site monitoring, emergency planning, and risk assessment.

5. Vulnerability Map (Map of Potential Damage)

Includes economic assets and is used as a tool for emergency planning, priority setting and as a basis for the production of risk maps.

6. Risk Map

Shows at a glance how great the probability of risks occurring and their possible effects are. The risk map is the basis for the chronological and financial prioritization of protection measures and is the most appropriate tool for decision making about structural and non-structural measures.

7. Intensity Map

Provides the spatial extent and the corresponding intensities of a natural event, having a specific return period or probability of occurrence.

The type and complexity of the project define which map types will be applied for the assessment.

Benefit for the Client

This methodological approach gives the following benefits to the Client:

Block/Rock avalanche, Swiss Alps, 2004

STATE-OF-THE ART METHODOLOGY

The working steps are well defined and standardized and can be applied for different natural hazards for both infrastructure projects (includes moving live assets) and for fixed assets such as power plants.

MODULAR CONCEPT APPLICABLE TO THE NEEDS

The necessary and most economic mitigation measures (both physical and procedural) can be adjusted to the size and complexity of the situation and project.

EFFICIENT AND EFFECTIVE TREATMENT OF NATURAL HAZARDS

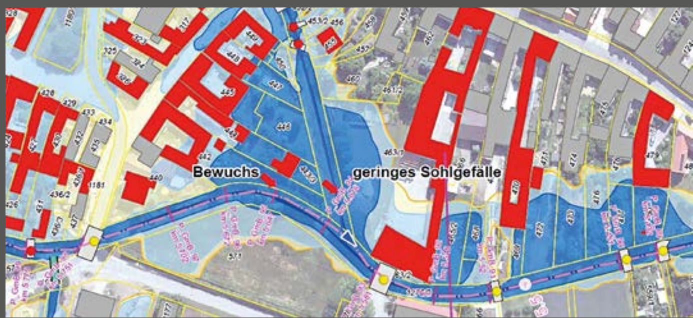
Only hazards with real impact on the project will be treated and the mitigation measures can be tailored to the risk. However, all possible hazards will be considered.

TRANSPARENT AND REPRODUCIBLE PROCEDURE

The standardization of the steps and measures enables transparent reproduction of the results for all stake holders.

COST

Our tailored studies according to the clients' needs lead to the most cost-efficient solutions.



Inundation and flood hazard maps for a river in Austria, 2019

3D drone mapping of geological characteristics, Austria, 2020

Mass movements into Zipingpu Reservoir, Wenchuan earthquake May 2008, China

The professional assessment of natural hazards requires extensive experience in observations and mapping in the field. AFRY has the experience and knowledge gained from all different geographical regions/environments around the world from an extensive list of successfully executed projects.

Selected Project References

160 MW HEPP Goeschenen, Heightening of 155 m high Goescheneralp Embankment Dam, Switzerland

Assessment of natural hazard risks around the embankment dam and the reservoir area

The borrow areas from where the material for the heightening of the Goescheneralp Dam was extracted and sections of the dam construction site are strongly threatened by different types of natural hazards.

To analyze the situation adequately and to design appropriate mitigation measures for a safe construction site, the standardized methodology prepared by the related Federal Offices of the Swiss Government was applied. Furthermore, the analysis was geographically extended around the entire reservoir rim for use as basic input data for the optimization of the new freeboard. The natural hazards of concern are rock-falls, rock avalanches, debris flows and snow avalanches.

1500 MW Mphanda Nkuwa Run-of-River Power Plant on the Zambezi River, Mozambique

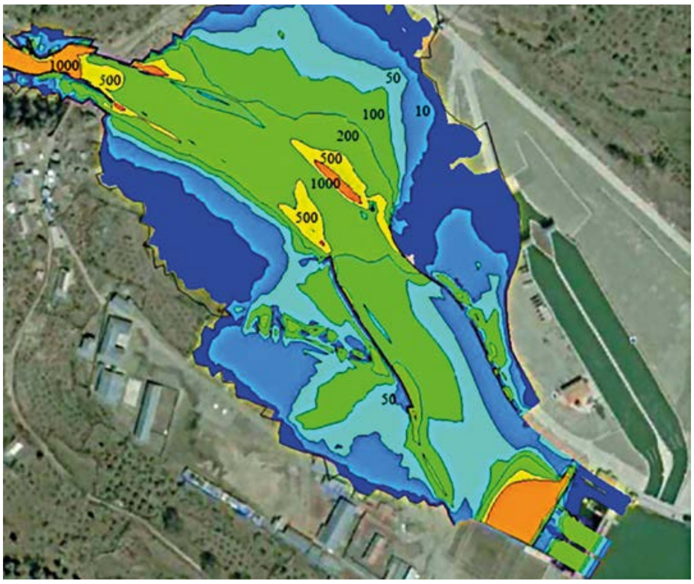
Seismic and seismo-tectonic assessment for the weir-powerhouse location and the reservoir area

AFRY was contracted to conduct assessments of the seismo-tectonic situation in the Province of Tete (Northwestern Mozambique), the seismic hazards for the civil structures and the reservoir-triggered seismicity (RTS).

Based on document review and site inspection, the area was seismo-tectonically assessed and critical faults were identified. Additionally, the natural seismic hazard and the RTS were analyzed, a seismic monitoring instrumentation array outlined, and the design parameters defined.

Selected Project References

Damma-Glacier, Swiss Alps

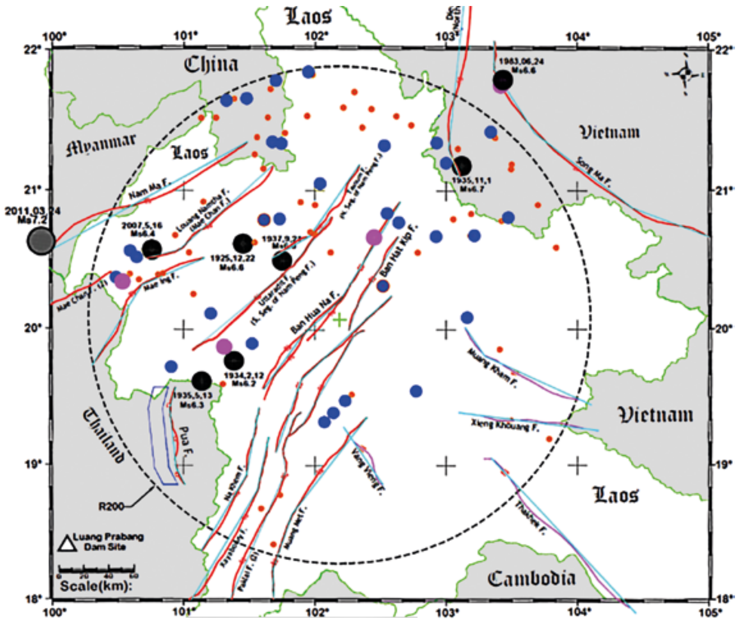


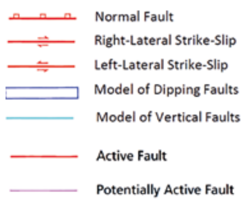
Baspa Stage II HEPP
Himachal, Pradesh, India

Detailed analysis of retrogressive erosion damages on the scheme after the flash flood event of July 2005

Due to heavy rainfall, a flash flood reached the headworks of the Baspa Stage II HEP and the water released from the reservoir resulted in landslides and retrogressive erosion causing a severe impact and damage to the weir structure and stilling basin.

AFRY was contracted for an independent review and assessment of the event and the hydrological, geological, operational and design, procurement and implementation of civil mitigation measures. The results of the study, field analyses and applied flood simulations based on the operational data were documented for the state authorities.

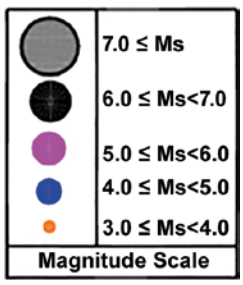




Luang Prabang HEPP, Laos

Seismic hazard assessment, seismic safety evaluation and design of a large scale hydro power plant for a region with moderate to high seismicity

A site-specific seismic hazard study was carried out which took into account both the regional features of Southeast Asia and local site conditions. The defined seismic design parameters for the MCE, SEE and OBE event were implemented in the design of the RCC gravity dam and civil structures.



Our specialists performed geological and geotechnical field investigations to assess input parameters for the seismic hazard study. Foundation and seismic parameters were applied to study the soil structure interaction (SSI) of the dam in various loading conditions.

Lower Kaleköy, Turkey

Assessment of landslide risk, planning of mitigation measures, and assessment of the resilience of large civil structures in a high seismic region

The 500 MW Lower Kaleköy Hydro Power Plant is located in a region of high seismicity in Turkey. The structure comprises a 95 m high asphalt core embankment dam and a 105 m high RCC gravity dam.

AFRY experts carried out comprehensive geological and geotechnical studies of an area prone to landslide failure. Extensive geophysical survey methods were employed for the determination of a 3D underground model and various failure mechanisms. The acquired information was used for the designing of mitigation measures to increase the stability against landslide and dam safety.

The seismicity on-site and the foundation conditions of the dam structure made comprehensive studies of the dam behavior under seismic loading indispensable. Soil structure interaction analysis (SSI) were also employed to ensure a safe dam design.

Glacier Lagoons Risk Assessment and Safety Management, Peru

Natural hazard and risk assessment for glacier lagoons and safety management

The lagoons of Aguascocha, Rajucolta, Parón and Cullicocha are tropical glacier reservoirs in the Cordillera Blanca of the Peruvian Andes. The main hazards for these lagoons are earthquakes and glacial ice-fall which cause glacial lake outburst floods (GLOF), posing a constant threat to the downstream inhabitants.

Above the Rajucolta Lagoon and Dam, 18 hazardous glacial blocks were identified, with the potential of causing dam overtopping wave heights of up to 20 m. The nine most hazardous glacial blocks were evaluated in detail by applying a sophisticated 3D CFD analysis comprising glacier block disintegration, impact and wave generation, and dam erosion. Risk mitigation measures from technical and economical perspectives were then evaluated and structural measures (dam strengthening, flood protection downstream) and non-structural measures (optimized reservoir operation rules, glacier monitoring) were designed.

AFRY is a European leader in engineering, design, and advisory services, with a global reach. We accelerate the transition towards a sustainable society.

We are 16,000 devoted experts in infrastructure, industry, energy and digitalisation, creating sustainable solutions for generations to come.

Making Future

Please contact us at:
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Front cover:
Rock-fall protection,
Goescheneralp Dam,
Switzerland, 2010