SETOF Soil Erosion and TOrrential Flood Prevention: Curriculum Development at the Universities of Western Balkan Countries

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WP1

Analysis of soil erosion state and torrential floods in Western Balkan Countries

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1 Prevention measures for erosion and torrent control in Austria

The Report is based on the flyer „Austrian Service for torrent and avalanche Control“, published by the Federal Ministry of Agriculture, Forestry, environment and water management (2016) and the proceeding „From practical experience to national guidelines for debris-flow mitigation measures in Austria“, published at the 7th Debris flow hazard mitigation conference, Denver (2019).

1.1 Introduction (natural conditions)

Hazards emerging from torrents, avalanches and erosion have mainly regional effects, but in the mountainous country of Austria natural hazards control as such is a task of national importance. As of 2015 11,922 torrents and 7,295 avalanches have been recorded in Austria. About 70 % of the federal territory (83,855 km²) is subject to the care of the Austrian Service for Torrent and Avalanche control; in the Federal Provinces of Vorarlberg, Tyrol, Carinthia and Salzburg this area covers more than 80 % of the provincial territories.

In Austria about 120,000 buildings and 1,500 kilometers of transport routes are exposed to the risk of torrents. Avalanches endanger in particular the living environment of the intra-Alpine valleys, where large avalanches frequently reach the bottom of valleys.

1.2 Historical review of erosion and torrent control

There is a long tradition of natural disaster mitigation in Alpine regions. In the 18th century, Joseph Walcher (1719-1830), an Austrian Jesuit, physicist and mathematician, worked on the topic of hydraulic and glacier lakes. In his work ”Nachrichten von den Eisbergen in Tyrol” (Walcher, 1773), he investigated the Vernagt glacier, Gurgler glacier and especially the Rofner glacier lake, which threatened the Ötz Valley by repeated glacial lake outburst floods. These outburst floods had catastrophic consequences for the province of Tyrol in the years 1600, 1678, 1680 and at 1845. In the year 1788, an edict promulgated by Wenzel Graf von Sauer, incited working-groups to establish mitigation measures (Graf von Sauer, 1788). Franz Seraphin von Zallingerzum Thurn, priest and physicist, worked on this edict and addressed the issue of inundation in Tyrol in his work “Abhandlung von den Überschwemmungen in Tyrol” in the year 1779 (Zallingerzum Thurn, 1778;1779). One of the first technical drawings can be found in this publication. Also in France, Jean Antoine Fabre was involved in the topic of mitigation measures in Alpine regions with his book “Essai sur la théorie des torrens et des rivéres” (Fabre, 1797). In the next decades, the topic gained interest, but most work remained theoretical (Aretin, 1808; Streffleur, 1852; Müller, 1857). It was the work of Josef Duile that started practical implementation of mitigation measures (Duile, 1826). He was an engineer, primarily in the field of hydraulics and road construction with a keen interest in torrent control. Due to his leading role in this field, he was called to Switzerland and applied his knowledge there. He can be considered as father of the European torrent control. In this time, two technical domains characterized the progression

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of the torrent control: one was hydraulic engineering and the other was forest engineering. Hydraulic engineering was mainly applied to the lower part of the torrent while forest engineering addressed the headwaters. The political question who should further be responsible for torrent control works led to a controversy between Arthur Freiherrn von Seckendorff (forest engineering) and Weber von Ebenhof (hydraulic engineering) (Länger, 2003). During this time, Seckendorff started to study the methods developed in France, especially the works of Prosper Demontzey (1880). Owing to the major catastrophes in the years 1846 and 1856 along the rivers Loire and Rhone in France, increasing knowledge developed in this field and public support started and led to a legal foundation of mitigation works in the years 1860 and 1864, especially related to reforestation.The severe floods in Tyrol and Carinthia in the year 1882 initiated, as in France, a rethinking. Julius Graf Falkenhayn (k.u.k. Minister of Agricultur) travelled to France in the year 1883 to learn of the methods used, and to implement them in Austria (Wang, 1901). The emperor of the Austrian-Hungarian monarchy passed the torrent control act in 1884, stating that torrent control works have to be executed on a national level, with public funding and with a systematic approach. Seckendorff introduced the forest engineering background from France successfully. The government implemented a legal basis for financing and organizing the torrent control service to ensure further development. The educational course „Afforestation and torrent control in mountainous areas“ was established 1879 at the University of Natural Resources and Life Sciences, Vienna (BOKU) for students and the staff of the new established service.

The construction materials used at this period consisted of the locally available construction materials near the torrents (Wang, 1901). Wood and dry-stone masonry were used for mitigation measures. Progress was achieved through dissemination of experience and not by research because no research facilities existed at the time. Nonetheless, first innovative experimental structures were raised, for example:

- Barrier with a self-cleaning function (dosing) was installed in the Fischbach, Tyrol (1924-1928)
- A cement mortar arch dam was built in the years 1951/52 in the Finsingbach, Tyrol, to study the failing conditions of this construction type.
- Prefabricated construction of a dam of reinforced concrete was built in the Winklergraben, Upper Austria (1929-1931).

Due to the improvement of materials and mechanization on building sites in the second half of the 20th century, new methods were established in the torrent control service. Increasing usage of heavy machinery in the steep regions enhanced construction efficiency.

Depending on the two main types of structures used, the arch dam and the gravity wall, different formulas were used for design. The design calculations either focused on water or earth pressure. In the year 1972 the Austrian Centre for Forest Research (BFW) held an international colloquium on check-dams in Vienna. Lichtenhahn presented at this colloquium the later often-used load model for design (Lichtenhahn, 1972). He proposed an empirical multiplier to increase the hydrostatic pressure to include load of debris-flow pressure. In practice, this multiplier ranges significantly and led to different structural designs of check-dams.Due to this long tradition in torrent control works in the Austrian Alps, numerous different types of protection works were designed in different regions in Austria.

Nowadays the design of technical structures is based on the EUROCODE concept, that specifies how structural design should be conducted within the European Union. Based on this, the technical standard series ONR 248xx was established, encompassing torrential processes, snow avalanches and rock fall. An interdisciplinary working group (ON-K 256) developed the new standards for the load models, design, construction and life cycle assessment of torrent control works. For torrent control following national documents have been developed and published by the Austrian Standards Institute:

- ONR 24800 (2009): Protection works for torrent control - Terms, definitions and classification; Contains the terminology and classifications of torrent control including the terms concerning the design and function of torrential barriers. An important classification is the definition of functional barrier types.
- ONR 24801 (2013): Protection works for torrent control - Impacts on structures; stresses on torrential barriers result from water (hydrostatic, dynamic), earth and debris-flow impacts.
- ONR 24802 (2011): Protection works for torrent control - Design of structures; for the design of torrential barriers, the Ultimate Limit States (ULS) and the Serviceability Limit States (SLS) must be considered. The concept gives specific design rules (e.g. stress combinations) for torrential barriers.
- ONR 24803 (2008): Protection works for torrent control - Operation, monitoring, maintenance; a fundamental requirement to guarantee a minimum safety level of the protection works is periodic monitoring of their condition and effectiveness. The monitoring concept, in the ONR 24803, is divided in two parts, the inspection and the measurement or intervention part.

By these technical standards, the “traditional” assessment and construction concepts for torrent control structures were adapted to the EUROCODE standards. The documents are based on and interact with EN 1990 (basic of structural design), EN 1992-1-1 (design of concrete structures), EN 1997-7 (geotechnical design) and the related documents for the Austrian national specifications.

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1.3 Prevention measures

In the Alps basic techniques of "torrent control" have been known for a long time. The first torrent defense works were constructed around the year 1500. Originally, control plans took advantage of the possibilities of using "living" construction material (bioengineering), aimed at preventing the erosion of loose rock, or promoted the protective effect of forests. Particularly impressive examples of these forest engineering measures are the successful reforestation of torrent catchment areas or the stabilization of large erosion areas (scars) planted in the early 20th century.

Comprehensive plans concerning the management of sediment transport in torrential catchment areas and corresponding types of dams and barriers were developed in the seventies and eighties. Over the past few years holistic planning approaches and the management of catchment areas within the meaning of the objectives of the European Union's Water Framework directive have become important tasks. Today the modern system of torrent- and erosion control measures comprises active and passive measures with permanent or temporary effects.

			permanent effect	temporary effect
active mitigation measures	proactive (preventive)	disposition management	catchment care forest management activities soil bioengineering structural measures maintenance	maintenance (regular inspection, control, special check)
		event management	structural measures	temporary local protection structures
	reactive			immediate technical assistance
passive mitigation measures	proactive (preventive)		hazard zoning landuse planning building codes evacuation and contingency plans	monitoring information warning and alert blockade evacuation
	reactive			disaster management

Figure 1: Chart on established mitigation measures in Austria

Active mitigation measures may affect the initiation, transport or deposition of torrential flows, and can therefore modify its magnitude and frequency characteristics. This can be achieved either by changing the probability of occurrence (disposition management), or by manipulating the flow process itself (event management).

Passive mitigation measures are used to reduce the potential losses by, for example, altering the spatial and temporal character of either the damage produced by the torrential process or the associated vulnerability. Vulnerability of a disaster can be changed either with a proper land use planning based on hazard maps and meeting building codes, or

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through immediate disaster response. Nowadays early warning systems become more and more important. Communication and training is the prerequisite for an effective application for these measures.

1.3.1 Structural measures

According to the specified protection goal a strategy can be selected and taking into account the potential behavior of torrential system. To implement the chosen strategy, mitigation measures are selected that fulfill defined requirements, so called functions. The joint effect of these functions within the torrential system should contribute to reach the protection goal in the most effective and efficient way. The performance of the functions must be evaluated at least after a torrential event to identify shortcomings and to optimize the selected measures.

Following functions of structural measures were defined in the national guidelines of Austria. They are grouped according to disposition and event management.

In case of disposition management:

- Stabilization

  Stabilization of the horizontal and vertical position of the channel and the embankment to minimize debris mobilization along the channel. The design channel slope should match with the transport capacity. Stabilization is usually realized by a combination of longitudinal and transverse structures (e.g. trench, channel adjustment).

- Consolidation

  Lowering the probability of slope and bank failures close to the channel by raising the channel bed to get a toe counterweight of the adjacent hillslope and bank. Decreasing the channel gradient by a series of checkdams additionally reduces erosion and stabilizes the channel. Consolidation can be supported by forest management activities and soil bioengineering.

- Diversion

  Creating a bypass to the original channel to avoid excessive sediment mobilization along specific channel reaches (tunnel, rock channel).

In case of event management:

- Retention

  Permanent deposition of sediments upstream of a structure. Once the retention basin is filled, it completely interrupts bedload transport and can lead to excessive erosion

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downstream. At this stage, a dosing function could be considered upstream of the structure.

Temporary or permanent retention of floodwaters during flood events to reduce peak flow.

- Filtration

  Separation and deposition of grain sizes exceeding a defined diameter or of large woody debris at the structure that may clog downstream reaches. If the structure is backfilled, still a dosing function remains. There is no natural remobilization of the deposited material, the basin must be excavated mechanically.

- Dosing

  Temporary deposition of sediments by creating backwater in a bottleneck (e.g. open checkdam) or by reducing the channel gradient in a channel reach with the help of a series of checkdams. The surplus of debris should be stored, and later released if the tailwater is deficient of sediments.

- Transformation/Energy dissipation

  Slowing and depositing of the surge front of a debris flow to ensure lower dynamic impact in the downstream reaches. In an array of different mitigation structures, a structure with this function is always in the most upstream position and should retain at least the volume of a debris flow surge. The commonly used term is debris flow breaker for a structure with this function.

Within the group of structural measures two functions do not modify magnitude or frequency, but just influence the flow direction of the torrential process on the fan.

- Channeling

  Enlargement and strengthening of the channel to assure the passing of the design flow without inundation of a potentially endangered area (e.g. trench, channel adjustment)

- Deflection

  Directing the flow towards areas of low consequences in the deposition area (dikes, deflection walls). Deflection is commonly utilized as the last element of a systematic torrent control to diminish any remaining risk.

Generally, there are technical and economic limits to each and every control measure. In some cases it is better to abandon the endangered area (desettlement) and shift the residential area to less threatened areas. In any case future need for control measures can be avoided by precautionary spatial planning.

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1.3.2 Hazard zoning

Hazard zoning as an instrument of showing the areas exposed to torrents and avalanches is an achievement of the sixties and was legally regulated in the Forest Act of 1975 (§ 7, 8, 11). According to the provisions of the Forest Act 1975, the catchment areas of torrents and avalanches as well as the zones endangered by them, reservation and reference areas are to be presented in hazard zone maps. Hazard zone maps have been prepared in Austria for 40 years. Austria has 2,102 municipalities, of which 1,394 need a hazard zone map approved by the Federal Minister of Sustainability and Tourism.

The task of hazard zone mapping is carried out by the members of the Austrian Service for Torrent and Avalanche Control. The identification of hazard zones is based on state-of-the-art methods and up-to-date knowledge, the personal experience, the documentation of historical disaster events (torrent and avalanche cadastre) and the presentation of possible damage events (scenarios), which are described with a probability of occurrence (recurrence probability) of 1 in 150 years. They are presented in the form of an area presentation on a 1:2,000 scale, mostly for the territory of a municipality on the basis of the digital parcel cadastre. Every hazard zone map is subject to a comprehensive control and approval procedure. The draft of a hazard zone map is forwarded to the major of the municipality and shall be available for public inspection for four weeks. Everybody who can demonstrate a justified interest is entitled to inspect the draft and to express his/her opinion on the draft in writing. After the expiry of this deadline a commission – comprised of a representative of the Federal Ministry of Sustainability and Tourism, the Federal Province, the competent section of the Austrian Service for Torrent and Avalanche Control and the municipality – has to examine the map – and, if necessary, to modify it, taking into consideration the opinions delivered in writing. The recognition (approval) of the hazard zone map is granted by the Federal Minister for Sustainability and Tourism. This comprehensive procedure ensures on the one hand a broad consensus at technical level and a high planning quality, and aims on the other hand at achieving a high level of public acceptance of this important instrument of land-use planning, as well as of the building and security sectors.

A hazard zone map takes into account all possible hazards emanating from torrents and avalanches and is an area-based expert opinion without direct legal binding effect. It is the basis for the projecting and the implementation of measures of the Austrian Service for Torrent and Avalanche Control as well as of the ranking of these measures according to priority.

Hazard zoning includes the experience and the knowledge of experts of the Austrian Service of Torrent and Avalanche Control as well as the results of digital process modelling (numerical simulation) or the reports made by eye witnesses of large-scale disasters. If the

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conditions in a catchment area change or if there are new findings as a result of disasters, the delimitation of hazard zones is subjected to an adaptation.

The implementation of hazard zone maps in the field of land-use planning and in the local construction sector often leads to conflicts with other, particular utilisation interests. The position of a plot of land within the red hazard zone is frequently felt by the owner to be a decrease in value. However, the disasters in the course of the last few years have explicitly shown the important role hazard zone maps play in counteracting a further increase in damage potential (objects to be protected) in endangered areas.

The Austrian hazard zones are characterized as follows:

- In red hazard zones the threat is so high that permanent settlement is not possible or only possible with a disproportionately high expenditure. The construction of new buildings is not recommended.
- In yellow hazard zones the permanent use for settlement and transport purposes is impaired. Building in these areas is only possible on condition that all requirements are complied with.
- Blue reservation areas are areas which are to be kept free for future technical (e.g. construction of a sedimentation basin) or biological control measures (e.g. afforestation).
- The brown reference areas indicate hazards other than those evoked by torrents and avalanches (e.g. stone fall and slide areas).
- Areas whose present state has to be preserved in order to ensure the protective function also in the future (e.g. natural diversion dams, flood retarding areas in the form of terrain synclines, etc.) are identified as violet reference areas.

1.3.3 Natural hazards information and expertising

Communicating the risk associated with the natural hazards of alpine areas is an essential contribution towards improved hazard awareness of the population. The goal pursued is first to create social acceptance of the impending hazards and the necessary preventive measures and, in a second step, to make citizens participants in the process of preparing for natural hazard events.

With its hazard zone map the Austrian Service for Torrent and Avalanche Control has an effective instrument at hand with which to communicate the risks of natural hazards.

The key function of this instrument is the public provision of information on the potential impacts of natural hazards in specific areas. Following the principle of publicity set forth in the Forest Act also written comments by all persons concerned in the process of hazard zone planning were soon possible (1975). The required integration with other plans and land-use interests comes by presenting the hazard zones within the framework of the local spatial planning (land-use plan, local development concepts) and the geographic information systems (GIS) of the Federal Ministry for Sustainability and Tourism and the Provinces.

Information about natural hazards is provided through digital and analogous media, but also through conversations with citizens. Special information offered for children and teenagers is a chance to teach them playfully about natural hazards and their risks. As a matter of necessity there are two major levels of communication during the planning processes of active or passive protection measures:

- communication with stakeholders (beneficiaries, adjoining owners, holders of rights, citizens' initiatives, NGOs)
- communication in connection with various technical plans of relevance to specific areas

The torrent and avalanche cadastre is the main data source. This geoinformation system provides comprehensive information about catchment areas, hazard maps, expertising, events and technical measures and their state of condition.

Expertising includes giving advice in different administrative procedures for federal, provincial and municipal authorities. The aim is to raise public awareness and, as a consequence, the perception and acceptance of natural hazards. A high level of awareness and acceptance encourages making own precautions and object protection measures. Examples of object protection measures include elevated entrances or deflecting fences and walls.

1.4 Institutional and legal framework in the field of erosion and torrent control

The protection against torrents and avalanches is laid down in the Austrian constitution as a competence of the Federal Government (Art. 10), both with respect to legislation and execution. On the basis of the Forest Act of 1975 the Federal Government attends to this task via a decentralized agency immediately subordinated to the Ministry of Sustainability and tourism, labeled as the Austrian Service for Torrent and Avalanche control.

In the Forest Act (§ 102) all tasks of its offices are laid down, among them

- the drawing up of hazard zone maps,
- the planning and implementation of technical and forest-biological control measures,
- the consulting services and expert activities,
- the care for the torrent and avalanche catchment areas,
- the administration of the subsidies allocated, and
- the representation of the public interest concerning the protection against alpine natural hazards.

The Forest Act includes also provisions on the headquarters and organization of the offices. Presently there are 7 provincial headquarters (Vienna, Lower Austria and Burgenland in the

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same one) and 21 regional headquarters (Figure 1). Further, 3 staff units (Geology, Snow and Avalanches, Geo-information) and 4 expert teams (torrential Processes, Ecology, Monitoring and Measurement, Flood retention) fulfil important planning tasks.

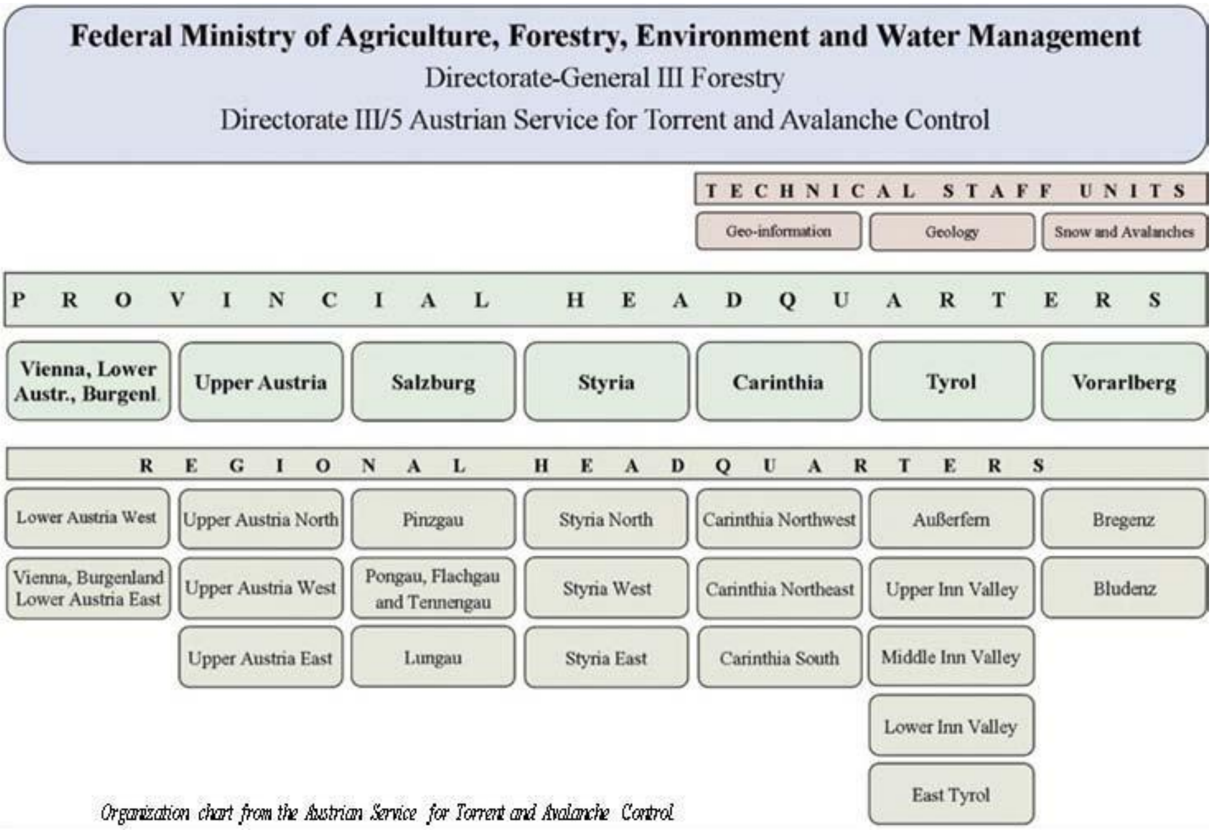

Figure 2: Organisation chart ofthe Austrian Service for Torrent and Avalanche Control (2016)

The Austrian Service for Torrent and Avalanche Control and its offices (including the three technical staff units) have about 300 staff members working in the fields of technology and administration and approximately 700 workers employed on the basis of contracts for work and services to fulfil the tasks defined by the Forest Act of 1975. Also the legal foundations of the hazard zone map, which is one of the forest land use plans, are laid down in the Forest Act (§ 7, 8, 11) and its regulations (1976, 2011). As far as its legal effect is concerned, the hazard zone map is only an expert opinion, but its content (hazard zones) may become binding due to its being laid down in the local land-use planning. The provincial laws regulating land use and building contain building restrictions for areas exposed to natural hazards. The identification of the hazard zones in the zoning and development plans makes it possible for the authorities to assess the risk for each individual parcel and, if necessary, to determine provisions for making a site apt for development.

Torrent, avalanche and erosion control measures are financed from the disaster relief Fund of the Federal State (Disaster Relief Fund Act, 1996). Subsidies are granted subject to the provisions of the hydraulic Engineering Assistance Act (“Wasserbautenförderungsgesetz”,

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1985), which defines the terms and conditions under which subsidization is provided as well as the principles of the planning and implementation of control measures.

Every year the Federal Government dedicates funds (subsidies) of about 85 million Euros from the disaster relief fund to torrent, avalanche and erosion control. Together with contributions from the Federal Provinces and from beneficiaries (municipalities, water corporations, others) almost € 160 million are thus available annually for investments in active control measures.

About 78 % of the available funds are spent on torrent control, 9 % on avalanche control, 8 % on rock fall and slide control measures, and 5 % on land-use management measures (protection forests, catchment area management). The share of maintenance activities is growing, that of new constructions is slightly decreasing.

However, comprehensive protection against alpine natural hazards includes also organizational measures (emergency alert, alarm, evacuation), monitoring systems and civil disaster control, tasks which are mostly implemented by the Federal Provinces. Modern natural hazard management can best be explained by means of the principle of the risk cycle, which begins with the event (disaster) and comprises disaster intervention, repair, reconstruction, prevention, and measures of disaster preparedness. The objective is to improve and enhance society's preparedness for future natural disasters. Provision of these security services requires the cooperation of experts of numerous technical disciplines and many public and private organizations. A task of natural hazard management is also to harmonies all normative documents and relevant technical plans to serve the goal of protecting against natural hazards.

To coordinate this task the political field of strategy "Protection against natural hazards" has been established at the Federal Ministry of Sustainability and Tourism, which is to attend to the task beyond the specific competences of the individual ministries, regional units and technical fields.

1.5 New trends of erosion and torrent control in Austria

Based on European directives (e.g. water framework directive) different aspects in designing control measures have to be taken into account, especially ecological aspects play a significant role. Engineers have to consider the biological quality (fish, benthic invertebrates, aquatic flora) and the hydromorphological quality such as river bank structure, river continuity or substrate of the river bed. Additionally the topic „connectivity"is of increasing importance in water related protection concepts. This means to include woody debris and sediment transport into the protection strategy, because both factors may increase the risk of torrential processes. On the other hand, these immanent components during floods and debris flows are of high ecological importance for river habitats.

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Structural measures are permanent adapted according to the gained experience by torrential events. But the major challenge in respect to structural measures is to extend the durability of these measures and to develop an appropriate asset management. In 2020, the liable standards „ÖNORM“(ÖNORM B4800), replacing the ONR Series 248XX, will be published.

In connection with forestall measures the influence of climatic change has to be considered. For example, the spreading of invasive species, of dangerous forest pest insects and the increasing risk of forest fires changes the traditional methods in forest management.

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