BORIS

Cross **BO**rder **RIS**k assessment for increased prevention and preparedness in Europe

D2.1

Comparison of National Risk Assessments

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1. SUMMARY

Project entitled Cross border risk assessment for increased prevention and preparedness in Europe (BORIS project, GA. 101004882), sponsored by Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO), focuses on improving disaster preparedness and prevention in cross border areas. Its main objective is to develop a harmonised methodology and tools for seismic and flood risk assessment and demonstrate their application for the selected cross-border sites.

Comparison on national risk assessment (D2.1) is the first of the three deliverables of the BORIS WP2 entitled Analysis of the context and need assessment. Each project beneficiary presented the national seismic and flood risk assessment that was discussed in several meetings. As a consequence of project activities, the national risk assessment (NRA) from Slovenia, Italy, Austria, Turkey, and Montenegro is summarised in this report. Each section addressing the NRA comprises four subsections describing the analysed risks, seismic risk assessment, flood risk assessment and multi-risk assessment.

The last version of NRA of Slovenia was issued in 2020. The NRA addressed 15 risk types, which were mainly assessed by deterministic risk assessment methods. However, risk due to nuclear accidents was based on a probabilistic approach. The seismic stress test of building stock in the Republic of Slovenia, which was performed independently of the NRA, also implemented a probabilistic approach. The seismic stress test's outcome and the plan to enhance seismic resilience in Slovenia were established by performing the time-based risk assessment, a state-of-practice approach in contemporary earthquake engineering. Using two different methods for seismic risk assessment proved that the deterministic scenario-based assessment approach could provide biased conclusions about seismic risk, especially when compared to other risk types. In the case of flood risk assessment, Slovenia strictly follows the EU Water Framework Directive and the EU Floods Directive. The flood risk assessment utilises a deterministic scenario-based risk method that classifies flood risk into five risk levels. Because Slovenia is a small country, there is no need to distinguish between different levels of detail with respect to the spatial scale. The flood and seismic risk are thus assessed at the municipality level. However, the location of buildings and other relevant components is considered by taking into account the spatial coordinates of each component separately.

The Italian NRA was developed at the end of 2018 by the Department of Civil Protection (DPC) in agreement with EU decision 1313/2013 and the Sendai Framework for Disaster Risk Reduction. The NRA addresses ten types of risk. The time-based probabilistic seismic risk assessment is state-of-practice in Italy. It is based on a multi-model methodology, developed by six research units of ReLUIS and EUCENTRE, which are centres of competence of the Department of Civil Protection. The seismic risk was assessed by the IRMA tool. It is based on the OpenQuake engine, developed as a part of the Global Earthquake Model. The collaboration between EUCENTRE and ReLUIS, with the coordination of DPC, led in December 2018 to the production of the seismic risk maps for the Italian territory published in the National Risk Assessment (NRA) document (ICPD, 2018). However, Italy's national flood risk assessment is based on the deterministic scenario-based risk assessment approach that is fully in line with the EU Floods Directive (2007/60/EC) but in contradiction with the time-based probabilistic approach used for the seismic risk assessment. To implement the Floods directive in Italy, the Italian territory was divided into seven districts, further subdivided into 47 flood management

units. Three scenarios were defined on the basis of the interval of the mean return period of selected flood parameters. The risk is communicated by four risk classes that are assigned to pairs of flood hazard and flood consequence classes.

In Austria, disaster risk assessment and management are the responsibility of each federal state. However, the Federal Ministry of Agriculture, Regions and Tourism of the Republic of Austria is taking care of performing detailed (natural) hazard analyses for many years. The risk assessment approaches carried out in Austria are based on Risk Assessment and Mapping Guidelines for Disaster Management of the European Commission, the ISO Standard 31000 and the national standard for risk management ONR 490002. Single-hazard scenario-based risk assessment methods are used to address nine different risk types. A detailed national seismic risk assessment is not yet available in Austria, but it is outlined by the probabilistic seismic hazard maps that were revised in 2020. However, the flood risk assessment is quite detailed. It is based on the EU Floods Directive. The implementation of the EU Floods Directive is available to the public through the web portal Water Information System Austria (WISA). The flood risk management plan, issued in 2015, is under revision. It covers the entire federal territory and comprises 391 units that include 722 municipalities and districts of Vienna. The risk management plan is based on three flood scenarios associated with the intervals of mean return periods of flood parameters. Interested stakeholders can use the HORA platform, an online tool for illustrating the flood, avalanche, earthquake, landslides, storm, lightning, hail, and snow hazard levels for any location in Austria.

Turkey's first National Disaster Risk Assessment (NDRA) report was prepared in 2019 for natural disasters such as earthquakes, floods, forest fires, landslides, rockfalls, and avalanches. The risk is communicated with the risk matrix, which comprises four risk classes depending on the likelihood of the adverse scenario and the consequence class. The risk matrix is used to compare risks due to different hazards. The seismicity in Turkey is high, which forces Turkey towards enhancing seismic resilience. The National Earthquake Strategy and Action Plan are thus continuously being developed since 2012 by the Ministry of Interior, Disaster and Emergency Management Presidency (AFAD). The seismic risk is assessed for four seismic scenarios associated with the spectral accelerations for mean return periods of 43, 72, 475, and 2475 years. Seismic scenarios are defined by the AFAD-RED platform, which is also capable of estimating consequences. Like other countries, Turkey is also assessing flood risk in compliance with the EU Floods Directive. The flood management plan was published in 2015. The risk assessment is based on the flood hazard maps indicating the flood inundation area, flow water level or depth and flow water velocity related to the mean return period of 50, 100, and 500 years. The flood hazard maps and flood risk maps are accessible through GIS-based web applications. No multi-risk assessment study has been performed in Turkey at the national level.

Montenegro's NRS is currently under development within the framework of Development of National Risk Assessment for all types of hazards affecting Montenegro (ECHO/SUB/2020/TRACK1/831677) that is sponsored by the European Commission, Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO). It is foreseen that NRA will provide results for nine types of risk, including seismic and flood risk. The risk assessment will be based on the deterministic scenario-based approach that is in compliance with the seismic risk assessment guidelines of the European Commission. Two earthquake scenarios, which were selected for the seismic risk assessment, are associated with the ground-motion mean return periods of 95 and 475 years with the epicentre in the region with the highest seismicity according to the seismic hazard map of Montenegro. However, Montenegro has already fully transposed the EU Floods Directive into the Montenegrin legislative system. The flood risk assessment is thus scenario-based and addresses the Danube basin and Adriatic basin. The report on the Disaster Risk Assessment of Montenegro is under development.

The NRAs of the five countries are mainly based on deterministic scenario-based risk assessment. It was realised that the flood risk assessment in all five countries is in compliance with the EU Floods Directive, but countries have selected flood scenarios differently. However, the national seismic risk assessment is more diverse. In Austria, it is based on the hazard maps. Turkey, Slovenia and Montenegro are assessing seismic risk based on selected seismic scenarios. In Italy, the seismic risk was evaluated by a time-based risk assessment approach, which was also implemented in Slovenia independently of the NRA. Most probably, the time-based risk assessment is the only valid option for unbiased multi-risk assessment in the future.

In Sections 2–6, the information about the NRAs in the five countries is presented in more detail. Section 7 is dedicated to the disaster risk assessments performed within the selected previous European projects. The presented information is the subject of further analysis to define data availability and needs for large-scale cross-border seismic risk and flood risk assessment.

2. NATIONAL RISK ASSESSMENTS FOR SLOVENIA IN 2020

The Report on Disaster Risk Assessment of the Republic of Slovenia (GRS, 2020) was issued by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief of the Ministry of Defence, acting as the National Coordination Body for disaster risk assessments and disaster risk management capability assessments. The National Disaster Risk Assessment should be amended every three years, which means that the next amendment is expected to take place in 2021, with the assessment version 2.0 from 2018 (GRS, 2018) serving as a basis. However, the contemporary seismic stress test of the building stock in Slovenia was performed in 2020 (Dolšek et al., 2020) for the needs of the Ministry of the Environment and Spatial Planning of the Republic of Slovenia. The novelties of that study are discussed in the section related to the seismic risk.

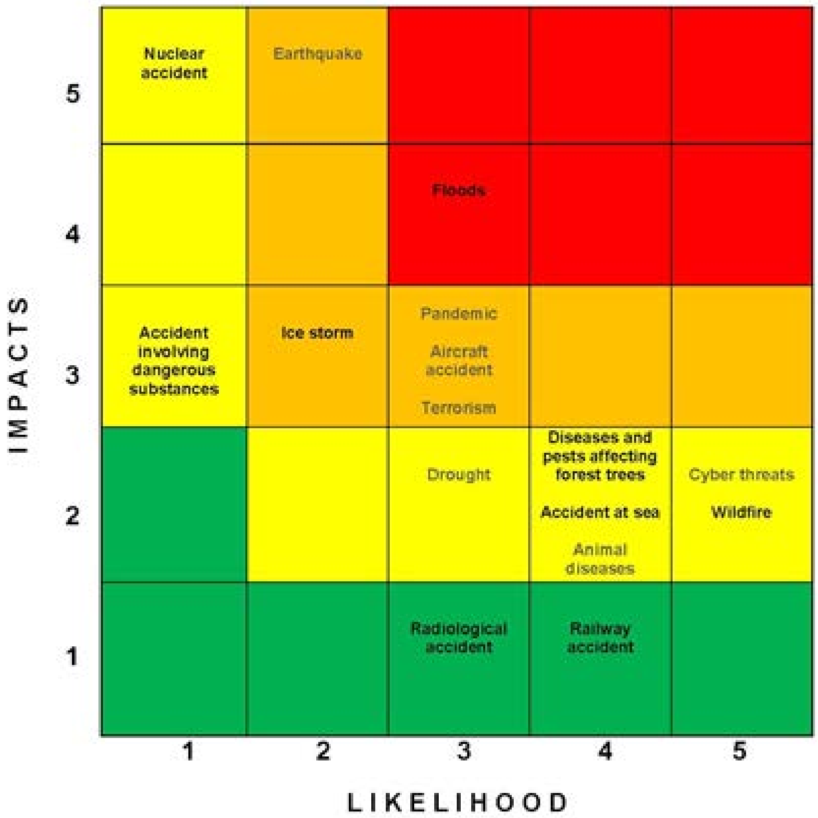
2.1. The analysed risks

The National Disaster Risk Assessment for Slovenia (GRS, 2020) encompasses 15 risk types: earthquakes, floods, health risks, nuclear accidents, fires, sleet, cyber risks, hazardous animal diseases, rail accidents, aviation accidents, terrorism, drought, accidents with hazardous substances, accidents at sea, and diseases and pests of forest trees. For most risk types the deterministic risk assessment method based on selected scenarios are used. For nuclear accidents, however, a probabilistic approach is used.

Based on the consequence and likelihood level of a given adverse scenario, its risk is evaluated by defining the risk level, which spans from low to very high. The evaluation of risk is graphically presented by the national disaster risk matrix (see Figure 2.1), which is one of the main results of the risk assessment and enables a direct comparison of different types of risks. The fields of the matrix are coloured according to the level of risk, i.e. green for low risk, yellow for medium risk, orange for high risk and red for very high risk. Slovenia identifies floods as accidents with the most significant risk because they have a medium likelihood of occurrence and can cause quite some losses, according to the national disaster risk matrix. A higher consequence level is expected only for earthquakes and nuclear accidents, which, however, have a lower likelihood of occurrence. See paragraphs 2.1.2 and 2.1.3 for more details on the assessment of seismic and flood risk, respectively.

A national assessment of the risk management capacity level for different types of risk was also conducted, which showed a satisfactory result for the investigated adverse scenarios. The overall capacity level for each type of risk was between 2.9 and 3.4 on a scale from 1 to 4, indicating that the risks are under control and it is likely that their impacts and occurrence in a given period (if specified) will be reduced. However, the lowest levels of risk management were observed for flood and earthquake risk, generally due to high financial and technical requirements for risk assessment and preventive measures.

In addition to the seismic risk assessment conducted within the National Risk Assessment for Slovenia, a seismic stress test of the building stock in Slovenia was recently performed (Dolšek et al., 2020; Babič et al., 2021a). It used a comprehensive probabilistic approach for seismic risk assessment and also estimated the impact of uncertainties, which are not considered within the deterministic analysis provided by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief of the Ministry of Defence acting as the National Coordination Body.



LEVELS OF IMPACT AND LIKELIHOOD	
5	Very high
4	High
3	Medium
2	Low
1	Very low

LEVELS OF RISK	
(red)	Very high
(orange)	High
(yellow)	Medium
(green)	Low

RELIABILITY OF RESULTS OF RISK ANALYSES	THE COLOUR OF THE ENTRY IN RISK MATRIX
Relatively reliable	Black
Moderately reliable	Dark grey
Relatively unreliable	Light grey

Figure 2.1: Slovenian National Disaster risk matrix (GRS, 2018).

2.2. Seismic risk assessment

In the National Risk Assessment for Slovenia (GRS, 2018; GRS, 2020), a deterministic scenario-based approach is adopted for seismic risk estimation. Three scenario earthquakes are considered based on historic events, all three located in regions with high seismic hazard. Only direct consequences of earthquakes, i.e. damage to buildings and the consequent impact on people, are considered, whereas domino effects, e.g. floods, fires or explosions, are neglected in the risk assessment. To estimate the consequences of scenario earthquakes, the POTROG methodology is used. The methodology was developed during the POTROG – Seismic Risk in

Slovenia for Civil Protection project (Lutman et al., 2013). The damage to buildings and the consequent impact on people is expressed based on the EMS-98 scale, which includes five discrete damage states (D1–D5). The overall seismic risk is expressed descriptively as small, medium, high or very high. The level of risk is obtained from the consequence level and the likelihood level (see paragraph 2.1.1). The likelihood level is determined based on seismic hazard (see paragraph 2.1.2.1), whereas the consequence level is obtained as the mean of three values, which indicate the impact on (i) people, (ii) economy, environment and cultural heritage, and (iii) politics and society (see paragraph 2.1.2.4). High seismic risk is estimated for the most representative scenario, where the earthquake epicentre is located in the central region of Slovenia, i.e. in the capital city Ljubljana, whereas the other two scenarios, in which the epicentres are located in the north-western (Bovec) and eastern part of Slovenia (Brežice), are associated with medium risk.

In addition to the seismic risk assessment conducted within the National Risk Assessment, a seismic stress test of the building stock in Slovenia was recently performed (Dolšek et al., 2020). The seismic stress test uses a probabilistic risk assessment, where the risk is calculated by following the conventional seismic risk integral consistent with probabilistic seismic hazard analysis (PSHA). The uncertainties in seismic hazard and building stock vulnerability are taken into account. The HAZUS damage scale, which includes four damage states (slight, moderate, extensive, complete), is adopted. Two types of risk measures are considered, i.e. the probabilities of reaching designated damage states in 1 and 50 years and the expected annual direct economic losses. Both types of risk measures are estimated for each building from the building stock. The probability of reaching the complete damage state and the expected annual losses are then used to evaluate the risk of each building. In the evaluation of risk, the estimated risk is compared to risk boundaries that correspond to grades from A to G. By using a recently developed grading system that takes into account long-term and short-term risk tolerance (Babič and Dolšek, 2019), the process of gradual grade reduction is then defined. Based on the building-specific grades, the number of buildings from the building stock with each grade in any time instance following the risk evaluation is determined. The estimated probabilities of the designated damage states and the expected annual losses also allow for the generation of risk maps at the national level.

2.2.1. Hazard model

The seismic risk is estimated for three scenario earthquakes that are determined based on historic events. All three scenario earthquakes are located in regions with high seismicity according to the seismic hazard map of Slovenia, i. e. in the north-western, central (Figure 2.2) and eastern region of Slovenia. As the intensity measure, the European macroseismic scale (EMS-98) intensity is used (Grünthal, 1998). An epicentral intensity between VII and VIII is selected for all three scenarios, which corresponds to return periods of 140, 189 and 128 years. Thus, the annual probability of occurrence is between 0.4 % and 1 % for all three scenarios, indicating likelihood level 2 on the national accident risk matrix, i.e. possible but unlikely. By moving away from the earthquake epicentre, the seismic intensity is reduced according to a circular symmetrical attenuation with the distance. For the consequence analysis, only regions with estimated intensities of VI or more are considered. The basic seismic intensities refer to medium-quality soil. Thus, they are adjusted by taking into account the soil type from available micro-zoning and geological maps and from comparable data in the literature. For soil type A, the intensity is therefore reduced, and for soil types D, E and S1, the intensity is adequately increased.

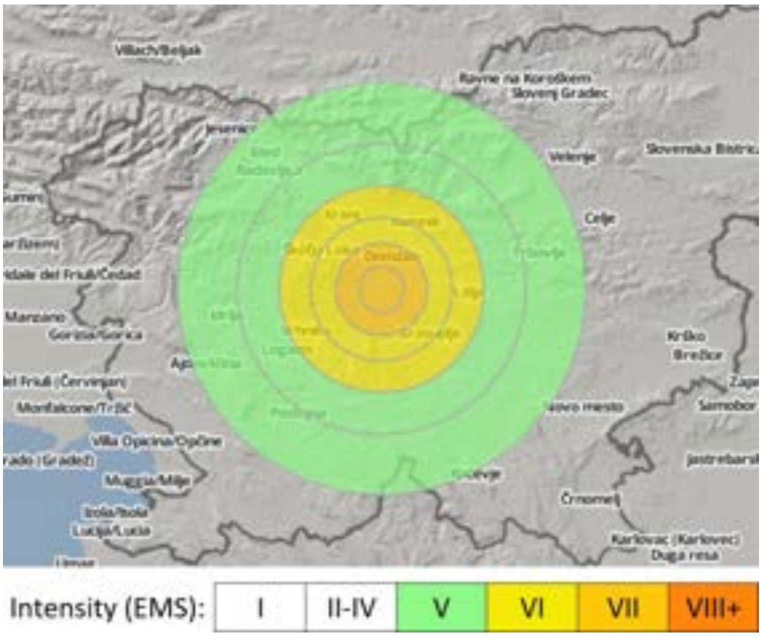


Figure 2.2: A map of EMS-98 intensity for the earthquake scenario with the epicentre in central Slovenia (Lutman et al., 2013).

In the case of the seismic stress test of the building stock in Slovenia (Dolšek et al., 2020), a probabilistic seismic hazard assessment is performed. The peak ground acceleration (PGA) is used as the ground-motion intensity measure. The seismic hazard curve is calculated for the centres of cells of 2.5 × 2.5 km that span over the entire country. In the calculation of seismic hazard curves, two different models are used, i.e. the official seismic hazard model in the Republic of Slovenia (Lapajne et al., 2003) and the SHARE seismic hazard model (Giardini et al., 2014, Woessner et al. 2015). In the calculation of risk, the weights of 1/3 and 2/3 are applied to these models, respectively. The effect of the soil is considered by applying the values of the soil factor from the draft of the new Eurocode 8 (CEN, 2020). The soil factor within each cell can vary, depending on the ground type of each building.

2.2.2. Vulnerability model

All three scenario earthquakes are assumed to happen during the night when the majority of the population is presumed to be at home. The National Risk Assessment is therefore focused on residential buildings, which are divided into six fragility classes from A to F. For each fragility class, the occurrence rates of the designated damage states are specified for each degree of the EMS-98 intensity. For example, it is considered that 25 %, 35 %, 30 %, 10 % and 0 % of buildings in fragility class B reach damage states D1–D5, respectively, if they are exposed to EMS intensity VIII. The classification of buildings to fragility classes is made based on the so-called RAN-Z grade (between 0 and 10), which is determined using a neural network method (Peruš et al., 1995) that considers the year of construction, the number of storeys and the material of the load-bearing structure of the building. The conversion between the RAN-Z grade and the vulnerability classes is defined based on engineering judgement following the guidelines from Grünthal (1998).

In the case of the seismic stress test of the building stock in Slovenia, buildings were divided into building classes based on the material of their load-bearing structure (masonry, reinforced concrete and other), construction period (before 1965, 1965–1981, after 1982) and the number of storeys (1–3, 4–7, 8 or more). Such a classification results in 27 building classes. However, due to a low number of buildings in some of the building classes, those building classes are merged so that altogether 20 building classes are defined. For each building class, a set of fragility curves is defined based on previous studies (FEMA, 2015; Schäfer et al., 2011) and by considering an adjustment factor related to the conservatism of seismic load applied in those studies. The fragility curves are expressed as analytical functions of the PGA that have the form of a lognormal cumulative distribution function.

2.2.3. Exposure model

The building stock data are obtained from the Cadastre of Buildings by the Surveying and Mapping Authority of the Republic of Slovenia. However, some of the buildings from the building stock are excluded from the consequence analysis because they are not included in the POTROG database. Such are, for example, small auxiliary buildings, buildings built after 2009 and special buildings that would need an individual assessment. The database of the buildings considered in the consequence analysis was created by using data from the Real Estate Register (GRS, 2008), a publicly accessible database of the real estate in the territory of the Republic of Slovenia. The Real Estate Register was created in 2008. It contains building-specific information, e.g. the location of a building, the year of construction, the occupancy class, the net floor area, the predominant material of the load-bearing structure, the building value based on real estate mass appraisal procedure, the number of storeys, and the building height. In addition, to evaluate the impact of earthquakes on the economy, environment, cultural heritage and society, the number of exposed cultural heritage buildings, energy infrastructure facilities and facilities on state roads is also calculated, but their damage is not estimated.

To estimate the impact of earthquakes on people, the average number of people per housing unit in each municipality is obtained from the Central Population Register managed by the Ministry of Interior of the Republic of Slovenia. Personal data from the register may be obtained only by state authorities and other users to perform prescribed tasks, to manage databases or to conduct statistical, socio-economic and other surveys.

In the seismic stress test of the building stock in Slovenia (Dolšek et al. 2020), the exposure model was developed based on the same databases as in the case of the National Risk Assessment. However, all the buildings from the Real Estate Register were taken into account, and facilities other than buildings were excluded from the analysis. The number of people per housing, which enabled to determine the population density (Figure 2.3), was also obtained from the Central Population Register.

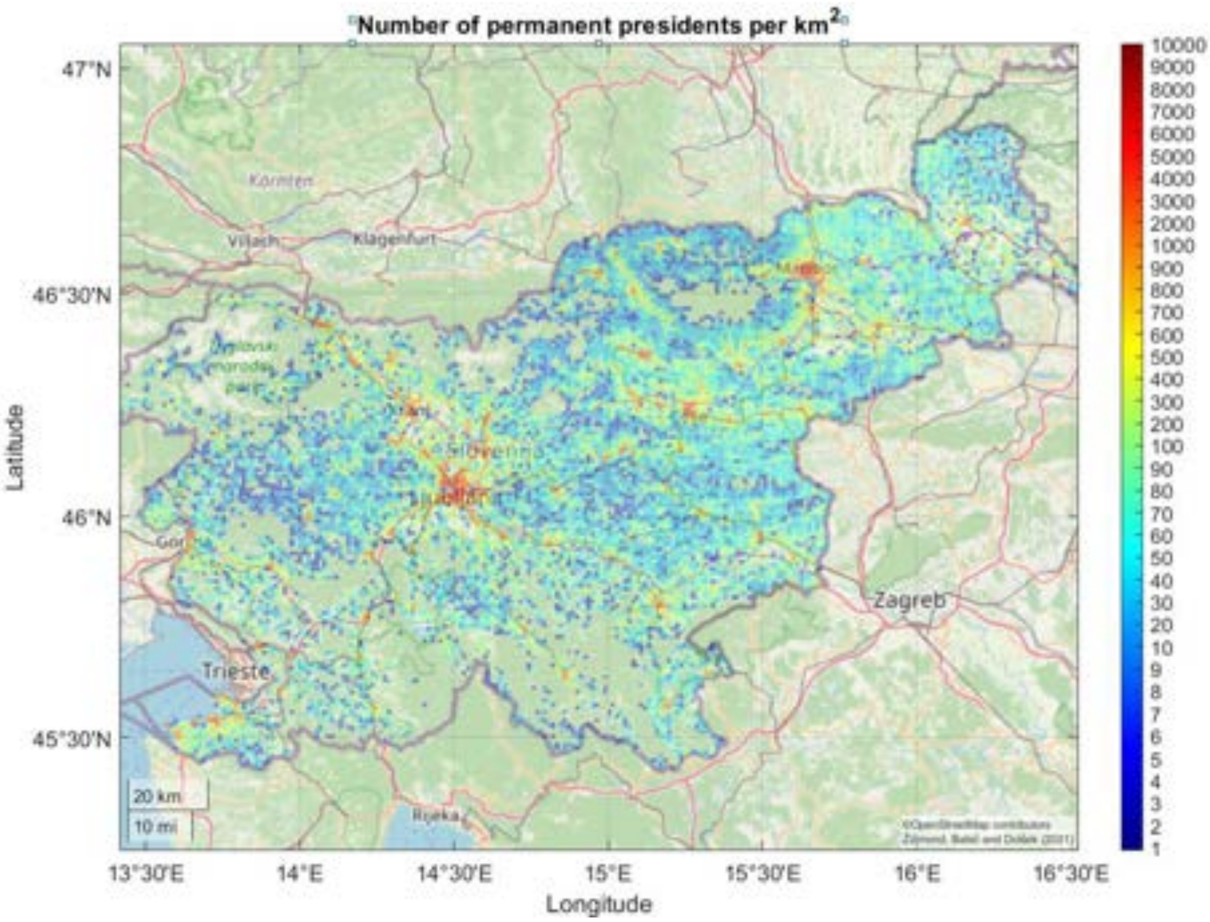


Figure 2.3: Population density in the Republic of Slovenia (Babič et al., 2021b).

2.2.4. Damage and Impact indicators

As explained in Section 2.1, the consequences of earthquakes in the National Risk Assessment are divided into three categories: impact on (i) people, (ii) economy, environment and cultural heritage, and (iii) politics and society. All three categories are assigned a number from 1 to 5 based on different indicators.

The number of functional (non-damaged or slightly damaged), the number of permanently non-functional (needing reconstruction), and the number of non-functional (intended for demolition or collapsed) residential buildings are estimated based on the damage states defined according to Grünthal (1998). Damage state D1 corresponds to functional buildings, damage states D2 and D3 to temporarily non-functional buildings, and damage states D4 and D5 to permanently non-functional buildings.

The number of affected people is then estimated from the number of damaged residential buildings by assuming a night-time scenario and using an average number of people per housing unit from the Central Population Register. The number of people to be temporarily and permanently relocated due to the effects of the earthquake is estimated from the number of temporarily and permanently non-functional buildings, respectively. The number of fatalities and injured people is estimated from the number of exposed people by using expert judgement and data from historic events by assuming that the quality of construction has improved since then. It is important to note that only a night-time scenario is considered. Therefore, daily migrations due to school, work or tourism and the variation of the population during the day or week are neglected in the analysis. However, they have a potentially large impact on the number of people exposed, especially for the scenario located in the capital of Slovenia. The overall impact on people is estimated from the number of fatalities, injured people and permanently relocated people. For example, less than 5 fatalities suggest consequence level 1, 5 to 10 fatalities consequence level 2, 10 to 50 fatalities consequence level 3, 50 to 200 fatalities consequence level 4, and more than 200 fatalities suggest consequence level 5.

The impact on the economy, environment and cultural heritage is estimated based on economic losses. Direct economic losses are assessed from the number of temporarily and permanently non-functional buildings by obtaining the worth of the building stock in the municipalities with the densest population from the Surveying and Mapping Authority of the Republic of Slovenia. Please note that such an approach can be misleading because the worth of non-functional buildings is not equal to the actual direct economic losses, which depend on the repair and replacement costs. The latter parameters are not considered in the consequence analysis performed within the National Risk Assessment. By comparing the worth of the non-functional buildings to the threshold values, the consequence level is then determined. Less than 100 million EUR (about 0.25 % GDP) relates to consequence level 1, between 100 million EUR and 0.6 % GDP to consequence level 2, between 0.6 % and 1.2 % GDP to consequence level 3, between 1.2 % and 2.4 % to consequence level 4 and more than 2.4 % to consequence level 5. Indirect economic losses are not estimated nor considered in the consequence analysis.

Consequence levels related to impacts on politics and society are determined based on the duration of downtime for administrative and other services, disruption of supply of drinking water, food or energy and behavioural reaction to accidents, all increasing with an increasing number of people exposed. Consequence levels for impacts on internal political stability and public order and peace are estimated based on situational descriptions provided for each level.

Within the seismic stress test of the building stock in Slovenia (Dolšek et al., 2020), the direct economic losses of buildings are estimated based on the replacement cost ratios associated with the designated damage states, by assuming the replacement cost of 1,250 EUR / m^2 of the net floor area (inclusive of VAT), and by considering the net floor areas of buildings from the Real Estate Register. The replacement cost ratios are obtained from HAZUS (FEMA, 2015), while the replacement cost is estimated from an online platform for the valuation of new construction (PEG, 2020) and by considering the ratio between the replacement cost and the cost of new construction equal to 13.5 %. In addition, the conversion between the damage state and the number of fatalities is established. This conversion is not used in the time-based risk assessment but in a complementary scenario-based risk assessment. It is considered that fatalities are caused by the building's collapse and that the latter occurs with a certain probability conditional to the damage state. The conditional collapse probabilities are obtained from HAZUS (FEMA, 2015). It is assumed that the number of fatalities in a collapsed building is equal to 10 % of all people inside the building. Other types of consequences (e.g. number of unusable dwellings, indirect economic losses) were not yet addressed.

2.2.5. Tool (platform) for seismic risk assessment

In the National Risk Assessment for Slovenia, the consequences of earthquakes were estimated with different applications developed during the POTROG - Seismic Risk in Slovenia for Civil Protection project (Lutman et al., 2013). The application Assessment of earthquake consequences, which is available online, can be used to calculate the consequences of an earthquake with a selected EMS-98 intensity and epicentre. The earthquake consequences are communicated in terms of the number of temporarily and permanently non-functional buildings and people occupying those buildings.

Within the seismic stress test of the building stock in Slovenia (Dolšek et al., 2020), IKPIR application was used, where IKPIR stands for Institute for structural engineering, earthquake engineering and construction IT, which is a part of the Faculty of Civil and Geodetic Engineering. The application, which was developed in Matlab, incorporates models described in Sections 2.2.1–2.2.4 and enables to perform a time-based seismic risk assessment and scenario-based seismic risk assessment based on the magnitude and hypocentre and other fault parameters. As of this writing, only a research version of the application has been developed.

2.3. Flood risk assessment

Following the adoption of the European Water Framework Directive (WFD) (Directive, 2000) and Floods Directive (Directive, 2007), the Republic of Slovenia has made great efforts to transpose this directive into Slovenian law and to prepare expert bases. Responsible for the implementation of the EU Water Framework Directive and EU Floods Directive is the Ministry for Environment and Spatial Planning of the Republic of Slovenia. The legislation has been prepared and implemented at a national level. The Republic of Slovenia has no regional level of flood risk assessment. The flood risk is assessed at the local level by dividing Slovenia's territory into 212 municipalities as local administration units.

The 5th WFD Implementation Report, together with the assessment of the second River Basin Management Plans (RBMP) and the first Floods Directive Implementation Report – assessment of the first Flood Risk Management Plans (FRMP) has been prepared in 2019 (SWD, 2019).

This 5th WFD Implementation Report was adopted on 26/02/2019 and consists of the following documents:

- A Commission Report to the European Parliament and the Council on the implementation of the Water Framework Directive (assessment of the 2nd RBMPs) and the Floods Directive (assessment of the 1st FRMPs), and an Annex with recommendations to all Member States on both Directives.
- A European Overview of the 2nd RBMPs - Commission Staff Working Document accompanying the report
- A European Overview of the 1st FRMPs - Commission Staff Working Document accompanying the report
- Country-specific assessments for EU Member States' 2nd RBMPs - Commission Staff Working Documents accompanying the report: Slovenia

- Country-specific assessments for EU Member States' 1st FRMPs - Commission Staff Working Documents accompanying the report: Slovenia

In the scope of the 2nd cycle of the Floods Directive implementation in Slovenia, the following activities have been carried out:

- New and additional records and descriptions of flood events with different types of damage consequences (for the period of floods after 2011);
- Upgraded analysis of maximum flows in the Republic of Slovenia;
- Additional graphical representations of recorded past flood events;
- Analysis of the impact of climate change on the characteristics of floods or on flood risk in Slovenia;
- Upgrading the identification of Areas of Potential Significant Flood Risk.

2.3.1. Flood hazard assessment

Rules on the methodology for determining areas endangered by floods and related erosion of inland waters and the sea, as well as on the method of classifying land into endangered classes (Official Gazette of the RS, 2007), and the Regulation on conditions and restrictions for carrying out activities and interventions in areas at risk of floods and associated inland and sea erosion (Regulation, 2008) were adopted. The flood hazard mapping based on the Regulation (2008) implementation is used and further developed in the process of preparing spatial plans.

Rules on the methodology for determining areas endangered by floods and related erosion of inland waters and the sea, and on the method of classifying land into endangered classes (Official Gazette of the RS, 2007) in its Article 5 defines flood hazard assessment as the basis for the determination of flood hazard areas and their classification. The results of the initial flood hazard assessment were displayed on the flood warning map (in Slovenian "opozorilna karta poplav"), which contains data on topography and land use. Within river catchment, sub-catchment or river channel section, the following information is provided:

- the boundary line of the extent of possible floods or parts of running and standing waters or parts of the seacoast where floods are known to occur, including the indication of the direction of flooding;
- the boundary line of the possible extent of erosion phenomena or parts of running and standing waters or part of the seacoast where erosion is known to occur;
- places of individual flood events with point markings;
- with point or line markings, individual water structures where floods and erosion may occur due to incorrect operation or their collapse.

The flood and erosion warning map also contains a text that includes a brief description of historical flood and erosion events, especially those that could reoccur in the near future, i.e. information associated to date of the specific event, source of data, description of the event and consequences for human life and health, the environment, economic and non-economic activities, cultural heritage and other relevant information on the flood situation in a given area. The flood and erosion warning map may, where appropriate, also include estimates of future floods and erosion and their consequences for human life, environment, the development of economic and non-economic activities, taking into account long-term planned development and climate change. In accordance with Article 7 of the Rules (Official Gazette of the RS, 2007), the flood warning map is supplemented with new data on flood conditions and, if it is significantly changed as a result, it is renewed at least every six years.

Since the implementation of the Rules (Official Gazette of the RS, 2007) and Regulation (2008), flood warning maps have been intensively updated by flood hazard assessment in Slovenia by performing detailed hydrological and hydraulic flood studies for defining the spatial extension of flood hazard areas. The flood hazard assessment in Slovenia follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. 10-, 100-, and 500-years flood return periods are considered in the calculations. The flood hazard information are publicly available on the portal called "eVode" (http://evode.arso.gov.si/) using a web GIS viewer called "Atlas Voda", the first publicly accessible viewer based in the state computer cloud, and in alliance with the INSPIRE Directive.

The flood hazard maps are updated whenever flood protection projects and spatial plans are prepared, generally the Slovenian Water Agency updates the Flood hazard maps every 6 months. In addition, the flood hazard maps have been intensively incorporated in the preparation of state or municipal spatial planning documents which might affect areas where flood hazard as well as projects requiring building permits in these areas. The Slovenian Water Agency as a consenting party requires the analysis of the flood hazard and flood risk situation and implementation of flood mitigation measures.

As of April 2021, the integrated flood hazard map in Slovenia covers 23 areas where flood hazard assessment was prepared, covering about 6,085 km^2 shown in Figure 2.4.

The methodology for determination of spatial extent of the Areas of Potential Significant Flood Risk (APSFR) has been developed by the Ministry of Environment and Spatial Planning by the Institute for Water of the Republic of Slovenia in 2012 (MOP, 2012). The methodology considered the presence of the identified flood hazard (existing flood warning maps and upgraded detailed flood hazard maps).

2.3.2. Flood vulnerability and exposure

The flood exposure and vulnerability for the APSFR were assessed based on the freely available spatial databases, which considered various combined (grouped) elements of vulnerability and exposure:

- Peoples health (data from the central register of the population, register of spatial units - record of house numbers). One of the main factors was population density in particular area exposed to flood hazard.
- Environment (water protection areas, Natura 2000 areas). An arbitrary assessment of the level of intensity of a potential source of pollution on the flood (IPPC or SEVESO) and the significance of the pollution impact were considered.
- Cultural heritage (central register of the cultural heritage). A working group consisting of members of the Ministry of Culture, the Institute for the Protection of Cultural Heritage of Slovenia and the Water Institute of the Republic of Slovenia prepared an assessment of the flood damage potential

of immovable cultural heritage. The result was a cultural heritage vulnerability assessment that has been used for further analysis.

– Economic activities (business register of Slovenia, data from the Statistical Register of Employment). The damage potential was assessed on the basis of the number of employees and the share of gross value added (GVA) contributed by individual industries/enterprises in each region.

2.3.3. Flood damage and impact indicators

For each type of vulnerability element, dimensional impact indicators were defined. In this way, more or less homogeneous groups (building blocks) were defined and further evaluated based on the interrelationships between the building blocks. A combination of the indicators was determined by the size of the damage potential of each building block. The analytical spatial unit for further calculation of the flood risk was defined as a raster cell of 75 x 75m cell size. The spatial distribution of the combined flood risk potential in Slovenia defined based on the methodology described above is shown in Figure 2.5.

Based on the methodology, a preliminary flood risk assessment of the Republic of Slovenia was prepared (MOP, 2012), and a spatial extension of 61 APSFR was defined. The methodology was upgraded in 2018 with the inclusion of the new/improved flood hazard data and data from the recorded flood events. Based on further analysis, additional APSFR were defined. The total number of APSFR is currently 86 areas (MOP, 2019). The spatial extension of the APSFR is shown in Figure 2.6.

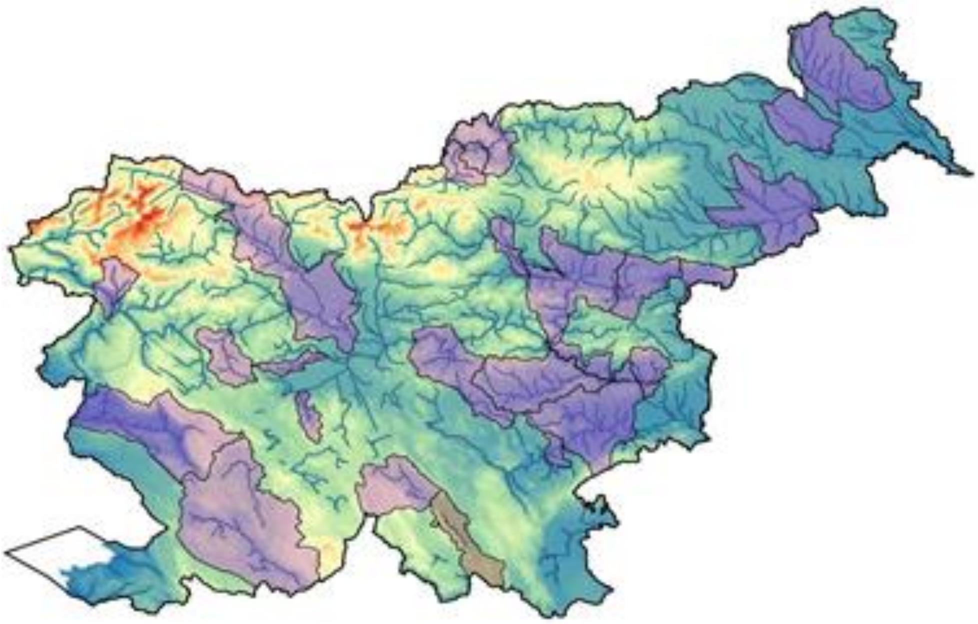


Figure 2.4: Slovenia and 23 flood hazard areas with implemented flood hazard assessment.

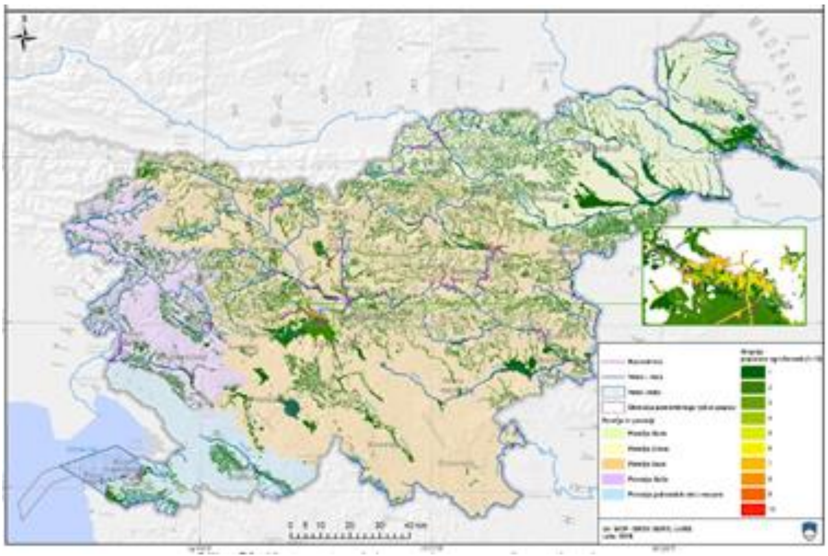


Figure 2.5: Spatial extension of the combined flood risk potential in Slovenia (green – low flood risk potential; red – high flood risk potential).

2.3.4. Implementation of Union Civil Protection Mechanism in Slovenia

Related to the implementation of the decision No 1313/2013/EU on a Union Civil Protection Mechanism in Slovenia, regulation for incorporation of the decision was accepted (Regulation, 2014). This Regulation is intended to be applied for the preparation of disaster risk assessments and data records for improving the disaster risk management capacity at local level. Implementation of the Union Civil Protection Mechanism in Slovenia is in the decency of the Ministry of defence and Administration of the Republic of Slovenia for Civil Protection and Disaster Relief.

More specifically related to flood risk assessment, two flood scenarios called S1 and S2 were developed (ACPDR, 2016). The scenario S1 – large floods have a return period of a flood event between 5 and 25 years. The scenario S2 – catastrophic floods have a return period of a flood event between 25 and 100 years. The Decree on the content and preparation of protection and rescue plans (Official Gazette of the Republic of Slovenia, No. 24/12) stipulates that risk assessments should show which municipalities and to what extent are endangered due to individual risk. The risk assessment at the municipal level is important from the ACPDR operation and organisation point of view. In the risk assessments, for the needs of the system of protection against natural and other disasters, municipalities and other planning bodies were uniformly classified into five risk classes. In the classification, the following elements were identified as the most important:

- the probability of floods,
- the spatial extension of the flooded areas,
- the number of people in the flooded areas,
- the number of buildings located in the flooded areas.

The results of the assessment of the flood risk exposure of the municipalities in Slovenia according to the identified risk is shown in Figure 2.7.

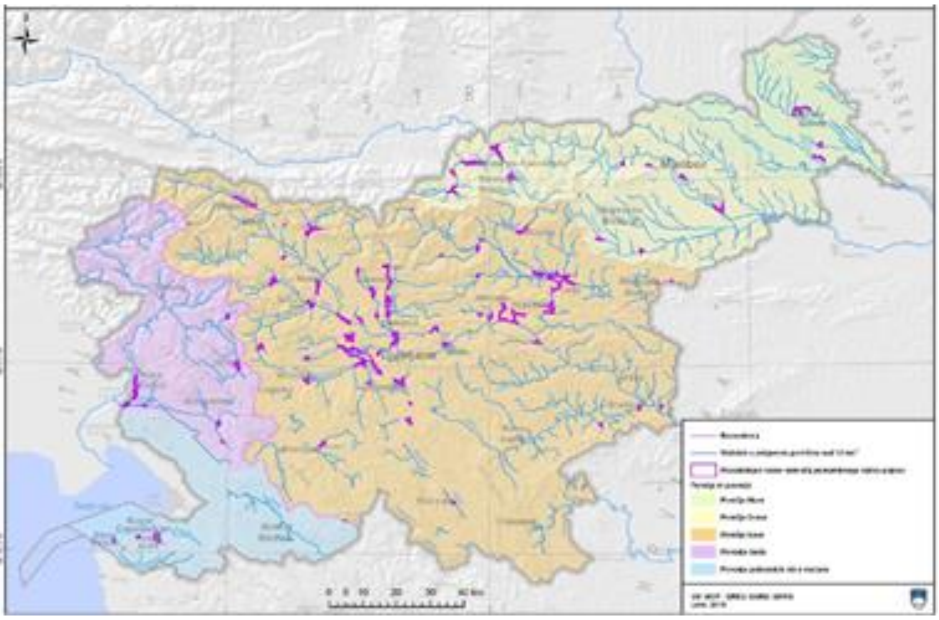


Figure 2.6: Spatial extension of the 86 Areas of potential Significant Flood Risk in Slovenia.

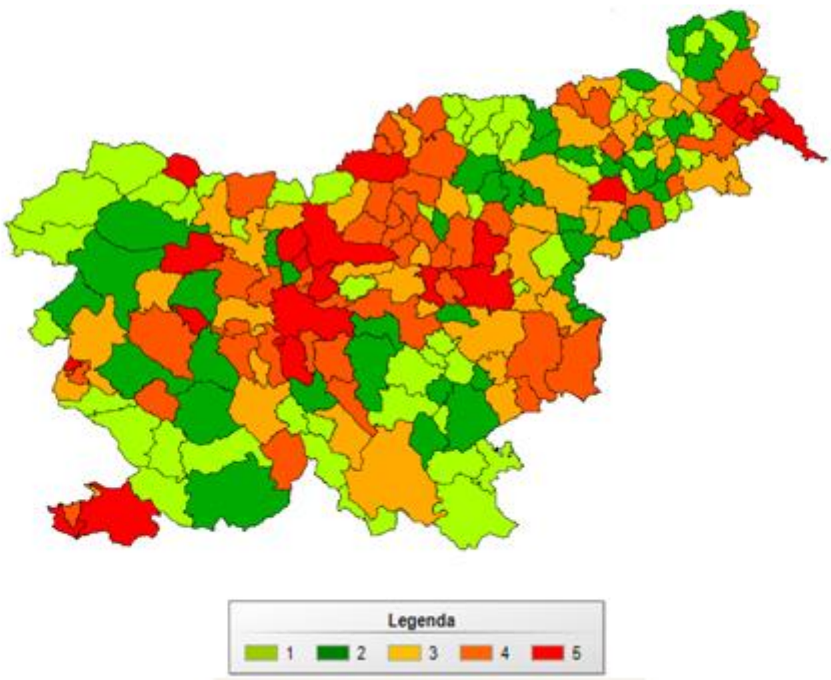


Figure 2.7: Assessment of the flood risk exposure of the municipalities in Slovenia (dark green - low flood risk; red - high flood risk).

Based on the determined level and class of the flood risk, the basic flood protection and rescue plan will be determined by the ACPDR in the scope of the obligations from protection and rescue planning at the municipality level.

There seem to be some differences and potential inconsistencies in the implementation of the EU Floods Directive (for which the methodological background for the implementation has been well established) and the implementation of the Union Civil Protection Mechanism where the methodology for assessment of the flood risk is adapted for more direct operation purposes. However, it is worth noting that many parts of the flood risk assessment made by ACPDR is actually based on the implementation of EU Flood Directive in Slovenia through the methodology developed by the Institute for Water of the Republic of Slovenia and the Ministry of Environment and Spatial Planning. In the Flood Risk Reduction Plan proposal prepared for the period 2015–2021 and for the municipalities categorised as APSFR, the concrete, high-quality operational municipal flood protection and rescue plans were identified as an important non-structural flood protection measure.

2.3.5. Tool (platform) for flood risk assessment

In 2014, a general methodology for assessing the benefits of flood mitigation measures based on the identified flood risk was prepared in Slovenia. However, the methodology needed to be reviewed and upgraded from the point of view of cultural heritage, watercourses, water infrastructure, and public infrastructure, while considering the latest flood damage data in past events. It was also necessary to develop an application that would enable assessment of flood damage and the analysis of flood damage reduction in case of flood protection measures implementation. Within the project Development of a Unified Method for Assessing the Benefits of Construction and Non-Construction Measures, the methodology was upgraded in view of more detailed spatial information on the presence of cultural heritage, water and public infrastructure, while taking into account the latest flood damage data from the flood events in the near past which were relatively well documented in terms of damage (Vidmar et al., 2019). The platform KRPAN was developed. The abbreviation KRPAN stems from Slovenian and stands for "cumulative calculation of flood damage and analyses". The most time-consuming part of the platform development is acquisition of datasets from different sources (ministries and agencies) and the construction and optimization of relational databases. Without the relational databases, the application's operation would be questionable because the method for flood damage calculation is based on a large amount of geolocated and interrelated data. The established relational database is openly accessible and can be periodically updated. All built-in GIS tools that are essential for KRPAN's operation are freely available (e.g., SAGA; GDAL).

The platform KRPAN was tested in three test areas. In addition, a test for the entire Slovenian territory was carried out in order to demonstrate the validity of KRPAN's methodology and applicability on the level of the whole country. It should be pointed out that at the state level, some entities may not contribute significantly to the final value of the expected annual flood damage, but they can contribute significantly to the value at the local level. The platform KRPAN is primarily intended as a tool to include the recognised flood risk in the process of the investment document preparation and to support decisions for policy makers.

2.4. Multi-Risk assessment

A multi-risk assessment was performed within the Slovenian National Disaster Risk Assessment. The comparison of different types of risks was enabled by utilizing the national disaster risk matrix (see Figure 2.1 in Section 2.1). This matrix is composed of five consequence levels on the ordinate axis and five likelihood levels on the abscissa axis.

The consequences of hazards are divided into three categories, which deal with the impact on (i) people, (ii) economy, environment and cultural heritage, and (iii) politics and society. Impact on people takes into account the number of fatalities, the number of injured or relocated people, etc. Economic and environmental impacts and impacts on cultural heritage take into account damage on buildings, agricultural and forest areas, etc. The consequence levels for these types of impacts are defined by losses in terms of a percentage of gross domestic product (GDP). Political and social impacts consider, for example, effects on daily life, financial, psychological and political stability.

The level of consequences for a given adverse scenario is characterised by a number from 1 to 5, whereby a higher level indicates more severe consequences. For example, consequence level 1 corresponds to not more than 5 fatalities and 20 evacuated people and economic losses lower than 100 million EUR (about 0.25% of the GDP). However, consequence level 5 corresponds to equal to or more than 200 fatalities or 500 evacuated people and economic losses higher than 2.4% of the GDP. The likelihood of adverse scenario is also characterised by a level from 1 to 5. Likelihood level 1 represents events with a return period of 250 years or more, while likelihood level 5 corresponds to events with a return period of only 5 years or less.

Based on the comparison of risks associated with different hazards, the flood risk was evaluated as the highest, followed by the seismic risk, sleet risk, risk of diseases and pests of forest trees and risk of aviation accidents. It should be noted that such a model for risk communication depends significantly on the definition of consequence levels and selected likelihood levels of adverse scenarios used in risk analysis. Based on such an approach, for example, the seismic risk cannot be classified in Slovenia as high risk by definition.

3. NATIONAL RISK ASSESSMENT FOR ITALY IN 2020

The National Risk Assessment (NRA) for Italy was developed at the end of 2018 by the Department of Civil Protection (DPC) in agreement with EU decision 1313/2013 and in response to the specific requirement of the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR, 2015) to periodically adjourn the assessment of disaster risk.

3.1. The analysed risks

The following risks are addressed: seismic, volcanic, tsunami, hydro-geological/hydraulic, extreme weather, flood, landslide, avalanche, droughts, and forest fires. The analysis of these risks has reached different stages of maturity. For most of the analysed risks, a probability-based methodology is adopted. Hazard maps are available for seismic, flood, landslide, and tsunami risks, while for the volcanic one, the hazard posed by most dangerous volcanoes is monitored, and the areas that are potentially affected by volcanic eruptions are identified. National risk maps are calculated for seismic and hydro-geological risks, with reference to which risk indicators are expressed in terms of human impacts, economic, environmental, and political/social impacts. Forest fire risk maps are available at a regional level, with a definition of a certain level of risk (e.g. low, medium or high) to a certain portion of the region. For avalanche risk, the plans of the areas exposed to avalanches, in which areas with different degrees of potential exposure to avalanche danger are defined, are available too.

3.2. Seismic risk assessment

In NRA for Italy (2018), the seismic risk is calculated following probabilistic seismic hazard assessment PSHA-based risk approach. Unconditional risk assessment is performed with reference to one-year and fifty-year observation time windows, as explained in Dolce et al. (2021).

The damage scale adopted is the EMS-98 scale (Grünthal, 1998), which identifies five damage states from D1 to D5 (plus no damage D0). In addition to unconditional risk (time-based) assessment, also conditional risk assessment, performed with reference to earthquakes with a selected return period, as well as damage and impact scenarios calculated adopting as input the shake-maps of the main Italian earthquakes that hit the country in the last decades, can also be calculated adopting the IRMA tool employed for the NRA (see Section 3.2.5); however, the conditional risk and scenario-based assessment are not explicitly considered for the NRA. Seismic risk is evaluated in terms of expected damage for the residential building stock and associated consequences (direct economic losses and impact quantities such as unusable buildings, homeless and casualties, as illustrated in paragraph 2.2.2.4).

To perform national seismic risk assessment, a multi-model methodology is adopted, developed through a collaboration of six research units belonging to two Centers of Competence of the Department of Civil Protection, namely ReLUIS (Network of university laboratories for seismic engineering) and EUCENTRE (European Centre for Training and Research in Earthquake Engineering) and presented in Dolce et al. (2021). In Italy, while seismic hazard is officially defined by a single model (see paragraph 2.2.2.1), the proposals for seismic vulnerability models are extremely diverse and could not be adopted singularly because most of them are applicable to specific sub-assets (masonry or RC buildings) and also because they use very different fragility models and associated uncertainties, which would lead to biased final risk estimations if used singularly. For this reason, four models for masonry buildings and two for RC buildings are used for NRA, as illustrated in paragraph 2.2.2.2. Damage and risk results are obtained singularly for each model, and then they are aggregated, simply joining the results for the models obtained for the same material type (masonry and RC) or specifying weights if several models are relevant to the same asset type (e.g. masonry buildings). More details are provided in Dolce et al. (2021).

The NRA methodology is implemented through IRMA, a WebGis platform (see paragraph 2.2.2.5) that provides tools to perform risk calculations and to produce national maps in terms of expected damage and consequences.

3.2.1. Hazard

Seismic hazard is obtained by the probabilistic seismic hazard analysis (PSHA). The official Italian hazard model (Stucchi et al., 2004; 2011) is based on the Italian seismic hazard map (MPS04) developed by Istituto Nazionale di Geofisca e Vulcanologia (INGV) and adopted at the national level with a Civil Protection Ordinance (OPCM 3519/2006). The results of the PSHA model in terms of maps showing the value of peak ground acceleration (PGA) and spectral acceleration (Sa) corresponding to an exceedance probability in a given period of time or, equally, to an assigned return period. Nine different hazard maps of Italy were realized by INGV for nine different return periods (2500, 1000, 475, 200, 140, 100, 72, 50 and 30 years) or probabilities of exceedance in 50 years (2%, 5%,10%, 22%, 30%, 39%, 50%, 63% and 81%). Figure 3.1 shows the hazard maps of the Italian territory in terms of PGA with a probability of exceedance of 10% in 50 years. The model provides the seismic actions for each point of a mesh (5 × 5 km) covering all the Italian territory. Because in the NRA framework, the exposure is given at a municipality level (see paragraph 2.2.2.3), the hazard is evaluated at the centroid of each municipality in order to have one single value. The formula to get the hazard value for a point different than the points of the mesh is coded in OPCM 3519/2006 (in principle, a distance-weighted average). The official hazard model is elaborated on rock or stiff soil category (soil type A). However, the IRMA platform allows considering also other types of soil (B, C, D) in performing damage and risk assessment, assigning the same soil type over the whole Italian territory. Different soil maps can be considered in a new version of IRMA (Mori et al., 2020; Forte et al., 2019). Moreover, calculation of damage scenarios for specific seismic events is also possible, considering as seismic input the shake-maps of the main seismic events recently occurred in Italy, which are also pre-loaded in IRMA (although such damage scenarios are not used in the NRA).

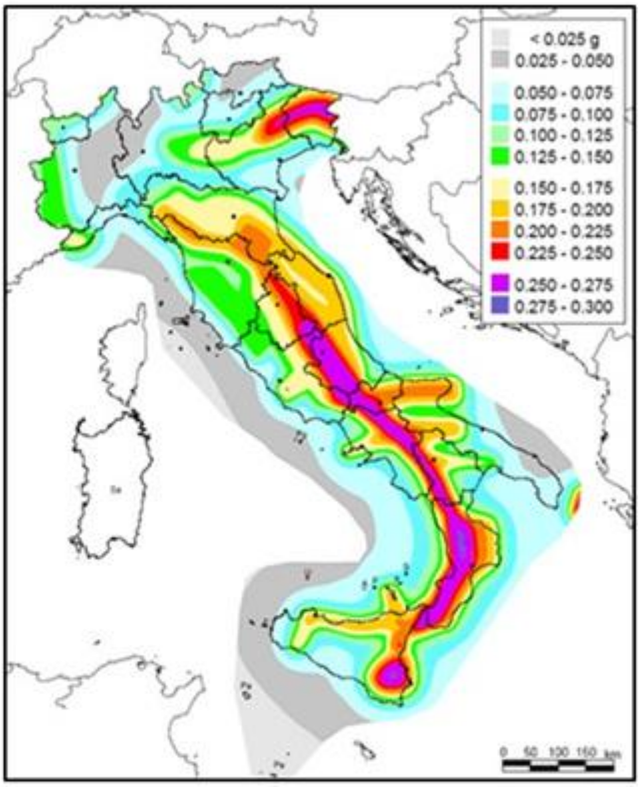


Figure 3.1: Seismic hazard map of Italy expressed in terms of horizontal peak ground acceleration for soil type A with a probability of exceedance of 10% in 50 years, referring to stiff soils (www.ingv.it).

3.2.2. Vulnerability

Building typologies are defined on the basis of the relevant parameters available in the national census database (ISTAT, 2001), namely construction material (reinforced concrete – RC, masonry – M, other construction types – O), number of floors and construction period. Buildings belonging to construction type O, commonly related to steel or wooden buildings or, more often, to structures with a mixed typology, have significantly lower percentage incidence in the Italian building stock with respect to M and RC buildings and they are not analysed in terms of vulnerability models. As these buildings are required to be considered in terms of exposure, the number of O buildings are subdivided between M and RC building types according to the criteria reported in Dolce et al. (2021), depending on the period of construction and on the percentage incidence of M and RC buildings in each town. Five vulnerability classes are defined (A, B, C1, C2 and D, sorted by decreasing vulnerability), coherently with the EMS-98 classification, and specific fragility functions are associated with each of them. The association of the building typologies with relevant fragility function requires a specific vulnerability-exposure model (VEM), which defines a general criterion for assigning each building typology to one or more vulnerability classes (i.e. the exposure model, in the form of a matrix that defines the percental attribution of each typology to each vulnerability class). Fragility curves are defined for the five damage levels of the EMS-98 scale, and the probability of reaching or exceeding a given damage state as a function of PGA is expressed by a cumulative lognormal distribution. Six research units from ReLUIS and EUCENTRE contributed in the definition of VEM adopted in the NRA for Italy, according to the multi-model methodology.

Four out of the six vulnerability models refer to masonry, as also shown in the left side of Figure 3.3, and two of them to reinforced concrete buildings. Moreover, the approaches followed to derive these models are different. In three cases, the vulnerability model relies on an empirical approach (Rosti et al., 2021a; 2021b; Zuccaro et al., 2021). Two models adopt an analytical approach to develop fragility curves (Borzi et al., 2020b; Donà et al., 2021). Finally, a hybrid heuristic approach is employed in the sixth model (Lagomarsino et al., 2021), which is based on the expert judgment implicitly encompassed in the EMS-98 scale but also calibrated on post-earthquake damage data observed in Italy. The way according to which each vulnerability class, and the relevant fragility curve, is associated to the existing building stock differs between the VEM models, and each research unit adopts specific criteria to assign building typologies of the census dataset to the relevant vulnerability classes (i. e. a different exposure model). Moreover, in the IRMA platform, it is possible to perform damage and risk assessment using a different VEM with respect to the ones adopted in the NRA, as well (see paragraph 2.2.2.5).

3.2.3. Exposure

The exposure database is derived from census data provided by the Italian National Institute of Statistics (ISTAT). Currently, 2001 and 2011 census databases, which provide information about buildings, dwellings and population, are available and publicly accessible. The data about buildings and dwellings include the structure's material (masonry, reinforced concrete or other), the number of storeys and the construction period. Eight different periods of construction are identified according to ISTAT 2001 database (>1919, 1919–1945, 1946–1961, 1962–1971, 1972–1981, 1982–1991, >1991) and eleven for ISTAT 2011 (adding 1992–2001, 2002–2005 and >2005 periods to the previous ones). Concerning the number of storeys, eight classes of height are identified in the 2001 census (1, 2, 3, 4, 5, 6, 7 or 8+ storeys), while only four classes of height are considered in the 2011 census (1, 2, 3 or 4+ storeys). Figure 3.2 shows an example of ISTAT 2001 building typologies distribution for an Italian municipality. As the 2001 database is characterized by more detailed information on some building characteristics, such as the number of storeys, it is used for the NRA 2018, although more recent census data is already available. For privacy reasons, at the census tract level, data are provided in aggregated form, meaning that the combined data about the structure's material, construction period and the number of storeys are not available, while disaggregated data are available at the municipality level, which is the spatial scale adopted in the NRA. Other relevant information about buildings and dwellings concern the occupancy type (i.e. residential or not), the dwellings' average storey surface and the state of conservation (i.e. excellent, good, poor or bad).

3.2.4. Damage and Impact indicators

In NRA, unconditional damage assessment is performed to evaluate seismic risk in terms of expected damage, considering two periods, namely a one-year and a fifty-year period. For each EMS-98 damage level (from D1 to D5), damage distribution provides the total number of buildings (or dwellings) affected, the percentage of buildings (or dwellings) calculated based on the total number of buildings in each municipality, the dwellings surface and the population living in buildings reaching each of the five damage levels.

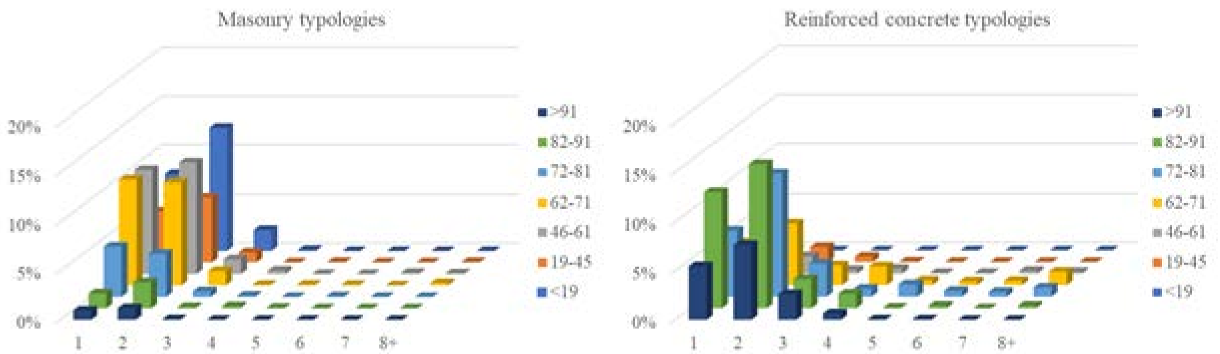


Figure 3.2: Proportion of masonry and reinforced concrete typologies in terms of construction age and storey number for the town Angri, identified according to ISTAT 2001 database.

The consequences of a seismic event are expressed in terms of human impacts, economic and environmental impacts, and political/social impacts. In particular, for each municipality, the following impact indicators are determined: expected number of unusable buildings or dwellings in the short and long term, expected number of collapsed buildings or dwellings, expected number of homeless people, casualties in terms of the expected number of fatalities and injured people, direct economic losses. The evaluation of seismic risk in terms of damage levels is the starting point for the assessment of the above impact indicators. The damage to impact conversion rules adopted in NRA for the estimation of the impact are presented in Dolce et al. (2021) and recalled below.

It is considered that all buildings (or dwellings) in damage state D5 are collapsed. Two categories of unusable buildings are identified: unusable buildings in the short term and unusable buildings in the long term. These quantities are calculated as functions of the number of M and RC buildings that experience a given structural damage level and of the percentage of unsafe buildings in the short (long) term defined for each structural damage level. The same equations can be used to estimate the number of unusable dwellings, simply substituting the number of buildings with the number of dwellings. The number of homeless people is estimated by the number of inhabitants in unusable buildings (in the short and long term), subtracting the estimated number of fatalities. Casualties are derived as a ratio of the building occupants, whereby considering only buildings in damage levels D4 and D5 (the most severe ones). The percentages of fatalities and injured people for the two considered damage states are assumed independent from the structure's material. Direct economic losses are computed based on the repair or replacement cost as a function of building damage level. The cost parameters are calibrated on the actual repair costs that were monitored in the reconstruction process following the Italian earthquake of L'Aquila 2009 (Di Ludovico et al., 2017a; 2017b).

The risk in terms of damage levels and consequences is calculated through the IRMA platform for each VEM adopted in NRA. The results are first combined separately for models relevant to Masonry (M) and Reinforced concrete (RC) buildings, assigning equal weight to different models, then the average results obtained for M and RC buildings are summed up. An example of results combination of different models to obtain risk maps is shown in Figure 3.3.

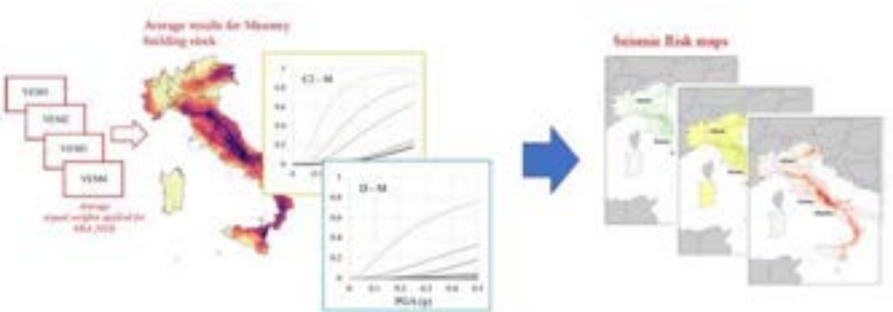


Figure 3.3: An example of the results combination process: the output of models for masonry (VEM1 to VEM4) are weighted to obtain the risk maps in terms of damaged dwelling (adapted from Dolce et al. 2021).

3.3. Flood risk assessment

The Floods Directive (FD) (2007/60/EC) requires each Member State (MS) to assess its territory for significant risk from flooding, to map the flood extent, identify the potential adverse consequences of future floods for human health, the environment, cultural heritage and economic activity in these areas, and to take adequate and coordinated measures to reduce this flood risk. By the end of 2011, Member States were to prepare Preliminary Flood Risk Assessments (PFRAs) to identify the river basins and coastal areas at risk of flooding (Areas of Potential Significant Flood Risk – APSFRs). By the end of 2013, Flood Hazard & Risk Maps (FHRMs) were to be drawn up for such areas. On this basis, Member States were to prepare Flood Risk Management Plans (FRMPs) by the end of 2015.

The Directive 2007/60/EC related to the assessment and management of flood risks (Floods Directive), was implemented in Italy with Legislative Decree 49/2010, with the aims to establish a reference framework for flood risk assessment and management. The main purpose is to reduce the potential negative consequences on:

- human health;
- economic activities;
- environment;
- cultural heritage.

The Floods Directive outlines an implementation path defined by a series of implementation stages, characterized by specific obligations and deadlines, which has as its final point the drafting of the flood risk management plan. The path identified by the Floods Directive takes place within a management cycle, which is renewed through an iterative process with a periodicity of 6 years (currently we are in the second cycle) that must also include public involvement through suitable information and consultation tools. The Directive provides that within 3 months of the deadlines established for each stage of implementation, a series of information (reporting) is reported to the European Commission, according to well-defined methods and formats. In each management cycle, it is envisaged that the following products corresponding to the various subsequent implementation stages are created at the hydrographic district or management unit level: preliminary flood risk assessment (Article 4), areas with potential significant risk of floods (Article 5), maps of the danger and risk of floods (Article 6) and, finally, flood risk management plans (Article 7). With respect to each of these products, the fulfilment of the Floods Directive requires that a series of information structured according to specific formats and schemes (scheme) be sent or "reported" (reporting) to the European Commission (EC) within 3 months of the deadlines shown in Figure 3.4.

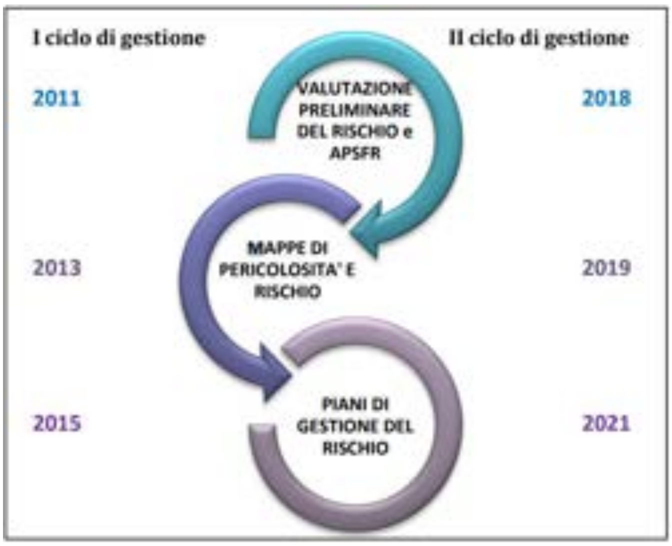


Figure 3.4: Flood risk management cycle (in Italian).

The implementation of Directive 2007/60 / EC requires the preliminary identification of the management units (Unit of Management - UoM) and the relevant competent authorities (Competent Authority - CA). The territorial and administrative structure that supported the implementation of the Floods Directive in the first management cycle was based on the subdivision of the national territory into 7 Districts in turn divided into 47 Units of Management whose territorial definition it follows that of the basins of national, regional and inter-regional importance of Law 183/1989. The competencies in relation to the obligations envisaged by the Floods Directive and its implementing decree were divided, in the transitional period, among 54 Competent Authorities including Regions, Autonomous Provinces, National Basin Authorities (with coordination hydrographic district to which it belongs pursuant to Article 4 of Legislative Decree 219/2010), Interregional and Regional, Ministry of the Environment, Territory and Sea (MATTM) and DPCN.

1The new administrative structure allows, pursuant to art. 4 paragraph 2 of Ministerial Decree 294/2016, to have a single competent authority within each District pursuant to art. 3.2 (a) of Directive 2007/60 / EC and art. 3.1 of the legislative decree n.49 of 23 February 2010.

Based on the FRMPs assessed, Italy's plans vary significantly in terms of the amount of information provided. For example, the FRMP for ITA (Eastern Alps RBD) includes a range of details, such as the cost of each measure that cannot be found in other FRMPs. Links to the FRMPs can be found via the following web page: http://www.isprambiente.gov.it/pre_meteo/idro/Piani_gest.html. This page provides links to the FRMP pages of the eight RBDs10. From the FRMP pages of the eight RBDs, there are links to the FRMP pages of lower-level UoMs.

Figure 3.5: Unit of Management map.

Going in major details every implementation cycle is supposed to define/review:
Preliminary risk assessment: provide an assessment of potential risks, based on available or easy-to-obtain information, such as recorded data and studies on long-term developments including in particular the consequences of climate change on the occurrence of floods, and to identify areas for which there is a significant potential risk of floods or which can be considered likely to occur.

The art. 4 of the Floods Directive requires Member States (MS) to carry out the Preliminary Flood Risk Assessment (PFRA) for each River Basin District (RBD), Unit of Management (UoM) or portion of district/International management unit falling within its own territory. This assessment must be based on available or readily derivable information. In accordance with art. 5 of the Floods Directive, the identification of the Areas of Potential Significant Flood Risk (APSFR) must derive from the results of the PFRA. In the case of international River Basin District or Unit of Management, the Competent Authorities of the Member

States concerned must share relevant information among themselves and the identification of the APSFR must be coordinated among them.

The existence on a national scale of the Hydrogeological Asset Plans (PAI), drawn up pursuant to Law 183/89, and of the relative maps produced with the indications and methods published in the DPCM of 29 September 1998 following Law 267/98. This led to the decision, shared between the Basin Authorities and the Ministry of the Environment of the Territory and the Sea and communicated to the European Commission, not to carry out the preliminary assessment of the risk of floods, making use of the transitional measures provided for in art. 13.1 (b) of the FD, and to proceed, therefore, directly to the elaboration of the maps of the danger and risk of floods with the criteria provided for by the directive and its implementation decree. Making use of the transitional measures was only possible in the first management cycle.

The Preliminary Assessment consists mainly a description of the flood events and the consequences that occurred in the places where they occurred (flood locations), as well as maps of the district at an appropriate spatial scale that include the boundaries of the hydrographic basins, sub-basins and, where existing, coastal areas, showing the topography and land use (art. 4.2a). Reporting for the obligations referred to in Articles 4 and 5 of the Floods Directive, consists of the compilation of two files in XML format containing the main information regarding PFRA and APSFR to which correspond files in GML format containing the spatial information differentiated by the type of geometry of the objects represented (points, lines, polygons). Part of the information requested and specifically those concerning past events, are collected centrally through the FloodCat - Flood Catalog platform. This web-GIS platform, created by the Department of National Civil Protection in collaboration with ISPRA and the CIMA Foundation - International Environmental Monitoring Center.

There is also an objective of coordination with other countries ensured in the RBD/UoM, in fact, the ITA, Eastern Alps - shares catchments with the other Member States – Slovenia and Austria – and with a third country, Switzerland. The FRMP states that the shared catchments with Austria and Switzerland are minor and do not involve flood risk issues; consequently, there have not been coordination activities. For Slovenia, flood issues in the shared catchment of the Isonzo/Soca are mentioned in the FRMP, but it is not specified that the identification of flood risk areas was coordinated; Italy's reporting sheet for the Isonzo (ITN004) also discusses cooperation with Slovenia but does not specify if the identification of flood risk areas was coordinated.

<u>Preparation of hazard and risk maps</u>: containing the spatial extension of areas that could be affected by floods, the characteristics of flood events in these areas and the potential negative consequences expressed in quantitative terms of elements exposed to risk.

The art. 6 of the Floods Directive obliges the Member States to prepare, at the river basin district or management unit level, hazard and risk maps of floods for the areas with potential significant risk of floods identified pursuant to Article 5, therefore also the temporary flooding of areas that are not usually covered with water.

The flood hazard maps contain the perimeter of the geographical areas that could be affected by floods according to three probability scenarios.

Legislative Decree 49/2010 characterizes events corresponding to medium probability as infrequent events with a return time between 100 and 200 years and events corresponding to high probability as frequent events with a return time between 20 and 50 years.

In addition to the extent of the flood, the hazard maps must indicate, for each scenario, the elevation (height with respect to the mean sea) or the depth of the flood (height with respect to the ground) and, where appropriate, the flow velocity.

The risk maps indicate the potential negative consequences deriving from floods in the context of the three aforementioned hazard scenarios expressed in terms of:

- indicative number of potentially affected inhabitants;
- type of economic activities persisting in the potentially affected area;
- number of plants referred to in Directive 2010/75/ EU (Industrial Emissions Directive) that could cause accidental pollution in the event of floods and protected areas;
- other information considered useful by the Member States.

The Floods Directive understands the risk maps as maps of the elements at risk (one for each of the 3 probability scenarios). Legislative Decree 49/2010, taking up the criteria established in the Prime Ministerial Decree of 29 September 1998, establishes that the risk mapping also provides for a representation in terms of risk classes (R1 - moderate, R2 - medium, R3 - high, R4 - very high), able to synthetically express, through a single map, the way in which the hazard (P1, P2, P3) and the potential damage are combined within floodable areas.

<u>Drafting of the Flood Risk Management Plan</u>: including the objectives of mitigation and management of the risk identified in the previous phases and the details of the measures to be implemented in order to meet these objectives.

Article 7 of the Floods Directive provides that Member States prepare flood risk management plans (FRMP) coordinated at the river basin district or management unit level for areas with potential significant risk of floods identified pursuant to art .5 and for the areas covered by art. 13.1.b.

As specified in the "Preliminary assessment" section, Italy has decided not to carry out the preliminary flood risk assessment, making use of the transitional measures provided for in art. 13.1.b of the Floods Directive, and to proceed, therefore, directly to the elaboration of the hazard and risk maps of floods. The art. 13.1.b has been applied to all the Units of Management in which the national territory is divided. Therefore the flood risk management plans (PGRA) must be drawn up for each Unit of Management. Article 7 establishes the main purposes and essential contents of the FRMP, further detailed in part A of the Annex to the Directive, and setting a date for completing and publishing the flood risk management plans on 22 December 2015.

FRMPs must address all aspects of flood risk management, and in particular prevention, protection and preparedness, including flood forecasting and warning systems, and take into account the characteristics of the catchment area or sub-basin concerned. Flood risk management plans may also include promoting sustainable land use practices, improving water retention capacities as well as relying on controlled flooding of certain areas in the event of a flood event. Furthermore, the Floods Directive suggests placing emphasis, if appropriate, on non-structural measures and/or measures aimed at reducing the likelihood of flooding.

The measures can essentially be traced back to four categories that correspond to the different aspects of flood risk management indicated by the Floods Directive:

- prevention - measures that act on the vulnerability and value of the elements exposed;
- protection - measures that affect the likelihood of flooding;
- preparedness - measures aimed at improving the response capacity of the population and the civil protection system to flood events;
- post-event reconstruction and evaluation - measures aimed at overcoming the critical conditions deriving from a flood event through safety and restoration activities.

Once the objectives that the measures must achieve have been defined and the measures that, applying to the various aspects of the aforementioned management, allow the objectives to be pursued, it is necessary to establish an order of priority of the measures, both because some of the measures could be preparatory to others, and because it is necessary in the management of limited and deferred funds over time. The prioritization of the measures necessarily passes through a cost-benefit analysis. ISPRA has developed a multi-criterion method for the attribution of the priority level, which allows associating to each measure a numerical score that expresses the socio-economic relevance of the objectives assumed by the measure, the presence and typology of the exhibited goods present in the area to which the measure is applied, the effectiveness of the measure in terms of risk reduction and the compliance of the measure with feasibility and technical sustainability criteria.

For the Eastern Alps (ITA), the FRMP refers to a different approach, also based on a multicriteria approach, but one prepared by the Austrian Environment Ministry, composed of four criteria, including short-term economic analysis. This method was tailored to the local conditions and needs in the Unit of Management/River Basin District and was adopted by Regional and Provincial authorities.

Main category: FRMP:	HUMAN HEALTH	ENVIRONMENT	CULTURAL HERITAGE	ECONOMIC ACTIVITIES
Eastern Alps (ITA)	- Protection of human health from direct and indirect impacts, which could be generated by pollution to or interruption of water services; - Protection of communities, avoiding adverse consequences to local governments, schools, hospitals and emergency services.	- Protection of protected areas/water bodies from floods' permanent or long-term consequences; - Protection from industrial contamination; - Protection from other permanent or long lasting environmental damages to biodiversity, land, wildlife, plants, etc.	- Preservation of archaeological and architectural sites, historical and artistic heritage, landscapes.	- Defence of properties (included residences); - Defence of infrastructure (i.e. telecommunications, road networks, electricity networks); - Protection of agriculture, fishery and forestry; - Protection of other economic activities and other sources of employment.

Figure 3.6: Objectives of Eastern Alps FRMPs

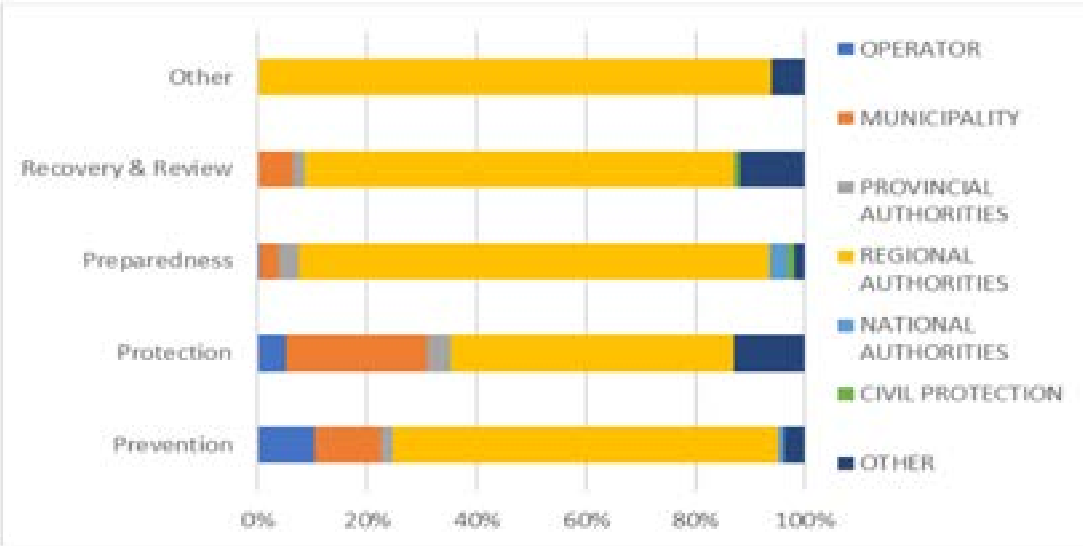
[2]


Figure 3.7: Level of responsible authority by measure aspect[3]

3.3.1. Hazard

The objective of this activity is to represent the areas potentially affected by floods according to pre-established scenarios (as required by Legislative Decree 49/2010) indicating, where possible and in relation to the level developed at this state, the information relating to the flood discharges peak, water depth and flow rate velocity.

On 22 December 2011, the MATTM communicated to the European Commission that Italy would make use of the transitional measures, as required by art. 13.1b of Directive 2007/60 / EC, and which therefore would not have carried out the preliminary risk assessment referred to in Article 4, having decided, before 22 December 2010, to draw up maps of the danger and risk of floods and to establish flood risk management plans in accordance with the relevant provisions of the directive.

The main problems are mostly related to the lack of consistency of the mean return periods adopted within the PAI already prepared by the various Basin Authorities with the reference intervals identified by Legislative Decree 49/2010 and the lack of uniformity of representation of tie rods and speed. Therefore, it is necessary to proceed to standardize the representation of the hazard classes in relation to the scenarios reported in Article 6 of Legislative Decree 49/2010, for the purposes of drawing up the hazard maps. In order to arrive at the definition of homogeneous criteria, to which to refer for the representation of the hazard classes, it must be remembered that the same is mainly a function of the following quantities:

- the mean return period, that is, the average time between two calamitous events (i.e. of greater intensity than a predetermined value);
- the water level or water depth (h expressed in m) and speed (v expressed in m/s) with respect to the mean return period. Note that Legislative Decree 49/2010 considers three scenarios: $20 \leq T \leq 50$ years (frequent floods - high probability of occurrence, P3), $100 \leq T \leq 200$ years (little frequent

floods - average probability of occurrence, P2);200 <T ≤500 years (rare extreme intensity floods - low probability of occurrence, P1)

In the first phase, a common methodology for the classification and mapping of the hydraulic hazard was defined in order to respond adequately to what is required by the Floods Directive and by Legislative Decree 49/2010, making the best use of what has been achieved so far by the individual Basin and Regional Authorities. In all PAI, various reference scenarios are considered for different return periods. In some cases fluvial bands (A, B, C) have been identified in other hazard classes (P4, P3, P2, P1). It is important to underline that almost all the AdB have linked the Hazard Classes/Classes to the Implementation Rules of the PAI, thus binding and defining the compatible uses on the perimeter areas, the planning of interventions and so on. Therefore, it is essential, until the complete integration between the current PAI and the future Flood Risk Management Plans, to preserve and where possible enhance what is currently in force, as a rule, on waterways and perimeter areas, concentrating, in this first work phase, on the possibility of determining transformation relationships between river bands – flood areas – hazard classes, with the aim of standardizing the reference mapping of hazardous conditions throughout the national territory in accordance with the requirements of the Directive 2007/60/ EC and by Legislative Decree 49/2010. In consideration of the deadline of June 2013, the activities related to the drafting of the hydraulic hazard maps, for the watercourses and territorial areas mentioned above, can therefore be configured as a passage, from the current maps (river bands/hazard classes or floodable areas) to hazard maps represented according to 3 classes as shown below.

Therefore, in the second cycle, it will be necessary to keep updated or prepare, where not available, the aforementioned register of events, in which information on the spatial and temporal location of the flood events and the adverse consequences associated with them can be traced. The catalogue of data on events within a geodatabase allows containing, in a single structure, information that may have a vector representation of different types of sites. The vector information on the sites affected by an event could in fact consist of points (e.g. centroid of the affected municipality), polylines (stretches of watercourses where the flood occurred) and polygons (e.g. flooded areas for which perimeter is available). As regards the information contents and the structure of the database, it is necessary to refer to those indicated in the outline of the Preliminary Risk Assessment.

Moreover, the identification of the flooded areas associated with different event probability scenarios is closely linked to the methodologies and schemes that are intended to be adopted not only in the phase of formation of the outflows, which strictly concerns the hydrological field, but also in the phase of propagation and transport on the area under analysis, more closely linked to the hydraulic and geomorphological aspects. This aspect must be included the embankments then has to deal with the fact that the calculation sections may not be rigid, as the collapse of the lateral containment structures, in particular of the embankments, can occur.

3.3.2. Vulnerability

The vulnerability (V) generally represents the rate of the single element at risk that can be damaged during an event and is expressed with a number between 0 (no damage) and 1 (total loss). Another is the knowledge of the exact typology, magnitude and frequency of phenomenology as well as the knowledge of the behavior of the single item displayed. The vulnerability of an area as a whole, on the other hand, is the percentage of the lost value intended as a "system" of human activities compromised following the occurrence of a specific potentially harmful process; for its exact determination it also requires the knowledge of the exact typology, magnitude and frequency of phenomenology as well as the knowledge of the behavior of the structures and how they influence the development of the relative activities. Taking into account that the same vulnerability may also vary based on random factors, such as the period of the year, the day of the week and the time in which the event occurs, and considering the data available, the relative evaluation it can be simplified by simply considering the category of elements exposed by assigning, on the basis of an aggregation into weighted classes, a value coefficient depending on the degree of possible impairment. To arrive at the parameterization of vulnerability, referring to the single class of elements at risk or even more in detail, referring to the single element at risk, the study activities are complex and onerous; in fact, it is not always possible to evaluate the level of protection of the building (intended, for example, as knowledge of the structural characteristics of a building or as the definition of civil protection plans) or the impact energy of the current and therefore to define numerically the degree of resistance to the stresses induced by the occurrence of the extreme natural event. Therefore, in this first phase of drafting the risk maps, reference is made to an estimate of the vulnerability understood as the vulnerability of the element, assuming in any case the same value (equal to 1) in all the areas included in the perimeters conducted for the definition of the hydraulic hazard, leading to an immediate transition from the maps of the exposed elements to those of the potential damage (damage estimated equal to the value of the element itself).

For the second cycle it was proposed to use a more complicated approach that distinguishes many aspects as:

- Vulnerability associated with the human presence: to characterize the vulnerability associated with the human presence, reference is made to values of speed and depth that determine “instability” with respect to the equilibrium (standing) position.
- Vulnerability associated with economic activities: as regards buildings, they can collapse due to water pressure, the undermining of foundations, or a combination of these causes. In addition, solid material carried by a flood, especially in the form of lumber and debris, can cause damage to structures.
- Vulnerability associated with the presence of cultural assets: At present, there is no knowledge or information available to establish a specific vulnerability of individual assets according to the characteristics of the flood, nor is it possible to establish a scale of values regarding the relative importance of goods themselves. Therefore, pending an in-depth analysis that allows at least a differentiation by type (museum, library, historical building or monument, archaeological site, etc.), is considered precautionary to associate, in the overlapping phase of flood areas with the layer of "Relevant assets historical-cultural and archaeological ", give Dc = 1, regardless of the values of h and v.

3.3.3. Exposure

The knowledge and classification of the elements exposed can take place through the use of a series of information layers whose level of detail will always be increasing:

- minimum level - available throughout the District: (i) data from Corine Land Cover project (CLC2006 - CLC2006 - adj. IV level) consisting of land use maps divided into 44 information layers (scale 1: 100,000 and with a sensitivity of 25 ha, geometric accuracy 100m); (ii) data from national and regional geoportals (various updates) consisting of large and small scale cartographic and land use databases; (iii) data from Cartography I.G.M. (scale 1: 25,000); or (iv) data from ISTAT censuses.
- detailed level - specific for each Basin Authority: (i) data obtainable from the maps contained in the planning tools in force (Water Management Plan, PTR, PTCP, Landscape Plans, PRGC / PUC, Implementation Plans, Detailed Plans, ASI Plans, ATO, Water Protection Plans, etc.); (ii) data from the regional technical charts (scale 1: 5000); (iii) data from specific aero-photogrammetric surveys; or (iv) data from field surveys. In addition to the data available as specified in the previous points, it will be possible to make use of other and different sources (historical cartographic, archival, bibliographic, etc.) and/or direct acquisition of information on the territory.

The data acquisition, at least of the first level, will allow the identification and mapping of the following macro-categories:

1. Urbanized areas (urban agglomerations, inhabited areas with widespread and scattered construction, expansion areas, commercial and productive areas) with indication of the number of inhabitants potentially affected by possible flood events;

2. Strategic structures (public and private hospitals and treatment centers, civil collective activity centers, civil centers, military collective activity centers - correspondence with class E of DPCM 29.09.98 and with what is reported in letter b, comm .5, art. 6 of Legislative Decree 49/2010);

3. Strategic and main infrastructures (power lines, methane pipelines, oil pipelines, gas pipelines and aqueducts, communication routes of strategic importance both for vehicles and railways, ports and airports, hydroelectric reservoirs, large dams).

4. Environmental, historical, and cultural assets of significant interest (natural areas, wooded areas, protected and restricted areas, areas of landscape constraint, areas of historical and cultural interest, archaeological areas, National and Regional Protected areas);

5. Distribution and type of economic activities persisting in the potentially affected area

6. Areas affected by production settlements or technological plants, potentially dangerous from an environmental point of view (pursuant to pursuant to what is identified in Annex I of Legislative Decree 59/2005), mining areas, landfills, purifiers, incinerators - and protected areas potentially affected;

Below are some data sources described in relation to the categories of elements shown in Legislative Decree 49/2010, which are added to those available on the National Cartographic Portal of the MATTM at http://www.pcn.minambiente.it/mattm/.

Indicative number of potentially affected inhabitants. At the national level, the data provided by ISTAT is available on an aggregation scale of the census section (last update: 2011). ISTAT has also made geographic data available free of charge (in shape file format - "Territorial bases and census variables" available on the page: www.istat.it/it/ enforcement/44523)

Infrastructures and strategic structures (highways, railways, hospitals, schools, etc.). In addition to information that can be downloaded from institutional sites or available from public bodies, there are updated commercial products such as Multinet and NAVTEQ that are not very expensive and have already been adopted for similar activities due to their completeness and continuous updates of the available themes.

Environmental, historical and cultural assets of significant interest. For this category, reference can be made to the data of the Ministry for Cultural Heritage and Activities (MIBAC) possibly integrated by regional and provincial sources.

Categorization of the exposed elements. For the preparation of the flood risk maps, the Italian legislation identifies a series of categories of exposed elements that can be included in the following 4 macro-categories: population, economic activities, cultural-archaeological heritage and environmental heritage, specifying that for the context national cultural-archaeological assets are identified in the category "other information considered useful by the Member States."

3.3.4. Damage and Impact indicators

In analogy to what has already been done in the drafting of the Hydrogeological Planning Plans, in line with the sector regulations (DPCM 29.09.98) and according to what is stated in the previous subsections, the analysis of the Damage, in this first phase of the Plan's work Alluvioni, will be conducted in a simplified way by associating the categories of elements exposed to homogeneous conditions of Potential Damage. In fact, there will be four homogeneous classes of Potential Damage, taking into account for their definition firstly, the damage to people, and then that to the socio-economic fabric and to non-monetizable assets. The four damage classes can be defined as follows:

- D4 (Very high potential damage): areas in which the loss of human life can occur, significant damage to economic, natural, historical and cultural assets of significant interest, serious ecological-environmental disasters;
- D3 (High potential damage): areas with problems for the safety of people and for the functionality of the economic system, areas crossed by communication lines and services of significant interest, areas where important production activities are located;
- D2 (Average potential damage): areas with limited effects on people and the socio-economic fabric. Areas crossed by secondary infrastructures and minor productive activities, mainly intended for agricultural activities or public parks;
- D1 (Moderate or zero potential damage): includes areas free from urban or productive settlements where free flow of floods is possible.

The potential damage map will therefore have four different backgrounds corresponding to the four levels of expected damage. From the graphic point of view, according to the homogeneous category of damage, three types of symbolism are possible:

- AREAL (field area): corresponding to all those categories that have an areal development such as urban centres or specific strategic structures (hospitals, schools, etc.);
- LINEAR: (solid line): corresponding to all those categories that have a linear development such as motorway and railway lines;
- PUNCTUAL (using appropriate symbols): corresponding to all homogeneous categories, which by their nature cover negligible surfaces or, in any case, not known in the exact delimitation.

As previously described, in the first cycle the hypothesis of Vulnerability to equal to 1 was used, but for the second cycle will be evaluated analytically and define on different assets:

- The damage associated with the human presence;
- The damage associated with economic activities;
- The damage associated with the presence of cultural assets.

Once the various damage classes have been defined as reported in the previous paragraph, it is necessary to define the risk value according to the danger of the expected event. Therefore, once the 3 levels of hazard (P3, P2, P1) and the 4 of potential damage (D4, D3, D2, D1) have been defined, the four consequent risk levels R4, R3, R2 and R1 will be established and the card of the risk. The D.P.C.M. 29.09.98 "Guidance and coordination act for the identification of the criteria relating to the obligations referred to in art. 1, paragraphs 1 and of the D.L. 11.06.98, n. 180" in reiterating that the Basin Plans must take into account the provisions of the Presidential Decree 18.07.95, defines, with reference to planning experiences already carried out, four classes of risk:

- R4 (very high risk): for which loss of human life and serious injury to persons, serious damage to buildings, infrastructures and environmental assets, the destruction of socio-economic activities are possible.
- R3 (high risk): for which there are possible problems for the safety of people, functional damage to buildings and infrastructures with consequent unavailability of the same, the interruption of the functionality of socio-economic activities and damage to the environmental heritage;
- R2 (medium risk): for which minor damage to buildings, infrastructures and environmental assets are possible that do not affect the safety of people, the usability of buildings and the functionality of economic activities;
- R1 (moderate or zero risk): for which the social, economic and environmental damage are negligible or nil.

CLASSI DI RISCHIO		CLASSI DI PERICOLOSITA'		
		P3	P2	P1
CLASSI DI DANNO	D4	R4	R3	R2
	D3	R3	R3	R1
	D2	R2	R2	R1
	D1	R1	R1	R1

Figure 3.8: Four risk classes as a function of hazard and consequence classes (in Italian).

The difficulties in quantifying the parameters and the unavailability of reliable data of sufficient detail that contribute to the definition of the risk levels (especially with reference to the vulnerability analysis) make it appropriate to adopt, at least in this first phase, simplified methodological criteria for an assessment and risk representation.

To date, many AdBs and Regions have carried out the mapping of hydraulic risk with similar criteria. The differences are not related to the risk classes which, as already mentioned, were defined with the D.P.C.M. of 29.09.98, as regards the criteria and choices made for the identification of the hydraulic hazard, the exposed elements and their attribution to the damage classes, as well as their matrix relationships for the attribution of the risk level. In this case, the hydraulic risk maps, currently in force, are in fact valid regardless of how they are made and the reference hazard; the effort to be made, for the deadline of June 2013, relates to the integration of the individual maps, which must also contain the number of potentially exposed inhabitants and potentially dangerous plants (pursuant to Annex I of Legislative Decree 59/2005), as indicated both in Directive 2007/60 and in Legislative Decree 49/2010.

3.3.5. Tool (platform) for flood risk assessment

Regarding tool and platform at the national level, the information is available and should be consulted on geoviewer.isprambiente.it, the web-based GIS of ISPRA (Figure 3.9) developed by the Institute for Environmental Protection and Research that is a public research body with legal personality under public law, technical, scientific, organizational, financial, managerial, administrative, asset and accounting autonomy (https://www.isprambiente.gov.it/it).

ISPRA is supervised by the Minister for the environment and for the protection of the territory and the sea. The Minister makes use of the Institute in the exercise of his powers, issuing general directives for the pursuit of institutional tasks. Without prejudice to the performance of the tasks, services and activities assigned to the Institute pursuant to the legislation in force, the priorities relating to the additional tasks are also indicated in the context of the aforementioned directives in order to prioritize the performance of the support functions to the Ministry of the Environment and the protection of the territory and the sea.

In parallel to ISPRA more devoted to the planning phase and collection of data from Units of Management, there are the Civil Protection Department devoted to the operational civil protection phase supported by competence centre as Fondazione Cima that developed a webGIS platform called Dewetra (https://www.mydewetra.org/) where it possible to consult almost all information necessary for FD and FloodCat platform (Figure 3.10) used by CA to collect the information of past event (https://www.mydewetra.org/apps/floodcat/index.html#?skin=3).

3.4. Multi-Risk assessment

The National Risk Assessment (NRA) for Italy, developed at the end of 2018 by the Department of Civil Protection (DPC), addressed risks related to 10 natural hazards, but the risk due to different hazards was not compared.

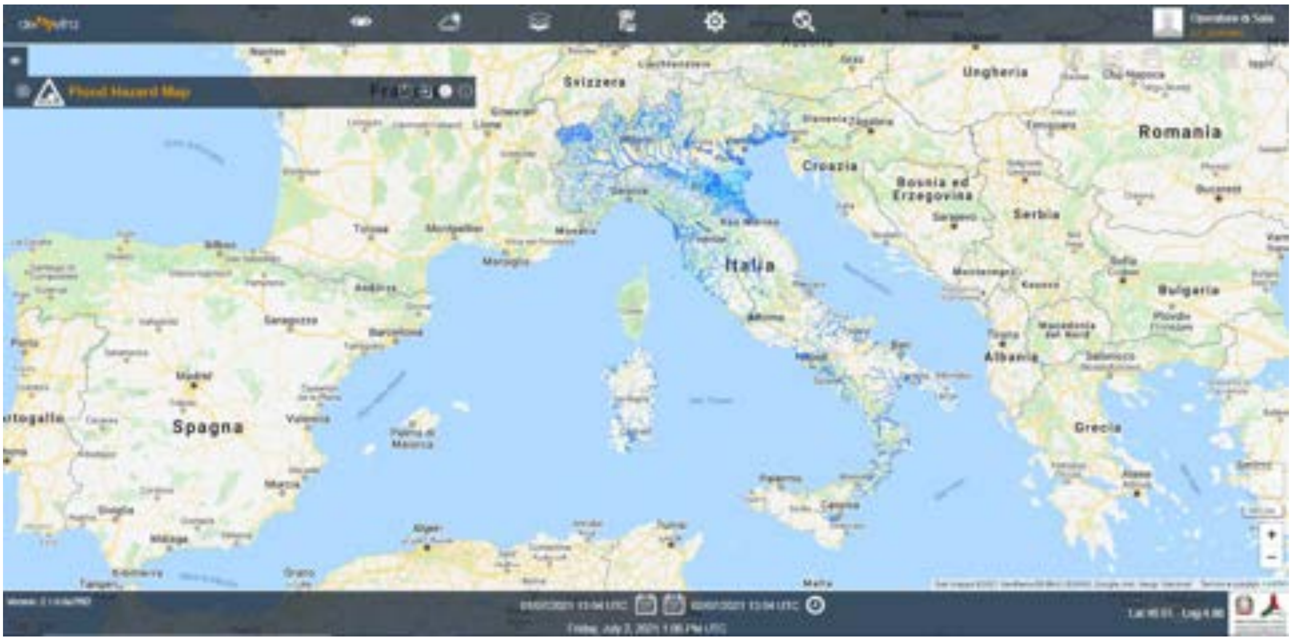


Figure 3.9: A screenshot of geoviewer of Ispra.

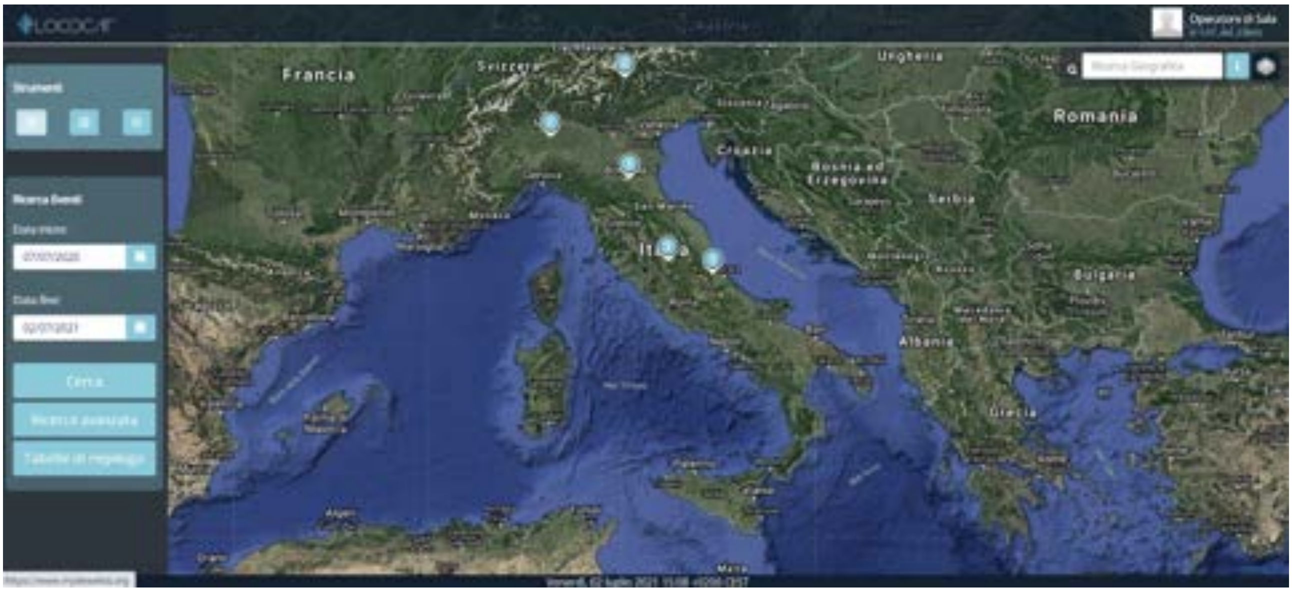


Figure 3.10: FloodCat platform used by CA to collect the information of the past event

4. NATIONAL RISK ASSESSMENTS FOR AUSTRIA IN 2020

In Austria, disaster risk management and assessments are not the responsibility of a single institution or authority due to the distribution of responsibilities between different ministries and the competences within the federal states. The prevention, recovery or reduction of the impact of disasters (disaster relief, emergency response) is predominantly a responsibility of the federal states. Moreover, the National Crisis and Disaster Management in Austria (SKKM) as part of the Federal Ministry of Interior (BMI) involves five components in their agenda: the population, the authorities, the response organizations, the economy and science. The methods used for civil protection management are primarily based on the “Risk Assessment and Mapping Guidelines for Disaster Management” of the European Commission, the ISO Standard 31000 and the national standard for risk management ONR 490002. These risk assessments are mainly scenario-based and focusing on single risks. However, the Federal Ministry of Agriculture, Regions and Tourism (BMLRT), in particular, the sections with a special focus on natural hazards, in line with the affected municipalities, provinces and federal states, have been conducting detailed hazard analyses for many years due to legal obligations.

4.1. The analysed risks

After the devastating floods of 2002 and 2005, the Federal Ministry of Agriculture, Regions and Tourism and the insurance companies agreed on the stepwise collection of all official hazard and risk maps as well as related information regarding floods, avalanches, earthquakes, landslides, storms, lightning, hail and snow load in the web portal Natural Hazard Overview & Risk Assessment Austria (HORA).

Besides that, the Federal Ministry of the Interior started in 2014 to develop a risk analysis process as part of the Austrian Crisis and Disaster Management (SKKM), which also includes a first nationwide risk assessment and a preliminary risk matrix. This assessment indicates that extreme weather events (heavy rain, heat, cold, hail), floods, avalanches, and technical events such as traffic accidents, industrial accidents and, in the case of cross-border events, especially pandemics, pose the greatest risk potential for Austria (BMI, 2014).

For the risk analysis on the national level a 5x5 matrix was chosen by the National Crisis and Disaster management. The classification of the theoretical "Scenario 1" (Figure 4.1, Figure 4.2) in the risk matrix with the categories: 1 = (In)-significant; 2 = low; 3 = high; 4 = catastrophic; 5 = critical (BMI, 2018).

In the past decade, most of the earthquakes in Austria occurred in Tyrol, followed by Lower Austria, Carinthia and Styria. Several times a year, earthquake events in neighbouring countries are also noticed by the population in Austria. The number of earthquakes recorded by the seismic network stations and localized in Austria comes to about 600 per year, i.e., more than ten times the number of events recognised by the population (BMI, 2014).

The data is collected by the stations of the Austrian seismic network that are equipped with STS-2 broadband sensors, which enable to record earthquakes down to a magnitude of 5. In addition, the Conrad Observatory at the Trafelberg (Lower Austria) was inaugurated in 2002 (ZAMG, s.a.).

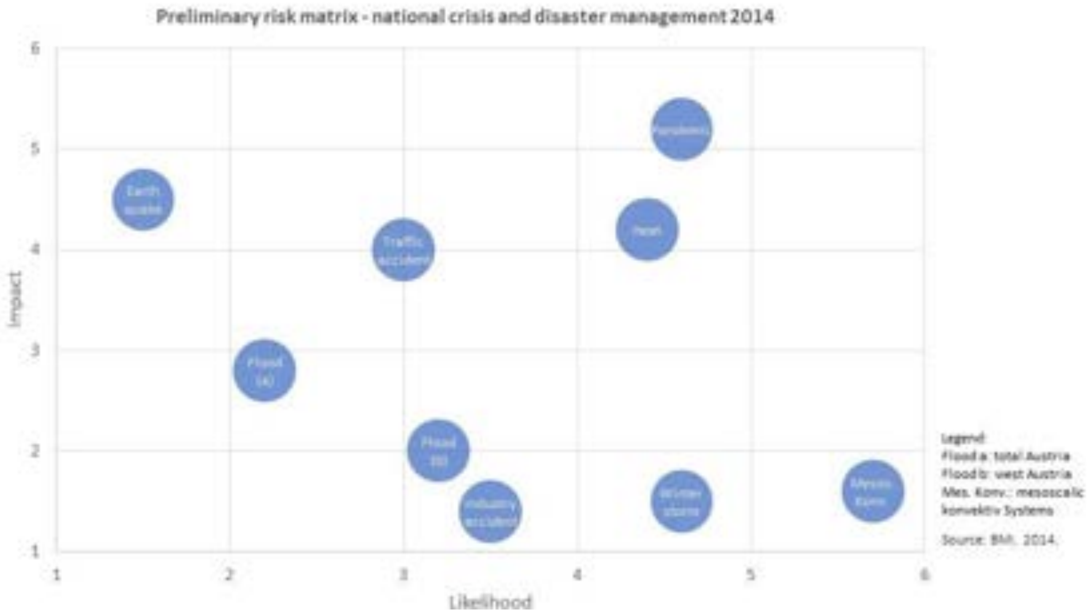


Figure 4.1: Preliminary risk matrix from 2014 by the National crisis and disaster management Austria (SKKM)

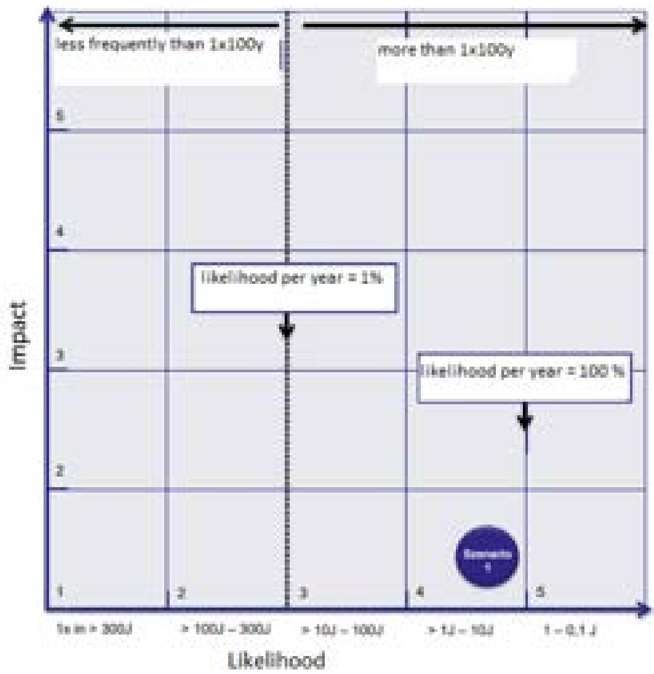


Figure 4.2: Risk matrix for the theoretical scenario 1 (BMI, 2018)

4.2. Seismic risk assessment

In Austria, the seismic risk is mainly outlined through a seismic hazard map by the Central Institute for Meteorology and Geodynamics (ZAMG). The map was developed by the seismologists of the ZAMG together with the GeoForschungszentrum Potsdam. Based on the epicentre map, the federal territory was divided into 29 areas that differ in their seismicity and geology. For the probabilistic calculations, the data available at GFZ Potsdam in 2006 was used. A revision of the map was undertaken in 2020 (see Section 4.2.1).

The seismic zonation has been based on ground acceleration values with a 10% probability of exceedance in 50 years, i.e., 475-year mean return period. The map is part of the national seismic building code (ÖNORM EN 1998-1), which is in accordance with Eurocode 8. Five hazard zones from 0 to 4 with different expected ground motions [m/s²] can be distinguished (Figure 4.3). Moreover, the levels of potential building damage – from moderate to total destruction – following the concept of the European Macromesian Scale 1998 (EMS-98) are expressed by the hazard zones. According to ÖNORM EN 1998-1 building standards (the national implementation of Eurocode 8), constructions in zone 4 need to be built with particular earthquake resistance, as ground accelerations can exceed 1 m/s² there. Likewise, the ground and soil type have a significant effect on the strength of the possible earthquake. Consequently, seven ground types have been defined in the standard. Furthermore, detailed hazard maps for specific areas are available, and the annex of the building standards includes an index with exact seismic design values for some locations. The map resolution is two kilometres, as the localization accuracy of earthquakes is within this range. Therefore, in the transition areas, some locations are in the adjacent zone. In these cases, the reference ground peak acceleration a_{gR} determined for the particular location is valid. If a_{gR} is exactly at the zone boundary, the higher zone should be selected, and higher construction standards should be implemented. Another map that is available online gives an overview of the current seismic situation by displacing the earthquakes recorded by network of ZAMG during the last 14 days. (BMLRT, 2021)

To sum up, in general, Austria has a good overview of seismic hazards due to the existing real-time monitoring, the hazard maps and through the Austrian Building Code ÖNORM B 1998-1. However, the seismic risk is currently not assessed in detail. Austria is rather focusing on implementing awareness-raising measures such as the earthquake handbook (Erdbebenratgeber) by the Ministry of the Interior and the Civil Protection Federation or the visualisation of the seismic hazard through the HORA platform (Section 4.2.5). In addition, preparedness and training activities of the emergency services are performed on a regional level.

4.2.1. Hazard (maps)

The latest seismic hazard map of Austria (Weginger et al., 2020), which was presented in May 2020, shows the maximum horizontal ground acceleration with an occurrence probability of 10% in 50 years (Figure 4.4). The improvements in the probabilistic seismic hazard assessment (PSHA) are based on the revised Austrian Earthquake Catalogue (AEC) and additional monitoring data from the last 25 years with improved depth, source-mechanism and moment magnitudes. The following improvements were made: locally adjusted ground motion prediction equations (GMPE) were computed by applying least-squares fitting to the local measurements, a neural network approach was implemented, and as a result, the final selection was made using statistical parameters such as log-likelihood and Euclidean distance domain. Verified calculation methods such as Bayesian Penalized Maximum Likelihood and modified Gutenberg Richter were used (Weginger et al., 2020).

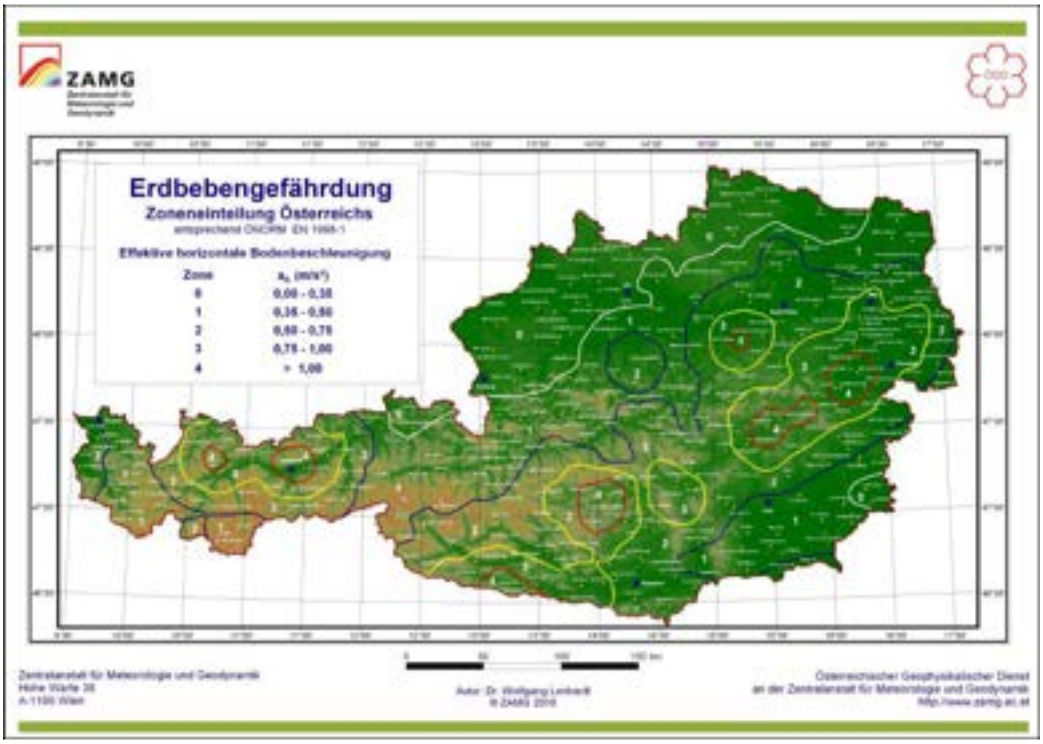


Figure 4.3: The seismic hazard map of Austria that is included in the current ÖNORM 1998-1 outlines the seismic zones and the "effective" ground acceleration in m/s^2 (which is considered to be 70% of the maximum ground acceleration (source: ZAMG, s.a. ©ZAMG 2010).

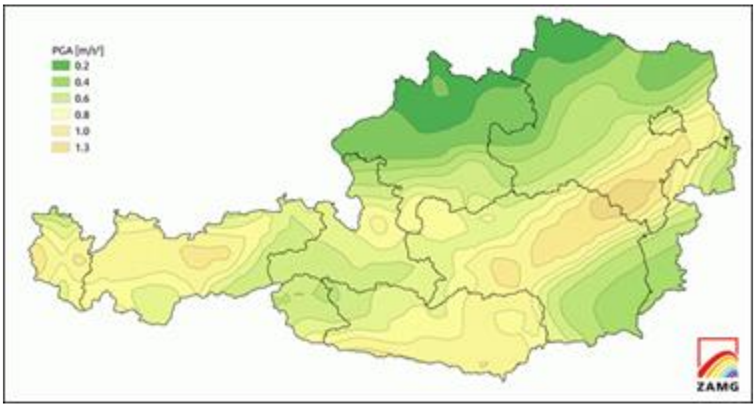


Figure 4.4: New earthquake hazard map presented in 2020 (ZAMG, s.a.; Weginger et al., 2020).

The measurement network currently consists of more than 45 stations and is continuously being expanded. The current network enables an improved localization of earthquakes as well as a more precise estimation of the quake depth and the quake mechanism. The map is mainly based on the Austrian earthquake catalogue compiled by the Earthquake Service of ZAMG for more than 100 years and continuously extended and improved. Thus, the results of historical earthquake research are constantly being upgraded. Overall, the calculation is mainly dominated by regional seismic activities and relies less on strong single events. The new results were compared with the current norm and the results of neighbouring countries. They provide a basis for the establishment of a new standard for earthquake-resistant construction in Austria. For this purpose, the uniform hazard spectra were compared with the new Eurocode draft. However, until the finalization, the current version of ÖNORM EN 1998-1 remains valid (ZAMG, s.a.; Weginger et al., 2020).

New Shake Maps have been presented in the scientific context and will be shared with end-users, who will also be trained for better understanding. Shake Maps provide near-real-time maps of ground motion and shaking intensity following significant earthquakes. They are automatically generated within a few minutes after the occurrence of an earthquake and are provided in terms of Intensity, PGA, PGV and PSA (Weginger et al., 2017).

4.2.2. Vulnerability

The concept of vulnerability is considered through the European Macroseismic Scale EMS-98 (Grünthal, 1998), where it is used to express differences in the way that buildings respond to earthquake shaking. Accordingly, six classes of decreasing vulnerability are proposed (A–F) in the vulnerability table. Currently, there is no vulnerability model in use in Austria that assigns buildings to vulnerability classes on a nationwide basis.

4.2.3. Exposure (data availability)

The dataset "Datensatz des Gebäude- und Wohnungsregisters (GWR II)" combines the address register and the building and apartment register. The address register enables the maintenance of an Austria-wide inventory of spatial address data down to the building level. In addition, addresses of apartments as well as structural data of buildings, apartments and other units of use are included in GWRII. Information on the number of full-time and other (secondary) residences is also included. The entire dataset is described in detail in the feature catalogue of Statistics Austria (2012). The dataset is divided into a spatial dataset of address points and several content tables.

Statistics Austria provides data on the construction period, the number of storeys and the number of underground storeys. For older buildings, the construction period is specified by an interval of several years (before 1919, 1919 to 1944, 1945 to 1960, 1961 to 1970, to 1980, 1981 to 1990, 1991 to 2000, 2001. For newer buildings (since 2000), the construction period corresponds to the year of construction. As of 2004, the exact date of construction is also entered. The construction method is understood to be a rough characterisation from a constructional point of view of the building material used. If the construction method is mixed, the predominant construction method is indicated. The following dominant material of the building can be specified: [ ] (not specified), [M] Brick construction, [B] Reinforced concrete frame, [S] Steel skeleton, [H] Wood frame construction.

The dataset on the building stock is available from the Federal Office of Metrology and Surveying (BEV) that is part of the Austrian Federal Ministry of Digital and Economic Affairs. The digital cadastral map (DKM) contains all information of the analog cadastral map as the data are consistent with the databases of the cadastre (property database, coordinate database) and improved by comparison with aerial photo information such as orthophotos and other technical documents (site plans, as-built plans). The data are accessible for the public via the geodata portals of each federal state. Due to different projects on the regional level, more detailed data is available in some areas. For example, in Styria, in the course of the project "Building Layer from Airborne Laserscanning Data" (2011-2017), all structures higher than four meters, greenhouses, terraces with basements and silos were manually digitized, based on the ALS data of the province of Styria. In addition, details of the average and maximum building heights are available.

4.2.4. Damage and Impact indicators (damage documentation)

In Austria, the population notices an average of 40 earthquakes per year - this corresponds to an average of about three earthquakes per month. Minor damage to buildings caused by stronger earthquakes is expected about every two-to-three year. Severe damage to buildings (intensity VIII on the EMS-98 scale) occurs significantly less frequently, and the average return period for such events is about 75 years. (BMI, 2014)

No standardised method for earthquakes damage documentation is currently applied. Also, no rules for damage-to-impact conversion are standardized. Historical data on certain events are collected and studied by the ZAMG. Different Apps and tools exist to collect events perceived by the public. The tool “your earthquake report” provided by the ZAMG enables the interested public to document earthquake damage to individual buildings. In detail, a short questionnaire is used to record the effects of earthquakes on people, objects, buildings and nature. The app "QuakeWatch Austria" makes it easy to send noticed earthquakes and damage reports to ZAMG. It provides information about all earthquakes of the last hours, days and weeks worldwide using charts and maps, sortable by Austria, Europe and the world. In addition, the app contains information on how to behave during earthquakes and on prevention/mitigation measures. (ZAMG, s.a.)

4.2.5. Tool (platform) for seismic risk assessment

The **HORA** platform – online since 1st June 2006 at http://www.hochwasserrisiko.at/ – is a digital hazard map that informs the public about the risk posed by rivers, avalanches, earthquakes, hail, storms, lightning and snow loads (https://www.hora.gv.at). The seismic hazard map combines the hazard map and the information on current events during the last 14 days. In addition, all information about the Austrian Seismic Network, the hazard map and the current events as well as precise a_{gR} values are available under https://www.zamg.ac.at.

4.3. Flood risk assessment

The organisation of flood risk management in Austria is divided amongst three authorities. This is due to the legal requirements, the diversity in landscapes and topography, and regionally different responsibilities: The waterways of Danube and March, but also stretches of the rivers Thaya, Enns and Traun are in the responsibility of the Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology. Torrents, where boundaries are defined by ordinance, are in the responsibility of the Torrent and Avalanche Control (WLV) in the Federal Ministry for Agriculture, Regions and Tourism (Section III -Forestry and Sustainability). Water bodies that are neither torrents nor waterways are in the responsibility of the Federal Water Engineering Administration (BWV). This task is fulfilled by the Federal Ministry for Agriculture, Regions and Tourism (Section I - Water Management) together with the federal provinces. (BMLRT, 2018a)

From the legal point of view, flood risk management is cross-sectoral, which, in Austria, is dealt with in both federal and provincial law. Union legislation is also relevant on a higher level by means of the Water Framework Directive and the Floods Directive. On the national level, the legal framework mainly consists of the Water Act, the Forest Act and the Waterways Act. They define the tasks of the ministries described earlier. Two additional ordinances regulate the creation of hazard zone plans: the technical guidelines for the implementation of flood protection measures and the laws on funding instruments as the Disaster Relief Fund and the Hydraulic Engineering Assistance Act (WBFG). The legal framework for flood risk management is completed by the Provincial laws on spatial planning (ROG) and emergency management as well as building regulations. While the districts and the respective provincial governments are responsible for the execution and supervision of the provincial laws (as building authority or the supervising authority of the municipalities), the municipalities have a degree of autonomy for initiatives regarding flood risk management, for instance, in zoning planning and issuing building permits. (BMLRT, 2018a)

All **implementation steps of the EU Floods Directive** are presented in the Webportal Water Information System Austria (WISA) and are available to the public. The implementation of the Directive is revised in 6-year cycles and adapted if needed. The Federal Ministry of Agriculture, Regions and Tourism (BMLRT), as the responsible authority, coordinates the process in close cooperation with the responsible federal state departments, especially the departments for flood risk management, water management, spatial planning, building regulations and emergency management also involving the public. The Flood Risk Management Plan is the superordinate planning instrument in Austria and created for the entire federal territory. It includes particularly those 391 areas, in 722 municipalities and districts of Vienna, Figure 4.5, that have been identified as Areas of Potential Significant Flood Risk (APSFR) in a preliminary risk assessment.

Referring to elaborated flood hazard and flood risk maps appropriate objectives are defined, and measures for achieving the objectives are selected from the field’s prevention, protection and preparedness. The first National Flood Risk Management Plan for Austria was published in 2015, intensive work on the first revision is underway:

- Step 1: The preliminary flood risk assessment for the first revision was completed in 2018 using updated data and a revised method.
- Step 2: The flood hazard maps and flood risk maps, which form the basis for Flood Risk Management Plans, were completed. These maps are currently optimised towards better user-friendliness.
- Step 3: The revision of the Flood Risk Management Plan until the end of 2021.

Figure 4.5: Spatial extension of the 391 Areas of potential Significant Flood Risk in Austria (red lines)

On the Web portal WISA, the overview map on areas at risk presents the number of potentially by a flood event affected persons per municipality. Moreover, additional information about the surface runoff is available. The hazard maps visualise the spatial extent of flooded area based on different flood scenarios (different flood discharge values and flood characteristics) with a high HQ30 and medium HQ100 probability as also extreme events HQ300. For every scenario, different water depths and flow velocities are available. The risk maps show the potentially affected elements (people, environment, cultural heritage and industry) in the flooded areas in different hazard scenarios. The number of potentially affected persons, i.e. those with a primary or secondary residence or workplace in the area, are displayed using a raster with a size of 125 x 125 metres (Figure 4.6). The predominant use of the areas, for example, for housing or as agricultural land, is also assigned (Neuhold, 2016; BMLRT, 2018a).

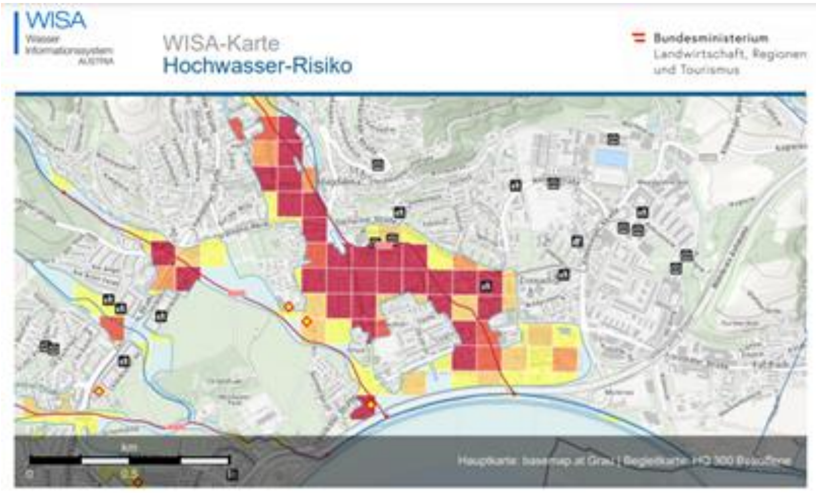


Figure 4.6: Example of the Austrian flood risk map, extension of a HQ300 flood scenario, showing the number of potentially affected persons per raster and the potentially affected infrastructure (e.g. train station, schools, hospitals, industry). Source: WISA Web portal https://maps.wisa.bmlrt.gv.at/

The Flood Risk Management Plan needs to be coordinated with the National River Basin Management Plan (NGP). In accordance with the Water Framework Directive, the NGP is to be created for all river basins; its goals are the protection, improvement and sustainable use of the water bodies. Published every 6 years, the NGP defines how to attain the goal of “good status” or “good potential” of the water bodies (BMLRT, 2018a).

The flood hazard assessment in Austria follows the general probabilistic event-based approach where the flood hazard is defined based on hydrologic and hydraulic modelling and calibrated with historic event data. Flood scenarios of 30-, 100-, and 300-years return periods combined with different possible scenarios, such as the failure of protective measures, or the influence of built-in structures (e.g. bridges) or protective measures are considered and used within the different hazard and risk maps and the hazard zone plans.

On the regional level River Basin and Risk Management Concept (GE-RM) serves to coordinate possible measures in a catchment area or longer water body sections to identify potential synergies and to avoid conflicts. It is coordinated with the objectives, measures and priorities of the National Flood Risk Management Plan (FRMP) and the National River Basin Management Plan (NGP), regional and spatial planning, building regulations, emergency management, nature conservation and other administrations and authorities as well as other users and those affected in the catchment. (BMLRT, 2018a)

At the local level hazard zone plans are to be created. They include torrent catchments and especially Areas of Potential Significant Flood Risk. The declaration of Yellow and Red Hazard Zones is a significant part of the planning process. As the Service for Torrent and Avalanche Control and the Federal Water Engineering Administration (operating under the Forest Act and the Water Act, respectively) are the competent authority for catchments with different topographies and processes, their approaches are slightly different. (BMLRT, 2018a)

Red Hazard Zones are characterised as areas with high process intensity. Therefore, the risk for life has to be assumed. In Yellow Hazard Zones, significant damage to objects or infrastructure has to be expected. As total safety by means of flood protection is economically and feasibly not possible, zones with low hazard probability (Residual Risk Areas) are also marked. These areas are flooded if existing protection measures are overtopped, or in case the measures fail (e.g. when a dyke breaks). Additionally, areas that are needed for potential future measures and their maintenance are marked as Blue Functional Areas. Areas with flood retention potential and those required for flood conveyance are marked as shaded Red-yellow Functional Areas. Hazard zone plans are to be considered in local spatial planning and in building regulations. In many federal provinces, building bans are defined in areas of high and moderate flood hazard, especially in Red Hazard Zones. Areas prone to a low probability of flooding are treated under the principles of risk prevention and risk reduction. Hazard zone plans are available to all municipalities, provincial authorities and federal authorities. For the public, they are accessible in the municipal offices and online via the HORA platform and the Web-GIS portals of every federal stated (BMLRT, 2018a).

In the survey of the planning basis, a distinction must be made between unobserved and observed catchment areas. The hydrological input data are to be coordinated with the provincial hydrographic services and, in the case of contact points, with the responsible services of the Forest Engineering Service for Torrent and Avalanche Control. If sufficiently long discharge series at gauging stations are available, discharge values and hydrographs characteristic for the region can be applied to the model. If no or only very short observation series are available, the hydrological input parameters are to be calculated using discharge diagrams, empirical formulas, regional hydrological analyses and/or rainfall-runoff models (BMLRT, 2018b).

Information on past flood events (e.g., event sequences, high-water marks, changes in stream morphology) is used for determining characteristic flood processes and for evaluating floodplains as further for the calibration and validation of model parameters in the course of runoff investigations. The link to past events that have actually occurred also increases acceptance and understanding among the affected population (BMLRT, 2018b).

4.3.1. Hazard

Three flood scenarios (see Figure 4.7, left) are considered within the different hazard and risk maps and the hazard zone plans:

- High probability of occurrence: 30-years return period;
- Medium probability of occurrence: ≥ 100- years return period;
- Low probability of occurrence/extreme flood: 300 years return period.

Results of the assessments are (intensity parameter): Discharges, extend of flood plain, water depths, water velocities. Flood hazard maps are available on the national level for all APSFRs and all torrent catchments. The visualization of the flow velocity is area-based with class boundaries of 0.25 m/s (0.25 m/s to 0.5m/s, etc.) for the scenarios HQ30, HQ100 and HQ300. In addition, vectors are included to represent the flow direction. Water depths are shown with class boundaries of 0.2 m (0 - 0.2 - 0.4 - 0.6 ....) for scenarios HQ30, HQ100 and HQ300. For the hazard zones (yellow and red) the interaction of water depth and water flow velocity is essential (see figure 4.7, right).

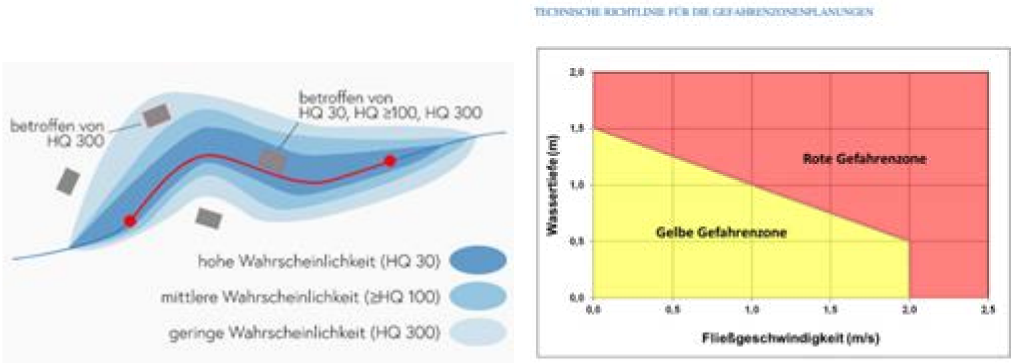


Figure 4.7: left: Austria used three flood scenarios to assess the individual hazard/risk (source BMLRT, 2018); right: Classification of hazard zones due to the interaction of the water depths (m) and flow velocities (m/s) (energy line) (BMLRT, 2018b).

4.3.2. Vulnerability

There is currently no national wide methodology (curve method, disaster loos data method, computer modelling methods and indicator-based methods) applied to assess the vulnerability against floods. However, if the vulnerability is understood or simplified as elements exposed (see the other subsections about vulnerability) then the Austrian risk maps consider the potentially affected elements: population, land use types, cultural heritage and industry and protection areas in the flooded areas for the different hazard scenarios. The number of potentially affected persons, i.e. those with a primary or secondary residence or workplace in the area, are displayed using a raster with a size of 125 x 125 metres. The predominant use of the areas (land use types within the floodplain) is classified as predominantly residential, industry and commerce, urban uses, agriculture, forestry and grassland, water, traffic areas, no data available. For example, for housing or as agricultural land is also assigned. Protection areas and water conservation areas within the potential flood plain are also available.

However, there are ongoing research studies, case studies and literature about physical vulnerability assessments, social vulnerability, institutional vulnerability, and climate risk and vulnerability assessments (Fuchs, S., Zischg, A. 2014; Leis and Kienberger, 2020; Papathoma-Köhle et al, 2019, 2021).

4.3.3. Exposure

In Austria, the potential flood inundation area of three scenarios (HQ30, 100, 300) are intersected with the information on buildings, population and land use data and displayed as risk maps (as above described). Further data and information layers are available through the Web-GIS of every federal, (with each federal state operating a separate one) as, for example, land use plans and local development concepts, information on historical and cultural assets, essential infrastructure and strategic structures.More information about is available data under seismic risk, Section 4.2.3. Exposure (data availability).

4.3.4. Damage and Impact indicators (damage documentation)

Red Hazard Zones are characterised as areas with high process intensity. Therefore, the risk for life has to be assumed. In Yellow Hazard Zones, significant damage to objects or infrastructure has to be expected.

Several institutions and sources across Austria, such as the Austrian Service for Torrent and Avalanche Control and protective forest policies (WLV), the Austria geological survey (GBA), Austrian meteorological service (ZAMG, s.a.), the federal administrations or the Austrian Federal Railway (ÖBB), national solidarity funds (for direct economic losses), conduct damage assessments after extreme events. The data gathered within these assessments includes mainly information on the natural process (intensity, extent, timeline) and, in some cases, information on damages to buildings and infrastructure. Furthermore, natural hazard events get documented when there is damage or disaster response. Documentation is mainly done on a regional and local level, but not on a household or parcel level (Wernhart et al., 2018).

There is an ongoing project that aims at proposing a national event and loss database that enables centralized access to harmonized event and loss information. By bringing together all relevant data providers and disciplines, CESARE (Collection, Standardization and Attribution of Robust disaster Event information 2019 - 2022) enables the co-development, proof of concepts and the experimental implementation of technical systems and interfaces, which support the public agencies BMI and BMLRT with the provision of national risk analysis reports towards the European Commission, the hazard documentation demands towards the UNISDR Sendai framework, and the evaluation of national solidarity funds information. The aim is to transform and combine data from different sources (FFG, ZAMG).

4.3.5. Tool (platform) for flood risk assessment

The online maps in water information system Austria WISA show the APSFRs and floodplains for HQ30, 100, 300, hazard maps with water depths and flow velocities, and risk indicators. The Risk maps show the potentially exposed elements of protection (people, environment, cultural assets and economy) under different hazard scenarios. For this purpose, potentially affected persons as well as forms of land use within the modelled flooded areas are shown. On this basis, it is possible to estimate the possible consequences of a specific flood event. In addition, the map shows places where special intervention is required in the event of flooding (e.g. hospitals or sources of pollution). Extreme flood events can overflow protective structures or cause their failure. In this case, a residual risk remains even in areas with existing flood protection. Maps are available at: https://maps.wisa.bmlrt.gv.at/.

Natural Hazard Overview & Risk Assessment Austria is a project by the Federal Ministry of Agriculture, Regions and Tourism and the insurance companies. The HORA risk map (http://www.hora.gv.at) offers the public a quick and easy initial assessment of their personal risk situation through the collection of publicly available hazard maps. In total, eight natural hazards can be visualised: flood, avalanche, earthquake, landslides, storm, lightning, hail and snow load.

“Naturgefahren im Wandel – Vorsorgecheck” is an innovative instrument to support communities in considering the local, individual risk to natural hazards and strengthen the risk prevention of municipalities. It is available at the following website: https://www.naturgefahrenimklimawandel.at/.

4.4. Multi-Risk assessment

Austria is currently not using a method that identifies cascading effects or the interaction of different hazards. However, it is possible to access the different hazard assessments (for different processes) for a specific point on HORA or via the federal state GIS.

With the new tool “HORA pass” (HORA, 2021), all hazards visible on the HORA platform (flood, avalanche, earthquake, landslides, storm, lightning, hail and snow load) can be displayed for any location in Austria and the area around it, which is individually selected as a radius (in metres). In a clear and easy-to-understand overall presentation, the expected intensity as well as recommendations for improving one's own precautions are provided via text explanations and a graphic (see figure 4.8). In addition, a more detailed legend is available, which provides more information about the hazard level.

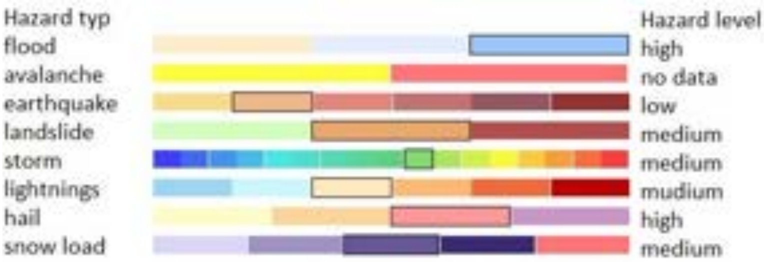


Figure 4.8: HORA PASS - Illustration of hazard levels (right column) per process/hazard type (left column) for a selected location (HORA, 2021).

5. NATIONAL RISK ASSESSMENTS FOR TURKEY IN 2020

5.1. The analysed risks

The first National Disaster Risk Assessment (NDRA) report of Turkey was prepared in 2019 for natural disasters such as earthquakes, floods, forest fires, landslides, rockfalls and avalanches. The majority of the population in our country lives in disaster-prone areas. In the risk assessment, three impact criteria, which are represented by eight impact indicators, were used (see Table 5.1). The impact criteria and indicators table were derived from the EU Staff working paper (SEC, 2010). The effects of the indicators were evaluated with a five-class system. The five classes correspond to an increasing level of seriousness: 'limited', 'significant', 'severe', 'very severe' and 'catastrophic'.

In the Risk Assessment, the following criteria are used:

1. Human life and health. The value of a human life is undefinably high. Loss of life, deterioration of health and displacement are seen as essential breaches of human value.
2. Economic values and the environment. Economic loss can have devastating effects on the well-being of people. The same applies to the loss of environment. The consequences can be long-term and hard to overcome.
3. Society's functionality. The value of families, communities, social networks and (historical) symbols are high for the functioning of people in a society. Society's identity is derived from shared artefacts, and damaging these has a high impact on the well-being.

Table 5.1: Impact criteria and indicators

Impact	
Criteria	**Indicators**
Human life and health	1.1 Number of fatalities
	1.2 Number of severely injured/ill
	1.3 Lack of fulfilment of basic needs
	1.4 Number of people who need to be evacuated
Economy and environment	2.1 Total economic impacts
	2.2 Impacts for nature and environment
Society's functionality	3.1 Disruptions to every day's life
	3.2 Loss of cultural heritage
	3.3 Loss of reputation

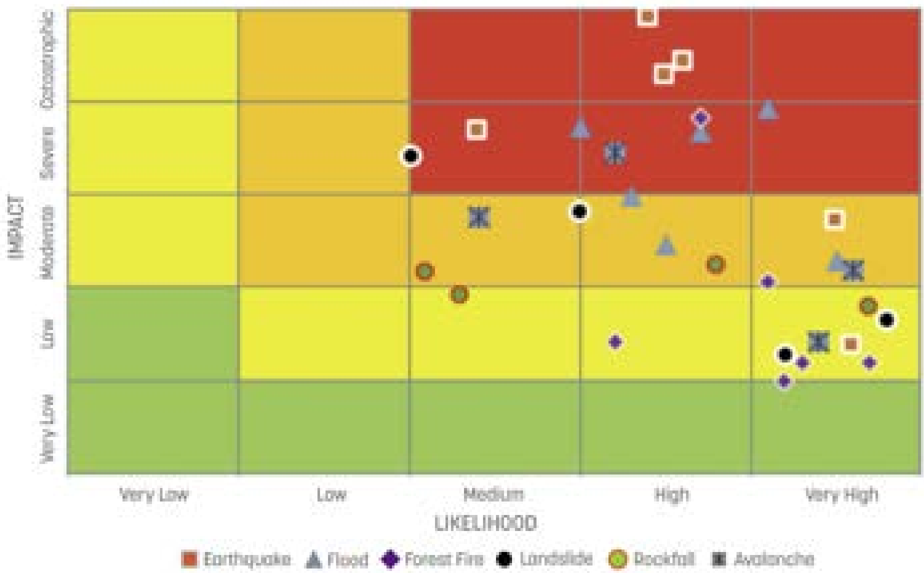


Figure 5.1: Turkey National Disaster risk matrix 2019.

5.2. Seismic risk assessment

In general, the seismotectonic structure of Turkey is defined by the westward movement of Anatolia due to the collision of the Arabian and Eurasian plates. Most of the deformations associated with this movement are located along the North Anatolian fault (NAF) and the East Anatolian fault (EAF), which are the main tectonic structures of Anatolia. On the other hand, the subduction of the African plate along the Aegean-Cyprus arc creates complex tectonic processes in Western Anatolia that include a backarc extensional regime (Bozkurt, 2001; Duman et al., 2016). With its current tectonic structure, Turkey is located in one of the most active seismic belts in the world. Since the beginning of the 20th century, 250 damaging earthquakes with magnitudes between 4.3 and 7.9 have occurred. These earthquakes caused more than 90,000 casualties and enormous economic damage. Especially the Izmit and Düzce earthquakes that occurred in 1999 led to the efforts to reduce the loss of life and economic damage caused by earthquakes in the country. One of the most important studies is the National Earthquake Strategy and Action Plan (UDSEP-2023), which was launched by AFAD in 2012. The purpose of UDSEP is to create a prepared and resilient society in reducing the risk of earthquakes and to cope with earthquakes, to establish an institutional infrastructure for this purpose and to determine the priorities of the relevant R&D activities. The main objective is to prevent or reduce the physical, economic, social, environmental and political damages and losses caused by earthquakes and to create new living environments that are earthquake resistant, safe, prepared and sustainable. Within the scope of UDSEP, the important studies aimed at reducing the earthquake risk are updating the hazard maps and the active fault maps that form the basis of hazard maps at certain periods. In this context, the active fault map of Turkey was updated by the General Directorate of Mineral Research and Exploration (MTA) in 2011 (Emre et al., 2013) and started to be used as a base for seismotectonic maps and hazard maps.

The previous Earthquake Zoning Map of Turkey, which came into effect in 1996 was updated by AFAD and published in the Official Gazette on March 18, 2018. The new map became legally effective on January 1, 2019. Different from the previous map, which shows earthquake zones, the new Earthquake Hazard Map (Figure 5.2) shows peak ground acceleration values having a 10% probability of exceedance in 50 years (a return period of 475 years). This map was prepared considering soil condition (vs_{30} = 760 m/s) and doesn't include the hazards caused by local soil conditions like liquefaction, ground amplification, subsidence, etc. In addition to the new Earthquake Hazard Map of Turkey, the data on peak ground acceleration, peak ground velocity, spectral accelerations at 0.2 sec and 1.0 sec periods with 2%, 10%, 50% and 68% probability of exceedance in 50 years was published in the Official Gazette. A GIS-based interactive web application (Figure 5.3) was developed to view and query earthquake hazard maps prepared based on this data in web environment.

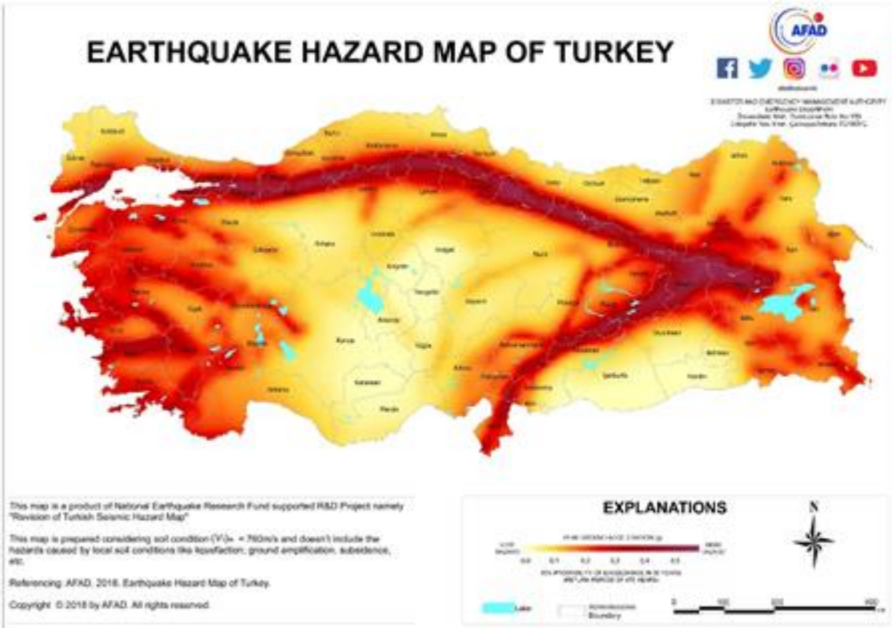


Figure 5.2: Earthquake Hazard Map of Turkey (AFAD, 2018).

AFAD Earthquake Department creates earthquake scenarios by utilizing AFAD-RED (Rapid Earthquake Damage and Loss Estimation System). AFAD-RED has been developed by AFAD Earthquake Department in collaboration with scientists with the aim of estimating potential losses of an earthquake occurring in Turkey and also for earthquake scenarios. AFAD-RED estimates potential structural damage (slight, moderate, extensive and complete), the number of casualties, the need for temporary shelter service and serviceability of critical facilities (i.e. schools, hospitals, governorship buildings etc.), transportation systems (i.e. bridges, highways, railways etc.) and lifeline systems (i.e. gas, petroleum, water and waste water lines). AFAD-RED also produces maps for seismic intensity, peak ground acceleration, peak ground velocity etc. The outputs generated by AFAD-RED are used as the basis of risk reduction, response and recovery activities.

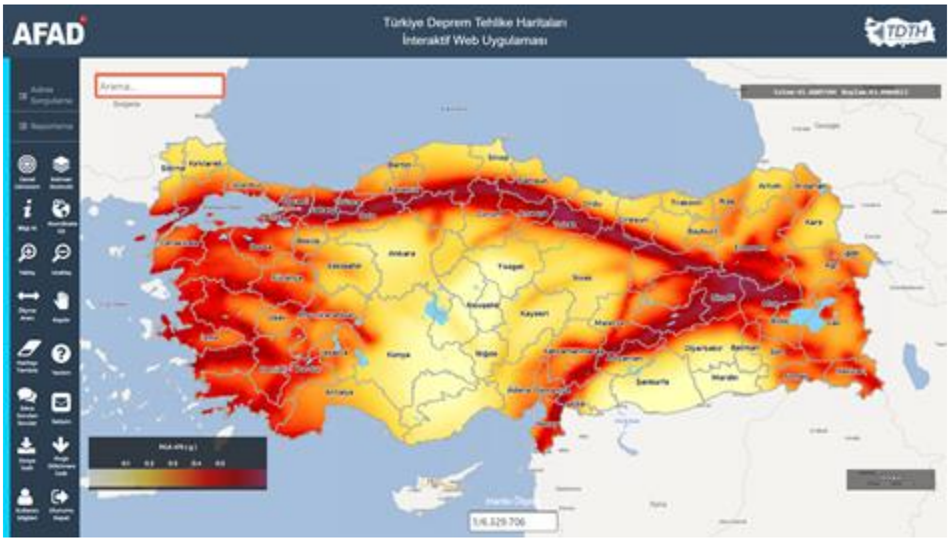


Figure 5.3: General View of "Earthquake Hazard Maps of Turkey Interactive Web Application" Interface

Within the scope of the Disaster Response Plan of Turkey (TAMP), up-to-date earthquake scenarios are created to steer capacity building and needs assessments during the preparation of national and local plans. Furthermore, earthquake scenarios involving earthquakes of different magnitudes are developed for drills at national, regional and local levels which are performed to review plans in terms of their implementation. AFAD-RED is also utilized in seismic risk assessment studies carried out for Provincial Disaster Risk Reduction Plans (İRAP), and earthquake scenarios are developed for all provinces in Turkey.

In the National Disaster Risk Assessment Report of Turkey (AFAD, 2019), two worst-case scenarios and two probable scenarios are considered. Considering the seismotectonic structure of Turkey, probable scenarios can be expected to occur in all regions containing active faults. The probable scenarios were developed by selecting only a couple of the regions in which such faults exist. The worst-case scenarios were selected from areas referred to as seismic gaps, where the main fault segments have not generated earthquakes for a long time and there is a high probability of earthquakes in the future. The locations of the İstanbul and Kahramanmaraş provinces selected for the worst-case and Muğla and Afyonkarahisar provinces for the probable scenarios are roughly shown on the seismic gap map of Turkey (Figure 5.4).

5.2.1. Hazard

The new Earthquake Hazard Map of Turkey (Figure 5.2) was prepared by the collaboration of public authorities and universities under the "Revision of Turkish Seismic Hazard Map" project supported by the National Earthquake Research Program of AFAD. The project implemented state-of-art knowledge in probabilistic seismic hazard assessment and took into account the recent studies on basic components of seismic hazard calculations (i.e. seismic sources, earthquake catalogues, ground motion prediction equations etc.). Seismic hazard maps in terms of peak ground acceleration, peak ground velocity, 5%-damped pseudo-spectral accelerations at 0.2 sec and 1.0 sec periods for a generic rock site (vs_{30} = 760 m/s) for return periods of 43, 72, 475 and 2475 years were produced. The horizontal component definition of these ground-motion intensity measures is geometrical mean.

As explained in Section 5.2, AFAD-RED is utilized for scenario-based risk assessment studies. AFAD-RED estimates seismic intensity, PGA, PGV, S_S and S_1 values and produces maps. Soil amplification is included in the calculations. An intensity map produced by AFAD-RED is shown in Figure 5.5 as an example.

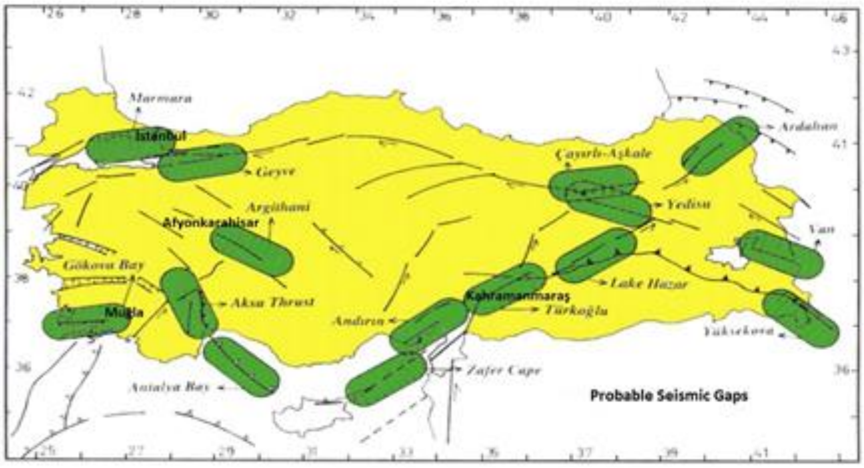


Figure 5.4: Probable Seismic Gaps in Turkey (Demirtaş and Yılmaz, 1996).

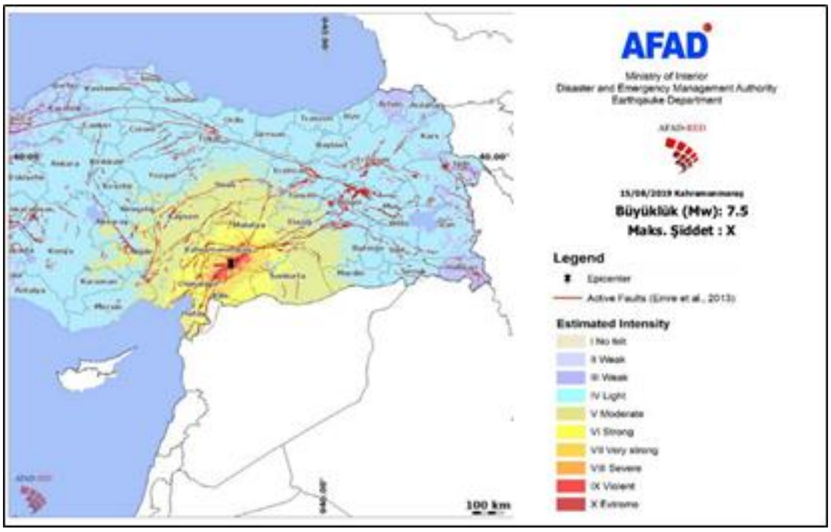


Figure 5.5: An Intensity Map Example Produced by AFAD-RED.

5.2.2. Vulnerability

AFAD-RED estimates the structural damages by utilizing spectral displacement and intensity based fragility curves (Nurlu et al., 2014). The fragility curves are defined for four damage states: slight, moderate, extensive and complete.

5.2.3. Exposure

The population and building database used by AFAD-RED is created by using data obtained from the Turkish Statistical Institute. The available database contains the number of buildings and population in each neighbourhood/village in Turkey. In general, the database is updated every year. The data are not publicly accessible.

5.2.4. Damage and Impact indicators

Regarding the indicators for the impact of disasters on human life and health used in the National Disaster Risk Assessment Report of Turkey (AFAD, 2019) as shown in Table 5.1. The outputs of AFAD-RED can be utilized when evaluating effects of these indicators. AFAD-RED estimates numbers of slightly, moderately, extensively and completely damaged buildings. It then estimates the numbers of outpatients, slightly injured people, severely injured people and life loss as well as the number of people who need temporary shelter depending on the estimated number of people in these buildings and the damage level of the buildings.

5.2.5. Tool (platform) for seismic risk assessment

As explained in Section 5.2, AFAD Earthquake Department creates earthquake scenarios by utilizing AFAD-RED (Rapid Earthquake Damage and Loss Estimation System). AFAD-RED system estimates potential losses in the disaster area after an earthquake in Turkey. The system is integrated with the National Earthquake Observation System operated by AFAD. Following an earthquake AFAD-RED automatically provides near real-time estimation of losses in the earthquake-affected region. The system also enables to perform manual secondary analyses by revised earthquake parameters, focal mechanism solutions, strong ground motion data etc. The AFAD-RED system can also be utilized to run earthquake scenarios by manual data entry. AFAD-RED uses several databases such as administrative information (country, province, district and neighbourhood boundaries), information on population, buildings, critical facilities, transportation systems, lifeline systems, geology (active faults), USGS vs_{30} map data, vs_{30} information from AFAD acceleration stations and so on. Different attenuation relationships are defined. AFAD-RED allows to choose more than one attenuation relationship and give a weight to each one. It uses fragility curves for the estimation of structural damage. As the main outputs, AFAD-RED estimates structural damage (slight, moderate, severe and complete), serviceability of critical facilities, transportation systems and lifeline systems, the number of casualties (outpatients, slightly injured, severely injured, life loss), the number of people who need temporary shelter. It also produces estimated seismic intensity, peak ground acceleration, peak ground velocity etc. maps. The software has regularly been updated due to new calculation methods, revisions in databases, and technological developments (Figure 5.6).

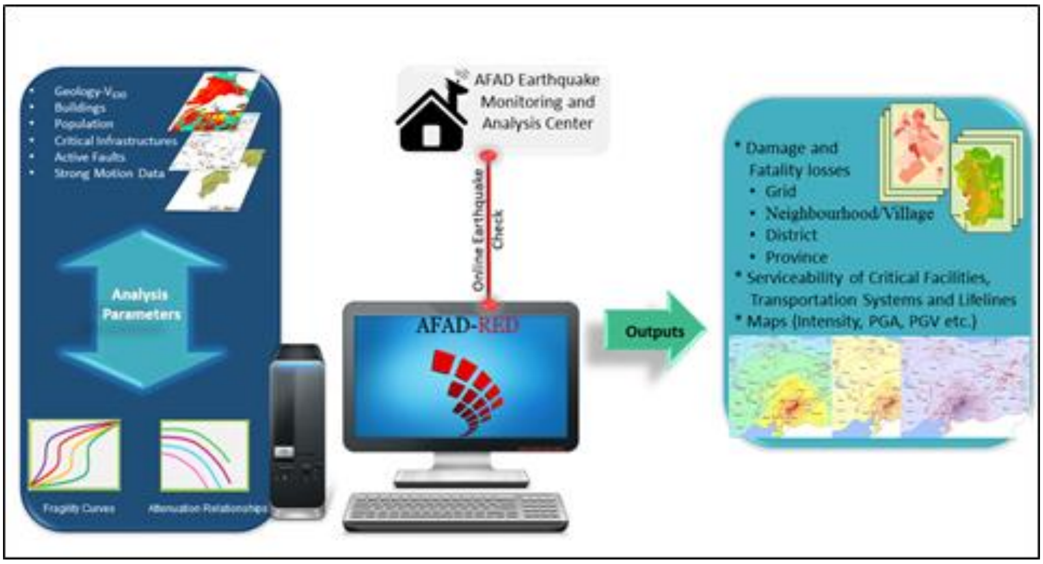


Figure 5.6: Working Principles of AFAD-RED.

5.3. Flood risk assessment

Turkey has started implementation and the transpose of the EU Floods Directive (2007/60/EC) as well as works for preparation of flood hazard maps, flood risk maps and flood risk management plans for river basins in 2013. The implementation of the Floods Directive is under the responsibility of the Ministry of Agriculture and Forestry (MoAF), General Directorate (DG) of Water Management. The legislation of the Floods Directive has been prepared and transposed at a national level. Moreover, The National Action Plan for EU Accession of Turkey includes an action plan regarding flood management and foresees a by-law on Preparation, Implementation and Monitoring Flood Management Plans which was published in 2015. DG Water Management of MoAF has been working intensively in the flood management field to transpose and implement the Floods Directive, which is also in line with the above-mentioned objectives/actions.

Capacity Building to İmplement Floods Directive has started with the project ‘Implementation of the flood Directive in a pilot basin, namely Batı Karadeniz (Western Black Sea) Basin’ in 2012. The project was completed at the end of 2014. DG for Water Management was beneficiary of the project. France (leading partner) and Romania were the partners in the project and were in close cooperation with the Republic of Turkey. The project had three components:

- Enhancing juridical capacity and improving technical and institutional capacity at adequate level.
- Implementation of the Floods Directive in a pilot basin, namely Batı Karadeniz Basin, aiming at decreasing adverse effects floods compared to the 1998 floods.
- Development of National Implementation Plan for the Floods Directive in Turkey through Regulatory Impact Assessment Methodology.

The Plan has advised that Turkey has had to start to implement the Floods Directive. Hence, the national authorities and the EU have worked closely to achieve full alignment of the national legislation to the EU acquis communautaire. Within the current period of IPA II (2014–2020), the EU implements the second seven-year multiannual programme for Environment and Climate Action and provides assistance in funding for projects aimed at improving environmental protection by addressing the challenges of climate change, environmental management for sustainable development and disaster management with strong emphases on flood risk management. The flood and drought management and plans for adaptation to the climate change and sectoral water allocation are considered as the fields that need to be supported by the Programme. Additionally, ensuring of experienced staff and specialised institutions capable of implementing Water Framework Directive (WFD) and specific directives complementary to WFD, harmonisation of directives, appropriate planning and smooth implementation of plans will be ensured.

Consequently, the implementation of Floods Directive in Turkey in a wider spatial scale has been started during the mentioned twinning project on Floods Directive and the preparation of flood management plans have been started in Turkey in 2013. While the first flood management plan has been finalized in 2015 (for Yeşilırmak Basin) and as of July 2021, the flood management plans have been finalized in 23 out of 25 basins. Flood management plans are still ongoing for 2 basins.

By the end of 2023, the flood management plans for all basins in Turkey has been planned to be finalized. Additionally, in accordance with Article 18 of the EU Floods Directive, process has been initiated for reviewing and updating Flood Management Plans in 4 River Basins which were completed in 2016.

The preparation of flood risk management plans for the basins in Turkey included the following actions:

- Undertaking the preliminary flood risk assessment;
- The preparation of the flood hazard maps;
- The preparation of the flood risk maps;
- The preparation of flood risk management plans (including risk management measures);
- The Revision of existing Flood Warning System as Flood Forecasting & Early Warning System and extension of coverage to the basin scale in line with the relevant articles of the Floods Directive.

The implementation of the plans is carried out in the following steps:

- Preliminary Report: Introduction to watershed, socioeconomics, land use, water resources, historical floods, methodology, and database studies.
- Interim Report: Preliminary Assessment of Flood Risks
- Interim Report: Hydrology Studies, Preparation of Basin Flood Metadata Catalogue
- Interim Report: Hydraulic Modelling, Preparation of Flood Hazard Maps
- Interim Report: Preparation of Flood Risk Maps
- Flood Management Plan: Flood Risk Prioritization Studies, Determination of Measures

In addition, all the information produced within the scope of the plans is published via web site and GIS based portal developed or enhanced during the projects. The main aim of these plans is to identify and assess flood risks in the basins and the sub-basins and to reduce the negative impacts of floods on human health, the environment, cultural heritage and economic activities. The aims to achieve the following objectives in FRMP's are:

- Reducing the negative impacts of floods on human health, environment, cultural heritage, social and economic activity;
- Planning flood management at basin scale;
- Ensuring that the organizations work together in a coordinated manner before, during and after the flood based on the institutional powers and responsibilities of the flood management;
- Increasing public awareness about floods;
- Ensuring more efficient use of financial resources;
- To clearly determine responsible and relevant institutions and organizations in flood management;
- By achieving these objectives, in the Tigris Sub basin;
- Supporting sustainable development;
- Maximizing the benefits of flood plains;
- Reducing the loss of life and property;
- Protecting the environment, historical and cultural heritage are aimed.

Finalized flood management plans are monitored with six months' intervals through monitoring portal. The FRMP's plan undertaken include as proposed by the EU-FD:

- Definition of the basin;
- Undertaking the pre-evaluation of flood risk;
- Preparation of flood hazard maps;
- Preparation of flood risk maps;
- Undertaking the flood risk evaluation;
- Identifying the flood management activities;
- Preparation of the measures table (PoMs);
- Application, monitoring and update;
- Undertaking cost-benefit analysis.

5.3.1. Hazard

Flood hazard assessment in Turkey has a certain approach that follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling with recurrence intervals (return period) of 50-, 100- and 500-years. Flood hazard maps indicating the flood inundation area, flow water level or depth and flow water velocity in case of flood according to three flood return periods (Q50, Q100, Q500) are generated. An example of a flood hazard map for 500 years return period flood is shown in Figure 5.7.

Flood Hazard Maps are prepared to define Hazard Rate by classifying in 4 different classes (Table 5.2) using the following Hazard Rating formula: *[water depth x (flow velocity +0.5)] + Debris factor* (van Alphen and Passchier, 2007).

Table 5.2: Criteria for determination of flood hazard classes (fluvial flooding)

Very High	**High**	**Medium**	**Low**
at calculated hazard rating > 2.50	at calculated hazard rating between 1.25–2.50	at calculated hazard rating between 0.75–1.25	at calculated hazard rating < 0.75

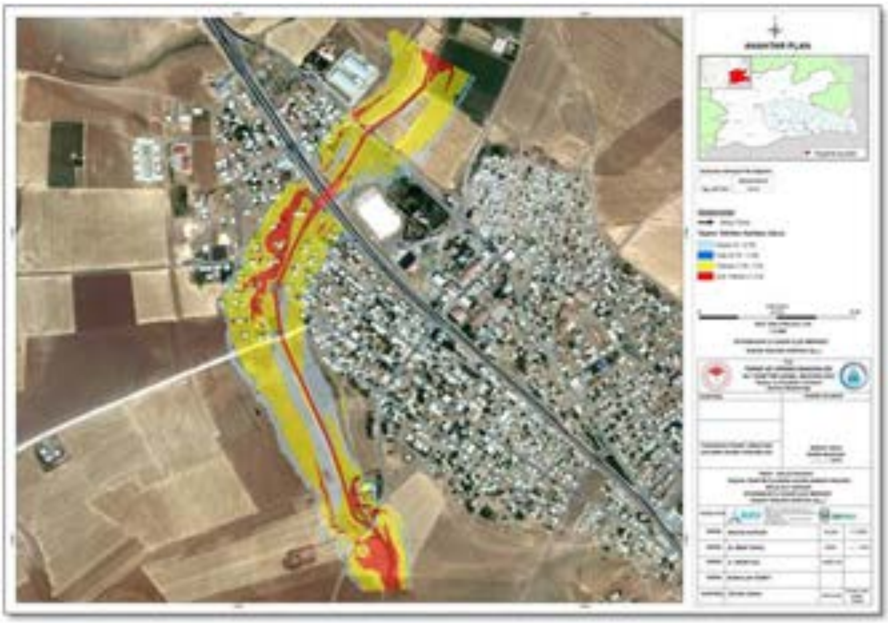


Figure 5.7: An Example of Flood Hazard Map (Q500) in 4 level hazard classification: Red represents very high, yellow represents high, dark blue represents medium and light blue represents low - Town of Diyarbakır in The Euphrates, Tigris Basin.

Flood Risk Pre-Assessment processes include the determination and assessment of potential flood risk through a quick scanning by using all the available data such as historic floods, meteorological and hydrological data, geological data, land cover, and soil maps. To find areas susceptible to flooding, at least one methodology is used (e.g., Alluvium field method). Other data like development plans, schools, mosques, hospitals, flood control facilities, and industrial facilities are also obtained for further studies in flood management plans.

Studies shall begin with data needs assessment based on existing data provided by DG Water Management and required data sets for preparation of PFRA in EU practices. A list of data set to be collected from the relevant stakeholders shall be prepared for the approval of the end recipient.

The data collection study covers gathering, organization and evaluation of all required data. These data shall cover at least:

- Negative effects of past floods on human health, environment, cultural heritage and economic activities;
- Topography, the route of streams and rivers, natural water retention areas, floodplains, soil groups, vegetation;
- General hydrological and geological characteristics of the basin;

- Existing manmade infrastructures natural features to mitigate flooding impact;
- Land use information; population, location of settlement areas, economic activity areas, strategic structures, cultural heritage building and protected areas;
- Legal framework and existing administrative structures for preparation prevention and recovery phases.

Preliminary Flood Risk Assessment in line with Article 4 of the EU-FD shall be undertaken by assessing past floods in the basin and their adverse effects, identifying possible floods in the future and their possible adverse effects, and defining risk areas through evaluation of the results of these studies.

Multi-Criteria Decision-Making (MCDM) method is used to compare and analyze the flood risk in a basin. A theory of tangible criteria measurement was proposed by Saaty. The weight of the criteria is evaluated through pairwise comparison matrices. The method supports the decision-making process by quantifying alternative priorities for decision-makers. Therefore it is a powerful and flexible technique to support setting priorities and improving decision-making processes (Figure 5.8).

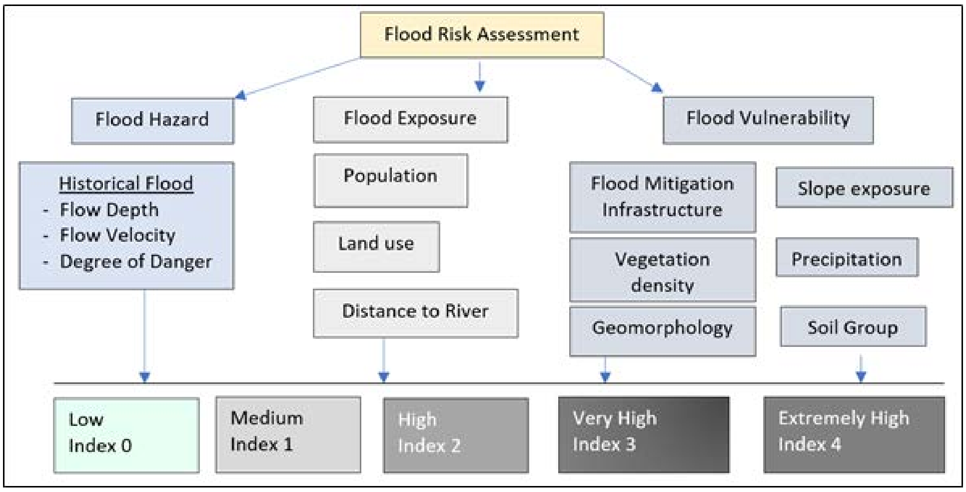


Figure 5.8: The hierarchy framework for flood risk assessment of a basin

Eight parameters for flood risk management evaluation criteria comprising hydrological, topographic and geomorphological features of the basin and economic, social, environmental aspects are to be taken into account which are hydrological and geomorphological features of basin, vegetation density, slope of topography, historical events, dwelling density, existing flood mitigation infrastructure along with social and economic activity (see Figure 5.9).

The possible flood risk will be assessed through 1D modelling for the selected major rivers and parts of the catchments:

1. The River Reaches covered by the Law No. 4373 on “Protection Against Flood and Inundation” published in the Official Gazette, No. 5310 on 21/1/1943;
2. The first, second and third highest ranks on the Strahler stream order, which are used to define the stream size based on a hierarchy of tributaries, are to be identified for flood modelling (the Horton – Strahler Method), as the scope of the PFRA.

3. Areas with landslide risk that may cause flooding will also be determined, based on the available data and observations, and will be included in the studies.

All studies defined in this activity shall be carried out and submitted in GIS environment. In the PFRA study, previous flood mitigation measures will be taken into consideration. Flood risk areas shall be shown both on the map and in list form that includes settlements, streams, agricultural, and industrial areas. The list shall include all assessed areas with their explanations of why they are defined as under risk/not under risk.

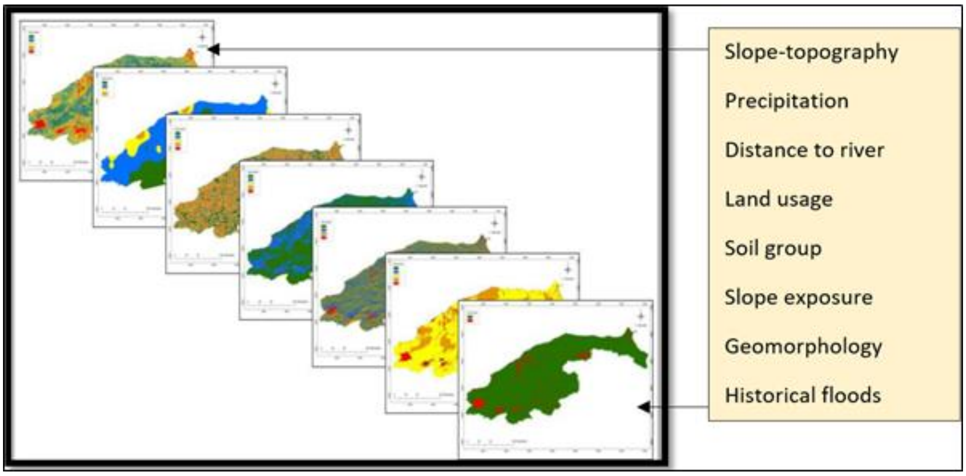


Figure 5.9: End Product with Multi-Criteria Decision-Making (MCDM) method: framework for flood risk assessment (Source: Flood Risk management Plan for Batı Karadeniz)

5.3.2 Vulnerability and exposure

The flood exposure and vulnerability for the flood risk assessment is the analysis of the potential negative impacts of flood based on freely available spatial databases providing data about people, environment, cultural heritage and economic activities, see Table 5.3.

PFRA and Multi-Criteria Decision-Making Model - The Analytical Hierarchy Process for PFRA is considered as typology.

5.3.3. Damage and Impact indicators

The main purpose of assessing flood risk is to ensure the safety of life, support flood management decisions, minimize the damage to private sector infrastructure, commercial and other economic activities. These measures will be taken against flood with certain return period. Below mentioned criteria are considered in the flood risk assessment study:

– Population affected by the flood;
– Damage caused by the flood to the buildings and their contents;
– Affected strategic structures and infrastructure;
– Overall effects of the flood.

For all three flood return periods (Q_{50}, Q_{100}, Q_{500}) for the flood prone areas, a total of 9 maps were generated for each study area as followed by using “Flood Inundation Maps”;

- Population affected by flood maps (Figure 5.10): The affected population from potential flood is identified and Q_{50}, Q_{100} and Q_{500} flood risk maps are prepared for the settlements showing low, medium and high risk areas. In addition, the number of people exposed to floods will be calculated for settlements in street base.
- Flood economic damage maps (Figure 5.11**)**: Economic damage in the Q_{50}, Q_{100} and Q_{500} flood prone areas, based on flood damage-depth curves (developed by the Directorate General Joint Research Centre, DG-JRC) considering buildings, commercial facilities, industrial facilities, transportation/cars, infrastructure/length of roads and cultivated lands will be given as layers in GIS environment and showing the degree of risk as low, medium and high. In addition, annual expected average damage will be calculated for APSFR. The GIS base map as shown in Figure 3 shall be prepared.
- Flood risk maps (Combined effect) (Figure 5.10): The flood risk may be greater for the strategic structures and treatment plant, buildings such as schools, hospitals, worship places, policlinics, child care and aged care homes whose residents may be much more vulnerable during a food event. Hence, the risk factor shall be taken greater, by consulting to the stakeholder, compared to the for those areas and the risk map shall be prepared in accordingly.

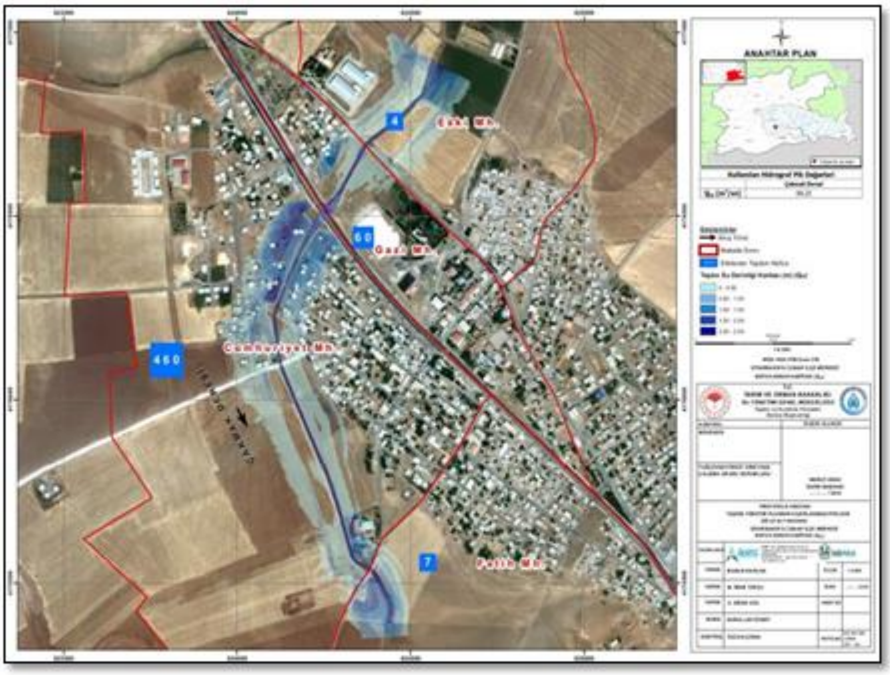


Figure 5.10: Flood inundation map for Q_{500} with the number of population affected from flooding- *Town of Diyarbakır in The Euphrates – Tigris Basin*

Table 5.3: Infrastructure classification according to the vulnerability

Essential infrastructure
Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk.
Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood.
Highly vulnerable
Police stations, ambulance stations and fire stations and command centres and telecommunications installations required to be operational during flooding.
Emergency dispersal points.
Schools, worship buildings, kinder gardens, age care and nursing homes
Basement dwellings.
Caravans, mobile homes and park homes intended for permanent residential use.
Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as "essential infrastructure")
More vulnerable
Hospitals.
Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels, worship buildings, kinder gardens, age care and nursing homes
Buildings used for dwelling houses, student halls of residence,
Non–residential uses for health services, nurseries and educational establishments.
Landfill and sites used for waste management facilities for hazardous waste.
Sites used for holiday and camping, *subject to a specific warning and evacuation plan*
Less vulnerable
Buildings used for shops, financial, professional and other services.

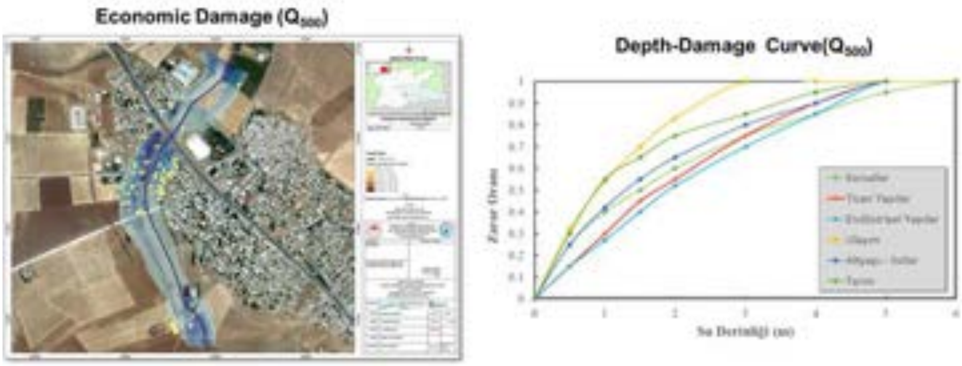


Figure 5.11: Economic loss map for Q_{500}-flood – Town of Diyarbakır in The Euphrates – Tigris Basin.

5.3.4. Tool (platform) for flood risk assessment

Flood Risk Management Plan (FRMP) is the management plan which includes the measures to be taken for risk management in areas that are under the risk of flood by considering flood risk pre-assessment, flood hazard and flood risk maps. FRMPs include a table of very concrete and detailed measures, mainly on rehabilitation of the riverbed and rearrangement of road crossings. Moreover, all measures are prioritized. Also, for each measurement, a cost-benefit analysis is made.

A WEB application software based on GIS is developed to provide public access to the project results. Flood hazard maps and flood risk maps are presented through the application. In this way, it will be ensured that public institutions, organizations and people will be aware of the flood risk, and it will help to minimize flood damage and loss of life. The application can be reached through the following link: http://taskinyonetimiportal.tarimorman.gov.tr/.

The purpose of this plan is to organize all works required for preventing and/or reducing financial loss and intangible damages to arise for the human life, property, environment, natural, historical and cultural assets as a result of a possible flood in the catchment and the coordination among the institutions.

With this plan, it is possible to improve the administrative and technical capacity of reducing the negative consequences of the floods, to better coordinate the different groups, including local authorities, industrialists, farmers, the tourism sector, etc., to increase the awareness, including the general public. At the same time, the requirements of EU Floods Directive will also be fulfilled.

Furthermore, roles and responsibilities, method, basic principles and rules are also established for preventing or mitigating the damages of flood within the catchment and for ensuring that in case of flood, the required interventions as well as recovery activities required after the flood are conducted by the relevant divisions timely and effectively.

5.4. Multi-risk assessment

No multi-risk assessment study has been performed within the National risk assessment.

6. NATIONAL RISK ASSESSMENTS FOR MONTENEGRO IN 2020

The Report on Disaster Risk Assessment for Montenegro is currently under development through the project "Development of National Risk Assessment for all types of hazards affecting Montenegro", (ECHO/SUB/2020/TRACK1/831677) of the European Commission, the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO). Ministry of the Interior - Directorate for Emergency Management coordinates the project. The project started with the implementation on December 15, 2020. The deadline for the completion of project activities is December 15, 2021. This is the first time that this type of document is developed for Montenegro. The overview of the Disaster Risk Assessment for Montenegro will be given here in a volume that corresponds to what has been done so far.

6.1. The analysed risks

The National Disaster Risk Assessment for Montenegro (under development in 2021) encompasses 9 risk types: geological risks (earthquakes, landslides), climate change, floods, forest fires and open fires, infectious human diseases/epidemics, infectious plant diseases/epiphytes and infectious animal diseases/epizootic diseases, technical-technological accidents, radiation/nuclear accidents, critical infrastructure protection. For all risk types, a deterministic risk assessment method based on selected scenarios is used.

The consequences of risks are divided into three categories, which deal with the impact on (i) people, (ii) economy and environment, and (iii) society. Impact on people takes into account the number of fatalities, the number of injured and relocated people. Economic and environmental impacts represent the sum of the costs of disruption of economic activity, repair costs of facilities, public transport system and infrastructure, environmental restoration costs and other costs related to environmental protection (or environmental damage), the cost of immediate or long-term protection and rescue measures, the cost of health care and damage to cultural heritage. These types of impacts are expressed as a percentage of gross domestic product (GDP). Social impacts include categories such as disturbances in everyday life, disruption in functioning of government and administrative institutions as well as other factors that are considered important and cannot be measured individually.

The level of consequences for a given scenario is characterised by five categories from 1 to 5. Consequence level 1 corresponds to insignificant consequences (not more than 50 fatalities, the injured or relocated people and economic losses lower than 3% of the GDP). However, consequence level 5, which indicates the most severe consequences, corresponds to equal to or more than 1500 fatalities and evacuated people and economic losses higher than 15% of the GDP. The scenario likelihood is also characterised by a level from 1 to 5. Likelihood level 1 represents events with a frequency of 1 realized event in 100 years or less, while likelihood level 5 corresponds to events with a frequency of 1 realized event per year or more often.

In accordance with the guidelines of the European Commission, scenarios are presented in a matrix in order to make it easier to present and compare different risks. The risk matrix (5 x 5) as a visual tool gives a direct insight into the risk and a separate matrix for each category of impact is developed. The matrix consists of two axes, consequences and probabilities, each with five values, which gives a matrix of 25 fields. These 25 fields are divided into four risk categories: low, moderate, high and very high.

6.2. Seismic risk assessment

The National Risk Assessment for Montenegro (Ministry of the Interior - Directorate for Emergency Management Montenegro, 2021) is based on a deterministic scenario approach for seismic risk estimation. Two scenario earthquakes are considered: 1) Scenario 1 - most likely adverse event (earthquake with a return period of 95 years corresponding to a probability of exceedance of 10% in 10 years) and 2) Scenario 2 – the event with the worst possible consequences (earthquake with a return period of 475 years corresponding to a probability of exceedance of 10% in 50 years) both located at the same area with the highest level of seismic hazard. Only direct consequences of earthquakes, i.e. damage to buildings and the impact on people, are considered, whereas domino effects, e.g. floods, fires or explosions, are neglected in the risk assessment. The used seismic risk assessment methodology is in accordance with the Risk Assessment and Mapping Guidelines for Disaster Management of the European Commission (SEC, 2010). The damage to buildings and impact on people is expressed based on the EMS-98 scale, which includes five discrete damage states (D1–D5).

The overall seismic risk is expressed descriptively as small, medium, high or very high. The level of risk is obtained from the consequence level and the likelihood level. The likelihood level is determined based on seismic hazard (see paragraph 2.5.2.1), whereas the consequence level is obtained as the mean of three values, which indicate the impact on (i) people, (ii) economy and environment, and (iii) society (see paragraph 2.5.2.4). Moderate seismic risk is estimated for Scenario 2 that is an event with the worst possible consequences, where the earthquake epicentre is located in the south coastal region of Montenegro (Ulcinj municipality). Scenario 1, the most likely adverse event with the epicentre in the same region as Scenario 2, is associated with high seismic risk.

6.2.1. Hazard

Two earthquake scenarios are considered in the seismic risk assessment, both of them located in the region with the highest seismicity according to the seismic hazard map of Montenegro. The location of the epicentre for both analysed scenarios is the coastal area near the Municipality of Ulcinj (41.922N, 19.058E) with a focal depth of 10km. The assumed event of both scenarios is during the summer season in the month of August at night (2 a.m.) at the peak of the tourist season. The selected intensity measure is in accordance with the European macro-seismic scale (EMS-98). Epicentre intensity is IX for Scenario 1 and X for Scenario 2, which corresponds to return periods of 95 and 475 years or 10% probability of exceedance in 10 years and 10% probability of exceedance in 50 years. These probabilities correspond to Level 1 and Level 2 on the national accident risk matrix, respectively, i.e. insignificant and small. The distribution of expected earthquake intensities at rock level was calculated using the Software "Analysis" (Glavatovic, 2015), based on a numerical model for reduction of earthquake intensity as a function of magnitude and hypocentre distance. For the consequence analysis, only regions with estimated intensities of VI or more are considered, which covers all territory of Montenegro for Scenario 2 and the south and central regions of Montenegro for Scenario 1. The distribution of seismic intensity on the terrain surface is calculated by multiplying the values at rock level by the amplification coefficient at the discrete number of points. The amplification coefficient is determined based on micro-seismic zoning of urban areas of Montenegro. At the locations not covered by micro-seismic zoning, the amplification coefficient was determined by analogy in the soil structure.

6.2.2. Vulnerability

The vulnerability model for residential buildings is based on EMS-98 methodology: buildings are divided into six vulnerability classes from A to F. For each vulnerability class, the occurrence rates of the designated damage states (D1–D5) are specified for each degree of the EMS-98 intensity. The classification of buildings to vulnerability classes is done based on expert judgement and available census data: year of construction.

6.2.3. Exposure

Since systematized data on the exposure model for buildings in Montenegro are not available, SERA exposure model for Montenegro is used (Crowley et al., 2020a). SERA model is based on expert judgement and available census data of Montenegro from 2011. Useful information for vulnerability classification extracted from census data are year of construction, the number of dwellings, dwelling areas and population number (all publicly accessible). The number of exposed cultural heritage buildings, healthcare facilities, facilities for educational institutions and energy infrastructure facilities are also analysed, but their damage is not estimated. Data for this analysis are extracted from the National Plan for Protection and Rescue of Earthquakes (NPPRE, 2018).

6.2.4. Damage and Impact indicators

As explained in Section 6.1, the consequences of earthquakes in the National Risk Assessment are divided into three categories: impact on (i) people, (ii) economy and environment, and (iii) society. All three categories are assigned a number from 1 to 5 based on different indicators.

The impact on people is estimated by calculating the number of fatalities, injured and relocated people. The number of fatalities, injured and relocated people are calculated by estimating damage in residential buildings according to the EMS-98 methodology using a night-time scenario and SERA exposure model. The number of people that need to be relocated is associated with building damage state D4 and D5. The number of fatalities and injured people is estimated using the HAZUS model for four levels of injuries. Besides residential population, impact indicators are also calculated for tourists. For example, less than 50 fatalities, injured and relocated people suggest consequence level 1, 50 to 200 consequence level 2, 201 to 500 consequence level 3, 501 to 1500 consequence level 4 and more than 1500 suggest consequence level 5.

The impact on the economy is estimated based on economic losses. The calculated indicators are: cost of restoration of residential buildings (estimated based on damage level and value of building stock in affected municipalities – HAZUS model), costs of healthcare (based on the average cost of a hospital day treatment for the more severely and lightly injured), cost of immediate or longer-term emergency measures (estimated by expert judgement), costs of restoration of public transport systems and infrastructure (costs are calculated based on HAZUS model), cultural heritage (estimated based on data from Montenegro earthquake 1979), costs of environmental restoration (estimated by expert judgement) and costs of disruption of economic activity (estimated based on data from Montenegro earthquake 1979). Less than 3 % GDP relates to consequence level 1, between 3-5 % GDP to consequence level 2, between 5-10 % GDP to consequence level 3, between 10-15% to consequence level 4 and more than 15 % to consequence level 5.

Consequences for social stability include categories: the impact on services provided by the government and administrative bodies - the duration of downtime, the impact of non-functioning critical infrastructure on everyday life, psychosocial impacts, impacts on internal political stability and public order, impacts on foreign policy and the international position of the state. The total category of impact is determined as the average of all considered impacts (considered number of impacts is 8). Situational descriptions are provided for each level and the categories from 1 to 5 are assigned for each description.

6.2.5. Tool (platform) for seismic risk assessment

The Report on Disaster Risk Assessment for Montenegro is currently under development. Therefore, tools or platforms for seismic risk assessment are not yet available.

6.3. Flood risk assessment

The EU Floods Directive (Directive 2007/60/EC) has been fully transposed into the Montenegrin legislative system through the Law on Waters and the Role book on the detailed content of the preliminary flood risk assessment and the flood risk management plan. The current legislation in this area provides the preparation of a preliminary flood risk assessment, identification of areas significantly affected by floods, development of flood hazard maps and flood risk maps for areas significantly affected by floods for three return periods (low probability T >>100 years, medium probability T~100 years and high probability T=10–50 years) and development of flood risk management plans for areas significantly affected by floods. Having in mind the fact that the implementation of the EU Floods Directive (Directive 2007/60/EC) is at an early stage, also missing data, as well as a lack of capacity (organizational, personnel and technical) and the fact that the Water Information System has not yet been established, Montenegro requested a transitional period until the end of 2024, for the full implementation of the Floods Directive.

There is currently no cadastre of water infrastructure in Montenegro. The cadastre of water facilities and systems will contain data on the category of water facility, water area, catchment area, sub-basin, water body, the location (cadastral parcel and cadastral municipality), ownership relations, issued water acts and the functional condition of the facility (certificate). In order to implement the EU Floods Directive (Directive 2007/60/EC), a preliminary register of flood protection infrastructure has been prepared for both river basins in Montenegro (Danube basin and Adriatic basin), and it will be used to establish a cadastre of water facilities and flood protection systems.

As National Risk Assessment for Montenegro is still developing, here is given more detailed description, under the evaluation period. In the end, National Risk Assessment for Montenegro will be prepared in accordance with EU guidelines for national risk assessment.

National Flood Risk Assessment for Montenegro is scenario-based. The considered scenarios are based on events that have already occurred in the past, and their frequency and/or consequences distinguish them from other registered flood events. Based on these scenarios, critical areas are defined, which are characterized by the highest flood risk relative to the rest of the territory of Montenegro.

Scenarios for two basins will be processed:

a) Danube basin:

- Most likely adverse event;
- The event with the worst possible consequences;

b) Adriatic basin:

- Most likely adverse event;
- The event with the worst possible consequences.

Danube basin: Most likely adverse event

The area of the city of Berane is one of the most endangered by floods in the Danube basin. The frequency of floods is high. It is also important to mention the high sensitivity to floods that occur as a result of climate change. Extreme rainfall causes water spills from the mainstream channels and causes floods of a local character. These floods fall into the category of sudden (flash, torrential) floods, and they are characterized by a fast flood wave, whose response is up to 6 hours from the occurrence of intense precipitation. Taking into account the characteristics and frequency of floods, for the scenario of the most probable adverse event, the floods from November 2016 were taken as an event that is probable and realistic and that may occur in the near future. The floods in the basin of the river Lim in November 2016 were one of the biggest. Heavy rain that lasted for three to five days led to a state of natural disaster in almost all municipalities of that area.

Danube basin: The event with the worst possible consequences

The floods from the period November–December 2010 in the territory of the Lim river basin, from Plav to Bijelo Polje, were selected. The scenario of the event with the worst possible consequences for the Lim Basin will be presented through the actual event that occurred in 2010. Although in the period of thirty hours (November 30–December 1), which preceded the catastrophic floods in that area, about 50 l/m^2 of rain fell (which is not a record amount of rain for this area), catastrophic floods occurred. One of the main reasons was the antecedent soil saturation due to precipitation during November. The second is the sudden melting of snow. During November, the penetration of the cold front caused snowfall and the formation of snow cover in the higher mountain areas, up to 50 cm high. This was followed by the penetration of warm air mass, which on the last day of November and the beginning of December caused an increase in air temperature and a sudden melting of the snow cover. The third reason that also contributed to this flood scenario is the long-term deforestation in this area.

Adriatic basin: Most likely adverse event

Based on the analyzed flood events in the area of Skadar Lake, it can be seen that floods that affected the area of Skadar Lake in 2018, have been frequent in the last period. The occurrence of floods similar to the ones from 2010 until today has been registered in 2013, 2018, and 2021.

Adriatic basin: The event with the worst possible consequences
The floods on Skadar Lake and Bojana from November and December 2010 were chosen as the event with the worst possible consequences.

Within National Risk Assessment for Montenegro, the consequence assessment was done:
- consequences for human life and health;
- consequences for the economy;
- consequences for social stability - total material damage to critical infrastructure;
- consequences for social stability - total material damage to institutions/buildings of public social importance.

In accordance with the guidelines of the European Commission, the processed scenarios are presented in a matrix in order to make it easier to present and compare different risks.

6.3.1. Hazard

In order to define criteria and parameters used for risk calculation, must be kept in mind that hazard is mainly a function of the: return time, water depth and water velocity. The current legislation in Montenegro provides the preparation of a preliminary flood risk assessment, identification of areas significantly affected by floods, development of flood hazard maps and flood risk maps for areas significantly affected by floods for three return periods:
- T >>100 years, low probability of occurrence;
- T~100 years, average probability of occurrence;
- T=10-50 years, high probability of occurrence.

The deficiency of systematized data on flood events, causes and damages makes it difficult to review them historically. The analysis of the occurrence of floods on the territory of Montenegro has shown that the available data on flood events before 2010 are either incomplete or do not exist at all.

In the absence of official data, information found in various media (print media, television, municipal websites, Government website/reports) was also used. Data from 2005 can be found on the website http://www.desinventar.net, regarding the floods in Montenegro. However, on this site, some events are described on the basis of information from the media, which are uncertain.

Reducing the risk of floods on the entire territory of the country is a permanent task and goal while improving the protection of the most important centres of damage (cities, settlements, businesses, traffic infrastructure, etc.) and works and measures on interstate watercourses are priority activities.

6.3.2. Vulnerability

In the National Risk Assessment for Montenegro, vulnerability is defined for scenarios considered (Danube basin: Most likely adverse event, The event with the worst possible consequences; Adriatic basin: Most likely adverse event, The event with the worst possible consequences). Vulnerability is given through additional descriptive information on this parameter, for every scenario, for example:

Danube basin: Most likely adverse event

- Households located in the village "Riverside" are the most vulnerable due to constant damages caused by a high frequency of floods.
- Inhabitants of rural and suburban areas experience severe devastation of their estates and erosion of fertile soil when the water surface elevation of Lim is high.
- Lack of drinking water due to contamination caused by floods and possibility of contagion outbreak.
- Rural households and their residents get cut off from their main administrative centre, the city of Berane.
- The river Bistrica took away part of the new regional road Berane - Lubnica. The bridges on these rivers were endangered by the high water levels of Lim and Bistrica.
- The water supply system of Berane municipality was damaged.

Danube basin: The event with the worst possible consequences

- The population that was simultaneously exposed to floods and their consequences was the most vulnerable in the entire area. The long-term consequences also posed a danger to human health.
- The infrastructure was drastically damaged by these phenomena, which required high investments for rehabilitation and caused the impossibility of the normal functioning of all segments of life for a longer period of time.
- Residents of rural and suburban settlements, whose properties and part of the fertile land are devastated when water levels on the Lim and its tributaries are high.
- Lack of proper drinking water due to flood pollution and the possibility of an outbreak.
- The floods that occurred during this period caused huge damage to infrastructure facilities: bridges, main and rural roads, water and electricity networks.

Adriatic basin: Most likely adverse event

The floods that occurred in this period caused huge damage to infrastructure facilities: main and rural roads, water and electricity systems.

- The population that was simultaneously exposed to floods and their consequences is the most vulnerable in the entire area. The long-term consequences also posed a danger to human health.
- Infrastructure is often out of use with these phenomena, and in the long run the impossibility of normal functioning of all segments of life is significant.
- Residents of rural and suburban settlements, whose properties and fertile land are devastated whenever the water surface elevation of Skadar Lake gets high.
- Lack of proper drinking water due to flood pollution and the possibility of an outbreak.

Adriatic basin: The event with the worst possible consequences

- Population, agriculture, infrastructure, economy

6.3.3. Exposure

Constant or periodic floods, high levels of groundwater endanger the area of about 26,000 ha of land. Most of the land that is endangered by floods and other types of excess water is located in the southern part of Montenegro or in the area that is in the Adriatic basin (Figure 6.1). Large areas of land along the coast of Skadar Lake, zone of the lower watercourse of the Morača river, as well as the area near Bojana are the most flood-endangered areas in Montenegro. In addition to this, floods in Polimlje from Gusinje to Zaton (Figure 6.2), near Kolašin and Mojkovac, as well as in the valley of Ćehotina river, near Pljevlja, are of great importance.

Figure 6.1: Montenegro rivers in Adriatic basin.

Figure 6.2: River Lim with its tributaries (Danube basin).

Floods in Montenegro are manifested differently depending on the characteristics of the watercourse that causes floods. Along the valleys of most rivers, settlements, industrial plants and agricultural areas are endangered by short-term flood hydrographs. These water flows are characterized by considerable longitudinal slopes, high water velocities when flood waves occur, as well as significant amounts of suspended sediment and bedload. Along the streams, canyons alternate, sometimes very deep, with expansions - valleys, where settlements and industrial facilities are located, as well as traffic infrastructure. Agricultural areas located in these valleys, although relatively unassuming, are of great importance for agricultural production because the total resources of agricultural land in Montenegro are very limited. Due to such a concentration of goods in the valleys and the damage caused by floods, even on a relatively small scale, can be significant. It should be noted that floods, which occur due to considerable discharge of the mainstream, are very often superimposed with floods that occur from torrential tributaries and that it is often very difficult, if not impossible, to separate these two phenomena. Also, the consequences of floods along these flows are accompanied by changes in the morphology of the river bed, especially its meandering. This is the reason for which floodplains change their position and size.

6.3.4. Damage and Impact indicators

Damage and Impact indicators (number of affected people, population density, description by sex, age, persons with disabilities, etc.) are given for every considered scenario in the National Risk Assessment for Montenegro:

Danube basin: Most likely adverse event

- The number of households in the flooded areas is about 200. The estimated population is 1276.

Description of the consequences and events caused by the main event:

- Damage to residential buildings (flooded and partially damaged over 100 buildings).
- Damaged and permanently taken away agricultural land and plantations on them. The area of agricultural land that was permanently removed was 7.6 ha, and partially damaged 8.9 ha. Loss of domestic animals from endangered farms (1 cow, 6 goats and 5 pigs).
- Damage to small businesses (fishponds, destroyed water intake of the Buča pond in the length of 70 m. about 300 kg of dead fish (or taken away), 15000 young fish and about 500 kg of fish for consumption.
- Removed and damaged fruit seedlings - about 180 seedlings of continental fruit and 1000m of raspberry plantations.
- Flooded and destroyed bulky fodder (hay) about 9,900 kg.
- Damaged road infrastructure.
- Damaged bridges.
- Damaged city water supply.

Danube basin: The event with the worst possible consequences

The number of inhabitants is 2140, and the number of houses endangered by floods in the municipalities in the analyzed area is 422.

Description of the consequences and events caused by the main event:

In the entire area, leaving homes-evacuation, major damage to infrastructure (bridges, roads, water and sewage network, electricity network, etc.), damage to individual facilities have resulted in long-term dysfunction of all segments of society, for a long time, damage to agriculture land.

Adriatic basin: Most likely adverse event

The number of endangered facilities in this area is 599, and the total number of endangered populations is 2,040 people.

Description of the consequences and events caused by the main event:

In the whole area, leaving homes, damage to infrastructure (roads, water and sewage network, electricity network, etc.), damage to individual facilities have resulted in long-term dysfunction of all segments of society for a long time.

Adriatic basin: The event with the worst possible consequences

The number of inhabitants - 3857 and the number of houses endangered by floods in the municipalities in the analyzed area – 422.

Description of the consequences and events caused by the main event:

- interruption of inter-municipal roads and damage to main, local and rural roads;
- interruption of electricity supply;
- damage or destruction of a number of commercial buildings;
- disturbances in water supply and sewerage facilities
- damage to a large number of family, housing, agricultural and economic facilities;
- interruption and difficult supply of food for the population;
- problem in supplying the population in remote areas.

6.3.5. Tool (platform) for flood risk assessment

The Institute of Hydrometeorology and Seismology of Montenegro, in accordance with the Law on Hydrometeorological Affairs, is a centre for observation, measurement, collection, processing, analysis and dissemination of hydrological data and information. The Institute provides hydrological information to all entities in charge of flood defense, sends data for international exchange, on the basis of international conventions and on the basis of signed cooperation, as well as the media. At the WEB presentation of the Institute http://www.meteo.co.me, hydrological data from all stations from the observation network are available to users. Automatic stations record water levels every 15 minutes, and they can be read on the Institute of Hydrometeorology and Seismology of Montenegro website.

On its website, The Institute of Hydrometeorology and Seismology of Montenegro also posts warnings-meteorological alarms on extreme meteorological conditions that can be expected in certain parts of the country or in certain regions based on the forecast. Figure 6.3 below shows a map with a network of hydrological stations in the Adriatic basin and the Danube.

6.4. Multi-Risk assessment

The multi-risk assessment has been considered in the National risk assessment at the level of comparison of risks associated with different hazards. The infectious human diseases/epidemics risk was evaluated as very high for both scenarios considered. The seismic risk and climate change risk was evaluated as high and moderate, the flood risk as moderate and high and the radiation/nuclear accidents as low and moderate for most likely adverse event and event with worst possible consequences, respectively.

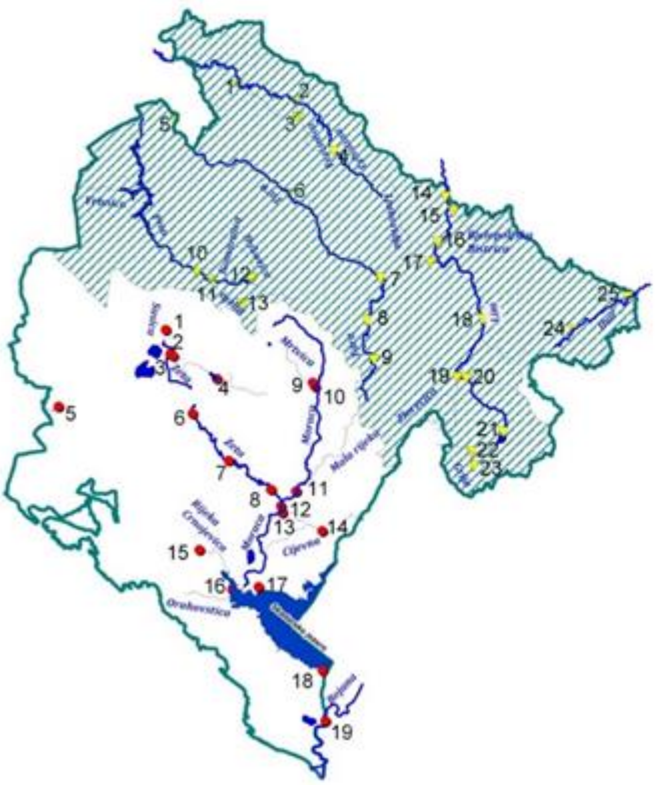


Figure 6.3: Hydrological stations (HS) network in the Adriatic and Danube basins.

7. DISASTER RISK ASSESSMENT IN EU PROJECTS

In this section, the selected European projects that addressed seismic, flood risk and multi-risk are presented to provide the basis for comparison of risk assessments at the national state-of-practice and the EU research and development level. For the seismic risk (Section 7.1), the SHARE and SERA projects are described, while for the flood risk (Section 7.2), the ANYWHERE project and two Interreg projects are presented. In addition, a description of the STREST project, which dealt with multi-risk assessment at quite a comprehensive level, is provided (Section 7.3). Moreover, the IPA DRAM and RASOR projects are presented in Section 7.3 as projects that dealt with multi-risk assessment.

7.1. Seismic risk assessment

The **SHARE** (Seismic Hazard Harmonization in Europe) project was a collaborative project in the cooperation programme of the Seventh Framework Program of the European Commission (Grant Agreement No. 226967).

The SHARE project was funded in order to provide an updated community-based seismic hazard model for the Euro-Mediterranean region (Woessner et al., 2012). The primary goal of SHARE was to build a framework for probabilistic seismic hazard assessment (PSHA) across all disciplines with a close cooperation of leading European geologists, seismologists and engineers and to provide integration across national borders without the burden of political constraints and administrative boundaries.

The project's main achievement is the 2013 Euro-Mediterranean Seismic Hazard Model (ESHM13) (Woessner et al., 2015), which provides a complete assessment of seismic hazard and associated uncertainties and was computed using the OpenQuake hazard engine (Pagani et al., 2014). It consists of more than sixty time-independent ground motion hazard maps for various ground motion intensities, from PGA to spectral acceleration at periods up to 4 seconds. The model uses harmonized and homogenized data from national, regional and site-specific PSHAs from across Europe. Based on these data, comprehensive hazard relevant databases were prepared, e.g. the SHARE European Earthquake Catalog with more than 30,000 earthquakes in the period 1000–2007 and the European Database of Seismogenic Faults with approximately 1200 mapped active faults. Additionally, a new model to estimate the maximum earthquake magnitude expected across Europe and a new strong ground-motion model were proposed.

The ESHM13 model is based on three time-independent earthquake source models to describe the expected future earthquake activity in different regions; an area source model, smoothed background seismicity and a fault source model based on active faults. The ESHM13 model includes all events with magnitudes of 4.5 and higher in the computation of hazard values, which are referenced to a rock velocity of vs30=800m/s. To capture the epistemic uncertainty in ground-motion prediction, a logic tree for the selection of best suited ground motion prediction equations (GMPEs) with associated weights was prepared for different tectonic regimes based on input data and expert judgment. Fourteen GMPEs were included in the logic tree based on a pre-selection from over 250 published GMPEs. For example, for stable continental regions, five GMPEs with even weights of 0.2 are proposed to be used for ground motion prediction.

The Euro-Mediterranean Seismic Hazard Model was meant to be used as a reference for future risk assessments, e.g. for energy infrastructures and within the insurance sector, and for the revision of the European building code EC8.

The **SERA** (Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe) project was a European project of the Horizon 2020 Research and Innovation Programme (Grant Agreement No. 730900).

The SERA project aimed to reduce the risk posed by earthquakes based on innovative research and development projects. During the project, a probabilistic seismic risk model has been developed, i.e. the European Seismic Risk Model (ESRM20). ESRM20 combines an update to the Euro-Mediterranean Seismic Hazard Model (ESHM13) (Woessner et al. 2015) with a new model for site amplification at the European scale, an exposure model covering 44 countries, and a wide range of vulnerability models for the building classes in the exposure model.

The seismic hazard model is used to develop stochastic catalogues of earthquakes. For each earthquake in the catalogue, amplified ground motions are simulated at the location of buildings in the exposure models by making use of newly developed ground motion models (Weatherill et al., 2020a) together with estimates of the site amplification as a function of the topography and geology (Weatherill et al., 2020b; SERA Deliverable D26.4, 2019a). The exposure model describes the spatial distribution of the residential, industrial and commercial buildings, and provides an estimate of their replacement cost and occupants at different times of the day (Crowley et al., 2020a). The buildings are further classified in terms of key attributes, including construction material, design level, and number of storeys. A study into the spatial and temporal evolution of design codes across Europe over the past century has been used to better classify the seismic design levels of the building stock (Crowley et al., 2021). All of the source data and developed models have been made openly available, with a creative commons license (CC-BY) at the repository created by Crowley et al. (2020b).

The vulnerability models developed within the SERA project describe the probability of loss conditional on a level of ground shaking. Analytical vulnerability models have been developed using capacity curves for a large number of building classes. A simulated MDOF design is assumed based on seismic design codes across Europe. Nonlinear dynamic analyses of an equivalent SDOF model are then used to obtain fragility functions. As part of the SERA project, a set of capacity curves for European reinforced concrete infilled frames and moment frames has been recently developed following a simulated design of prototype frames (SERA Deliverable D26.5, 2019b). A total of 264 reinforced concrete classes have been identified by combining different numbers of storeys (1 to 6), seismic design code levels (no code: CDN, low code: CDL, moderate code: CDM, high code: CDH) and lateral force coefficient levels (0, 5, 10, 15, 20, 25, 30 % of the weight of the structure). All models are available with creative commons licence (CC-BY) from the open repository created by Romão et al. (2021).

The main risk metrics provided by the European Seismic Risk Model are the average annualised human and economic losses, probable maximum loss and risk maps providing losses for different return periods. The risk metrics are currently being calculated using the OpenQuake-engine, open source software for hazard and risk assessment (Pagani et al., 2014; Silva et al., 2014). They will be released by the European Facilities for

Earthquake Hazard and Risk (EFEHR) (www.efehr.org) in the third quarter of 2021 through its risk services (https://maps.eu-risk.eucentre.it/).

7.2. Flood risk assessment

Due to the fact that overall, flood events cause huge economic damage across the territory of EU and its neighbouring countries, and since an important component of the Floods Directive implementation is also the exchange of information, there was a considerable number of EU projects related to flood risk assessment and management. The most comprehensive overview of the past and the ongoing projects can be found at: https://ec.europa.eu/environment/water/flood_risk/links.htm.

The **ANYWHERE** project (EnhANcing emergencY management and response to extreme WeatHER and climate Events; Grant agreement No. 700099) aims at establishing a pan-European platform on extreme climate risks that will enable to identify, in a number of geographic regions, critical situations that could lead to loss of life and economic damages. Such early-warning should contribute to improved protection measures and, in case of catastrophic weather situations, ameliorate the coordination of rescue operations which is of high importance in areas which are known to be exposed to high flood or multi-hazard (ANYWHERE, 2018). ANYWHERE proposes to implement a Pan-European multi-hazard platform providing a better identification of the expected weather-induced impacts and their location in time and space before they occur (ANYWHERE, 2019). This platform supports faster analysis and anticipation of risks prior the event occurrence, an improved coordination of emergency reactions in the field and help to raise the self-preparedness of the population at risk. Therefore, the ANYWHERE project concentrates on improving pro-active emergency response but doesn’t cover different approaches for flood or multi-hazard risk assessment.

Some projects related to flood risk management and assessment were also implemented in the river basins included in the Boris Project. Among more recent Interreg projects, in the scope of the Danube International Programme, the University of Ljubljana was a partner in the project **DAREFFORT** (Danube River Basin Enhanced Flood Forecasting Cooperation). The project aims to explore the current status of the national flood forecasting abilities where partners and the stakeholders could derive the common goals in order to develop the existing flood forecasting system in an inclusive way, therefore improve the forecasting system of the areas exposed to flood risk. Another project, **DANUBE FLOODPLAIN** (Reducing the flood risk through floodplain restoration along the Danube River and tributaries), was recently finished. The main activities of the project were: updating the floodplain areas inventory and their ranking using the Floodplain Evaluation Matrix-FEM; assessing the efficiency of floodplain projects in the Danube District and developing tools for increasing the knowledge and cooperation of experts, practitioners, decision-makers and stakeholders on floodplain restoration which could contribute to flood risk reduction.

7.3. Multi-risk assessment

The **STREST** (Harmonized Approach to Stress Tests for Critical Infrastructures Against Natural Hazards, Grant Agreement No. 603389) project was one of many EU-funded projects that addressed multi-risk assessment.

The main goal of the STREST project was to develop a harmonized approach to stress tests for critical infrastructures against natural hazards. This goal was achieved by developing the following tools and methods:

- Methods to harmonize the treatment of uncertainties and the mechanics of risk assessment (e.g. Marzocchi et al., 2015);
- Methods to consistently quantify the occurrence of low probability-high consequence events (extremes, cascading effects) and schemes to introduce them in hazard and risk evaluations (e.g. Mignan et al., 2016);
- Consistent taxonomy of different classes of critical infrastructures (CIs);
- Probabilistic models for the hazard, vulnerability and consequence assessment (e.g. Iervolino et al., 2015; Mignan et al., 2016; Selva et al., 2016; Casotto et al., 2015; Babič and Dolšek, 2016);
- A grading framework enabling the evaluation and communication of natural hazards risk (Babič and Dolšek, 2019);
- Probabilistic structural and systemic performance models (stress tests) to determine the losses in CIs, and their susceptibility to cascading effects that may amplify these losses, as well as interdependencies among different CIs (Esposito et al., 2020);

The methodology for the risk assessment was defined at multiple levels. At the lowest level, the risk was assessed for each component of the CI separately, while at the higher levels, a systemic risk assessment was performed. The risk assessment was either time-based or scenario-based and addressed a single hazard or multiple hazards simultaneously.

The STREST project focused on earthquakes, tsunamis, geotechnical effects and floods, and on three principal CI classes: (a) individual, single-site, high-risk infrastructures, (b) distributed and/or geographically extended infrastructures with potentially high economic and environmental impact, and (c) distributed, multiple-site infrastructures with low individual impact but large collective impact or dependencies.

The stress test methodology developed within the STREST project was applied to six different CIs (Argyroudis et al., 2020): a petrochemical plant in Italy, a system of large dams in Switzerland, a system of hydrocarbon pipelines in Turkey, a gas distribution network in the Netherlands, a port in Greece and a system of industrial buildings in Italy.

In the area of Western Balkans and Turkey, the Programme for Disaster Risk Assessment and Mapping (**IPA DRAM**) was implemented between 2016 and 2019 (IPA DRAM, 2019). The programme was financed by the European Commission – Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO). The need to further strengthen capacities in the field of civil protection and general risk management in this region, and coordination both within the region and with sister agencies in EU countries, was recognised by EU Member States and the European Commission through dedicated projects within the Instrument for Pre-accession (IPA). The IPA DRAM programme aimed at enhancing the capabilities of the partner countries to strengthen disaster risk management by creating an open platform for the development and improvement of national disaster loss databases, enhancing the coherence among the national systems and methodologies, and consistency with existing EU regulations, guidelines and good practices.

The main goal of the project was to improve the capacities of partner countries in natural disaster risk management. In particular, IPA DRAM was carried out through three thematic areas: disaster risk assessment; disaster loss data (for the analysis of damage data that help to understand the patterns according to which a natural disaster may occur—an area of work carried out in accordance with the Sendai Framework for Disaster Risk Reduction); and, finally, risk mapping. National disaster risk management systems require the development of all three technical components to be effective and in line with the programme results framework. As such, all activities are strongly connected to the disaster loss data (DLD) activities in order to enhance the use of DLD in the definition of the risk scenarios at the basis of disaster risk assessment (DRA) and to the development of a proper catalogue of maps that would also visually represent the created scenarios and the risk conditions on the territory, ultimately contributing to the future development of the Electronic Regional Risk Atlas (ERRA).

The Rapid Analysis and Spatialization Of Risk (**RASOR**) project (Grant agreement No. 606888) developed a platform to perform multi-hazard risk analysis to support the full cycle of disaster management, including targeted support to critical infrastructure monitoring and climate change impact assessment. RASOR adapted the newly developed 12m resolution TanDEM-X Digital Elevation Model (DEM) to risk management applications, using it as a base layer to interrogate data sets and develop specific disaster scenarios. RASOR overlays archived and near-real time very-high resolution optical and radar satellite data, combined with in-situ data for both global and local applications. The RASOR platform enables to combine hazard, exposure and vulnerability for a broad range of hazards including flooding, storm surge, earthquakes, landslides, tsunamis and volcano eruptions. The tool enables assessment of specific scenarios, for example for high, medium and low likelihood of occurrence for certain disaster types and to assess the effect of a changing drivers, e.g. climate change or land subsidence.

A scenario-driven query system allows users to project situations into the future and model multi-hazard risk both before and during an event. The query system enables the managers to determine the extent of hazard (e.g. flooding) in each area and determine, for example, the risk pending on Critical Infrastructure Systems in terms of their residual functionality as a basis for a systemic vulnerability analysis. Additionally, the developed platform allows managers to use real scenarios when determining new mitigation or prevention measures, and integrate new, real-time data into their operational system when organizing response activities.

One of the aims of the RASOR project was to develop models for flood hazard assessment based primarily on satellite data (RASOR, 2016). The flood models produce flood hazard maps (inundation depths and maximum flow velocities) that are delivered to the RASOR platform for visual inspection and overlays with other hazards and geographical information. The RASOR platform enables the user to combine the flood hazard with exposure maps and vulnerability functions to further assess the total flood risk.

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