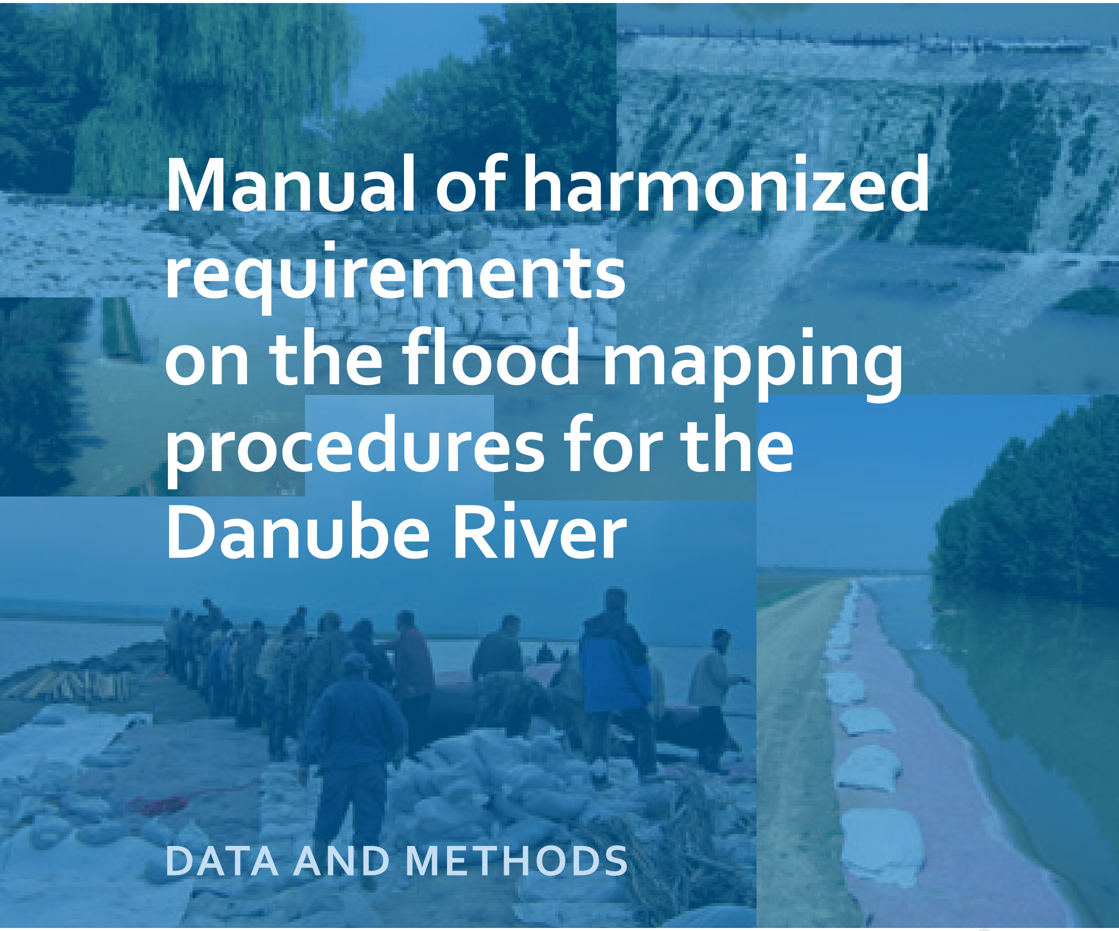
SOUTH EAST EUROPE
Transnational Cooperation Programme

Danube FLOODRISK

Programme co-funded by the EUROPEAN UNION



Manual of harmonized requirements on the flood mapping procedures for the Danube River

DATA AND METHODS

Jointly for our common future

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Foreword

Climate change poses major challenges to all parts of the European Union and will require specific responses as outlined in the European Commission's White Paper of April 2009. Extreme weather phenomena are likely to occur more frequently across Europe and therefore also in the Danube Region. Since water plays a crucial role in the region (as the territory coincides with the hydrological basin of the second largest river in Europe), we can anticipate that these phenomena will lead to increased flood hazard and risk along the Danube Floodplain, induced by water level variations which will have direct consequences on the citizens and businesses of the region.

All the countries of the Danube Region expressed their common intention to strengthen cooperation in responding to natural catastrophes such as massive floods. These events have a negative impact on natural landscapes and biodiversity, but also result in loss of life and damages to economic activities. Flood prevention is therefore of particular importance.

The EU Floods Directive provides a legal framework for a coordinated approach to assessing and managing flood risks. This means that Flood Protection Action Plans need to be formulated at sub-basin level, ultimately to lead to the adoption of a single Danube-wide Flood Management Plan. The Ministerial Declaration adopted by the Danube countries in the framework of their cooperation on water management state that "flood prevention and protection are not short term tasks but permanent tasks of the highest priority". The Declaration commits the signatories to "develop one single international Flood Risk Management Plan based on the ICPDR Action Programme for Sustainable Flood Protection".

The frequency and severity of floods on the one hand, but also of drought, icing and water scarcity on the other hand, are likely to present major challenges in the coming years, in the context of climate change adaptation.

In this context, the Danube Floodrisk Project has reveived an European Union Strategy for the Danube Region Label from the Priority Area 5. Many Danube authorities at national, regional and local levels, as well as civil society, have highlighted the importance of Danube Floodrisk Project and its results of the cross-country cooperation – a set of unified hazard and flood risk maps produced for the Danube floodplains, which will provide the basis for adequate risk management and planning activities. This can only happen through increased harmonization of data. The elaborated methodology, presented in this Manual, will be tested via three pilot projects for the implementation of concrete measures at local level, based on the produced maps, and further detailing local action plans for flood risk management, including development of the informational systems; improved tools for priority setting and cost-benefit assessment for the development of infrastructure adapted to extremes, capacity building, adaptive institutions, policy cohesion and mobilization of financing are the main elements for further planning the pilots activities. The two approaches, one control and the other resilience oriented, should be integrated, to allow balancing of equity, environmental and economic priorities, including soft and hard response at the community, national and river basin levels; here, at transnational level, ICPDR have the lead role by integrating all measures, in Flood Protection Action Plans, which will be continuously updated. The Danube Floodrisk Projects brings the needed support by elaborating the harmonized methodology by a large stakeholders' consultation, which required the collaboration of many institutions, from state services and administration, as well as active participation of inhabitants. The measure of the flood risk management effectiveness is given by the proper response of citizens and administrations which are aware of the danger and know what to do, respect the land planning rules, and build/expend the local warning systems in areas particularly susceptible to flooding.

The Manual has turned out to a needed publication, clearly assessed favorably by recipients. Particular thanks for this initiative are due to the ICPDR, to the Ministry of Environment and Forests of Romania which is the Project Lead Partner, and to representatives of project partners, mainly from research institutions as UBA – Austria, Via Donau – Austria, Vituki – Hungary, ISPRA – Italy, UTCB, and INCDD – Romania. Many thanks to all 24 partners' representatives from the Danube Basin, especially from Slovakia, Bulgaria, Serbia and Croatia for their good collaboration in harmonizing data and methodologies. We all appreciated collaborating with CESEP Romania, for their involvement, as well as with the main German consultants Geomer and INFRASTRUKTUR & UMWELT Professor Böhm und Partner.

Mary-Jeanne Adler, Ph.D.
Project Manager

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I. Project partners

MEF – Ministry of Environment and Forest (RO)
UBA-A – Federal Environment Agency Austria Ltd. (AT)
VD – via donau, Austrian Waterway Company (AT)
MOEW – Ministry of Environment and Water (BG)
UACEG – University of Architecture, Civil Engineering and Geodesy – Sofia (BG)
VKKI – Central Directorate for Water & Environment (HU)
VITUKI – Environmental Protection and Water Management Research Institute (HU)
DEF – Danube Environmental Forum (HU)
ISPRA – Higher Institute for Environmental Protection and Research (IT)
TUCEB – Technical University of Civil Engineering of Bucharest (RO)
RWNA – "Romanian Water" National Administration (RO)
DDNI – "Danube Delta" National Institute for Research and Development (RO)
CESEP – Centre for Environmentally Sustainable Economic Policy (RO)
SWME – Slovak Water Management Enterprise, state enterprise (SK)
CroWa – Croatian Waters, Legal entity for water management (HR)
IJC – "Jaroslav Cerni" Institute for the Development of Water Resources (RS)
JVP SV – Public Water Company „Srbijavode" (RS)
JVP VV – Public Water Management Company "Vode Vojvodine" (RS)
MAFWM – Ministry of Agriculture, Forestry and Water Management (RS)
RHMSS – Republic Hydrometeorological Service of Serbia (RS)

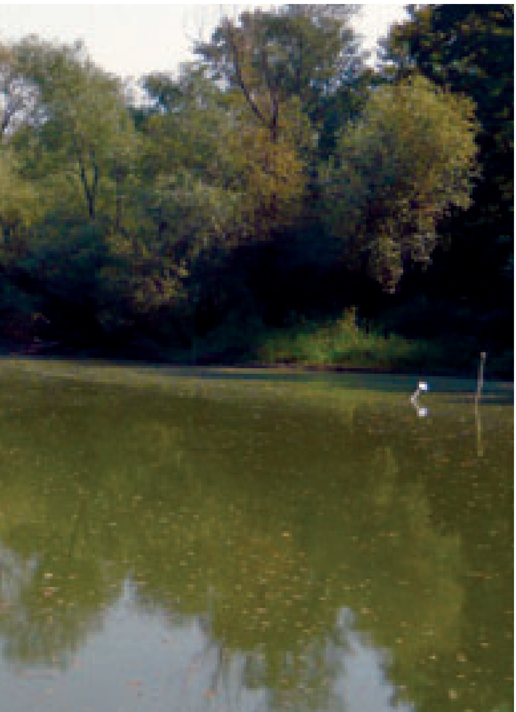
Observers
ICPDR – International Commission for the Protection of the Danube River (AT)
JRC – European Commission - DG Joint Research Center (IT)
BfG – Bundesanstalt für Gewässerkunde (DE)
LfU – Bavarian Environmental Agency (DE)
RPT BWL – Regional Council Tübingen (DE)

2. Introduction

The European Floods Directive is a driving force for many national, as well as international flood risk mapping activities, yet in some aspects it still does not define the map production procedure and expected results in every detail. Furthermore, due to the different actors involved in flood risk management and the different environmental, legislative, administrative and economic situation many different requirements exist. This manual aims to find a common interpretation of these different requirements.

Not all aspects of the EU Floods Directive can be addressed in this manual, as the Danube Floodrisk project only covers the hazard and risk mapping part, and possibly some examples of flood risk management plans, in certain pilot catchments. Nonetheless, although there is a focus upon the production of maps on the scale of a large river catchment (scale 1:100 000), the manual still considers as much as possible the needs and problems of the tributaries.

A large part of this manual covers the harmonisation process, including the specification of the goals, and tackles various technical questions relating to the scenario definitions, methods used, accuracy threshold and so forth. The basis for the description of harmonized products are the national laws of the project members, the European Floods Directive and good practice results from different flood risk mapping projects as well as existing maps or atlases.



3. Summary of good practice from other risk mapping projects

3.1. Rhine Atlas

"The target of the atlas [...] is to draw the attention of the citizens affected along the Rhine and in the Rhine valley to this residual risk. This atlas is part of the Rhine Action Plan and is a further development of the Rhine Atlas on ecology and flood protection published in 1998, representing maps of the inundated areas and the areas of ecological importance in the Rhine valley. [...]

The new Rhine Atlas represents potential areas at risk of inundation and the related possible damages. It is thus a data basis and a basis for measures within the first and the *third performance target of the Action Plan on Floods under implementation. The atlas invites to consider further measures supporting the target of reducing the residual risk. [...]".*

According to the Rhine Atlas (2001), distinction must be made between two cases:

Protected areas with a high level of protection - with respect to these surfaces, floods are mainly a risk in connection with dyke breaches, which mostly limits the area hit. This mainly applies to the Upper Rhine, the Lower Rhine and the Rhine delta. Along the French-German Upper Rhine between Basel and Iffezheim,

flood protection works protect against floods up to a recurrence interval of 1 000 years. In the Rhine delta, flood protection even covers statistic recurrence intervals between 1 250 and 10 000 years. Since the locations of dyke breaches cannot be determined in advance, the entire surface area lying below the river water level must be regarded as flood prone area. This amounts to the hypothesis that the dykes do not offer any effective protection. On the whole, this hypothesis is highly unlikely, but the risk of individual dyke breaches must be taken account of. The representation of both the flood risk and the potential damage highlights the most unfavourable situation of each surface share and thus represents the envelope for different extreme events. It thus represents the protection effects of the dykes.

Unprotected areas or areas with a low level of protection - in cases of extreme floods, low lying areas along a river section are hit. This largely applies to the High and Middle Rhine. Along these river sections, the surfaces represented may be flooded during one single event, which as far as dyked surfaces are concerned, is only probable on a local scale.

Since the monetary assessment is highly uncertain, indications are limited to orders of magnitude. The rough scale of 1:100 000, which is unsuitable for planning precise local projects, is however suitable for the targeted overview representation. Particular attention has been paid to the representation of the consequences of potential extreme floods by indicating the possible flood depth for these events, while as far as comparably frequent events such as floods with a recurrence interval of 10 or 100 years are concerned, only the outer limits of the surfaces effected are indicated. Life-threatening damages are caused by very rare events, when water levels overtop the dykes or the stability of dykes is threatened by sustained pressure. Until they occur, such damages are normally not believed to be possible. The Atlas represents the worst case flood depth at any given point and it must be taken into account that one and the same event cannot hit all surfaces represented along the entire Rhine, as the effects of retention and cutting the crest make floods downstream more unlikely. Thus, the Rhine Atlas does not represent the flood situation liable to occur due to a certain event along the entire course of the Rhine. The maps rather represent a synthesis of many possible extreme events, the most unfavourable flood situation for any given point and thus the threat posed to any individual and not the overall threat. This overall view is based on a statistic assumption; factors related to time are not taken into account.

3.2. Atlas of Saxony

For the first time hazard indication maps for the complete area of a German state were produced based on a unified methodological approach. The printed atlas at 1:100 000 scale comprises of 36 pairs of maps showing flood hazard and damage potential. In addition to the low land rivers methodology, where flood hazard is shown as a function of inundation depth, the river stretches of the mountainous areas show the hazard by indication of specific discharge, which is the product of inundation depth and velocity.

For the damage assessment different damage functions are provided for each of these regions. To calculate the maximum damage both approached were used for the calculation and the maximum of them was used for the map representation.

Also, for the first time in a large-scale mapping project critical infrastructure facilities like hospitals or power plants are displayed. This provides addition risk information for emergency, as well as regional, planning.

3.3. Elbe-atlas, ELLA-project

The flood hazard indication maps show the inundation depths for an extreme flood scenario ($HQ_{extreme}$), and the outline of the 100 year flood. Both scenarios were calculated without consideration of flood protection measures, such as levees. The maps show the overlay or summation of the possible flood events. Thus, the areas shown will never be flooded all at the same time, even in the case of a complete failure of flood protection.

All flood extents shown are scenarios originating from the Elbe itself, effects resulting from flooding in tributaries are not considered. The area beyond the main levee system (aimed at protection from a 100 year flood) and the outline of the 100 year flood scenario shows the protected area, where flood protection can be assumed. However, a residual risk exists in these areas in case of failures in the levee

system or an overtopping by water levels beyond the design flood.

The maps were produced within the INTERREG III B CADSES project ELLA and supported by funds of the German Federal Ministry of Transport, Building and Urban Affairs

3.4. Odra flood risk maps, OderRegio II-project

The OderRegio II-project was focused on preventive flood protection using spatial planning in the Oder catchment area in the frame of a transnational action programme.

The core content for the partial catchment areas was the compilation of the existing and planned flood protection installations.

The project was initiated following the catastrophic 1997 flooding on the Oder, and with the conviction that flood damage can only be avoided with all the actors involved together throughout the whole catchment. The State of Brandenburg, with the support of the European Union, initiated the OderRegio project in 1999. In a first phase until 2001, a "Concept of spatial planning for preventive flood protection in the Oder catchment" was developed with partners from the Czech Republic, the Republic of Poland and the State of Saxony. In the second phase from 2003 to 2006, this concept was further developed into an action programme by the end of 2006. Here, the action fields for preventive flood protection are substantiated with concrete measures in the sub-areas. Basic information for the population and decision-makers is provided in flood hazard maps. The effectiveness of measures for flood protection is analysed in thematic priority areas. Most importantly of all, however, OderRegio continues to contribute towards creating a joint understanding of preventive flood protection across both administrative and subject-specific boundaries.

The OderRegio project activities took the complete catchment area of the Oder into account which represents an area of 122 512 km^2. Corresponding partners from the Czech Republic, Germany and Poland also participated with leadership monitoring carried out by the Joint State Planning Department of the States of Berlin and Brandenburg.

This information was compiled from the project website www.oderregio.org, where the detailed reports (final report: "Transnational Action Programme – Preventive Flood Protection in the Catchment Area of the Oder") can also be found.

3.5. Excimap

Aware of the growing future need for flood mapping development in Europe, early in 2006 the European Water Directors decided to establish a European exchange circle on flood mapping (EXCIMAP).

EXCIMAP was an informal circle consisting of nearly 40 representatives from

24 European countries or organizations. It was set-up initially for encouraging and facilitating exchanges between European experts in view of developing flood mapping. The main objective of EXCIMAP was to produce a Handbook presenting the good practices (available in Europe) to mobilize when executing flood mapping.

In the meantime, the European Union adopted a European Directive on the Assessment and Management of Flood Risks. This Directive set out the requirement for the Member States to develop three kinds of products:

- a preliminary flood risk assessment: the aim of this step is to evaluate the level of flood risk in all regions and to select those regions on which to undertake flood mapping and flood risk management plans (see below)

- flood mapping, with a distinction between flood hazard maps and flood risk maps:

– the **flood hazard maps** should cover the geographical areas which could be flooded according to different scenarios. These maps are also indicated by flood extension maps;

– the **flood risk maps** should show the potential adverse consequences associated with floods under those scenarios.

- flood risk management plans: on the basis of the previous maps, the flood risk management plans should indicate the objectives of the flood risk management in the concerned areas, and the measures that aim to achieve these objectives. Examples are evacuation maps.

The focus in the Atlas was on river flooding, but some examples of coastal flooding were also included.

According to the EU Floods Directive Member states should produce flood mapping according to some minimum recommendations. To be consistent with the proposed European document, EXCIMAP decided to focus its work on the minimum requirements of the Directive concerning flood mapping.

As part of the work to be done for the EXCIMAP Handbook an inventory was made of examples of maps and mapping programmes in the participating countries. The result of this inventory is the “Atlas of Flood Maps”. It contains examples from 19 European countries, not counting the subdivisions that are made in some instances (Belgium, Great Britain and Germany) and from the USA and Japan. In addition special chapters are dedicated to trans-boundary flood mapping, flood maps for insurance purpose and evacuation maps.

In each chapter the authors of the Atlas have made remarks on content and layout of the maps, based on general cartographic principles.

3.6. Flapp

FLAPP stands for "Flood Awareness and Prevention Policy in border areas". The project operated from January 2005 until August 2007 and was an EU-funded network through which local and regional flood experts from across Europe share knowledge and experience about how to prevent and forecast floods, inform people and limit the damage when floods happen. The network developed long-term practical ideas for managing rivers and streams in ways that protect the environment, as well as defend Europe's communities and economy. The focus of the network was on integrated river basin management in border areas.

Various flood management issues were discussed within the FLAPP network:

- flood prevention by structural and spatial measures;
- sustainable flood management, especially related to ecologically valuable areas;
- flood forecasting and calamity management;
- cross-border cooperation to stimulate a river basin approach;
- communication with and involvement of the public to increase flood awareness.

This information was taken with some minor modifications from www.flapp.org (where more details can also be found).

3.7. FLOODsite

Flooding is the most widely distributed of all natural hazards across Europe with floods from rivers, estuaries and the sea threatening

many millions of people in Europe. Floods cause distress and damage wherever they happen and insurance company data show that the financial impact of flooding has increased significantly since 1990.

In April 2007, the Parliament and Council of the European Union agreed the wording on a new European Directive on the assessment and management of flood risks. The Integrated Project FLOODsite is listed as one of the European actions which has supported the Directive.

FLOODsite was an "Integrated Project" in the Global Change and Ecosystems priority of the Sixth Framework Programme of the European Commission. It commenced in 2004 and ran to 2009. The FLOODsite consortium includes 37 of Europe's leading institutes and universities and the project involves managers, researchers and practitioners from a range of government, commercial and research organisations, specialising in aspects of flood risk management.

FLOODsite covered the physical, environmental, ecological and socio-economic aspects of floods from rivers, estuaries and the sea. It considered flood risk as a combination of hazard sources, pathways and the consequences of flooding on the "receptors" – people, property and the environment.

Flood risk management is a process which comprises pre-flood prevention, risk mitigation measures and preparedness, backed up by flood management actions during and after an event.

Floods often cross international borders and so must flood risk management research. The research on these topics was integrated through decision support technologies, uncertainty estimation and pilot applications for river, estuary and coastal sites in Belgium, the Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Spain and the UK.

FLOODsite was active in stimulating the uptake of research advances through guidance for professionals, public information and educational material.

3.8. PREVIEW (FP6)

PREVIEW was an EC-co funded research project looking for new techniques to better protect European citizens against environmental risks and to reduce their consequences. The project provided new or enhanced information services for risk management in three thematic domains: Atmospheric, Geophysics, Man-made.

In order to support European Civil Protection units – local, regional, national and European authorities – better prevent, anticipate and/or manage different types of disasters PREVIEW drew on the most advanced research and technological developments using satellite observation in combination with other data and scientific models. PREVIEW was jointly developed by a consortium of 58 partners from 15 nations, gathering a wide range of technical skills and key representatives in risk management.

Concerning services relevant to plain floods within the test area of Kempten (Bavaria/Germany) different failure scenarios of the protection measures were simulated based on a high resolution LIDAR data set. Users of this information have been the city of Kempten, the federal state agency for environment and the local rescue services.

The main flood products developed in PREVIEW were:

- High resolution dynamic risk maps (containing flood hazard maps, dynamic failure scenario calculation, animation movies, assets maps and damage potential)
- Flood information system (www.floodrisk.eu)
- The following services were also provided to the users: data integration into the local

IT-system of Kempten and the training of local water authorities and rescue services.

3.9. RISK-EOS (ESA-GSE)

RISK-EOS was a project-based network of European service providers delivering geo-information services to support the management of flood, fire and other risks during the period of 2003 – 2008 under the GMES Service Element Programme.

The contracting organisation was the ESA (European Space Agency, coordinated by Infoterra France) and the RISK-EOS services were targeted to serve the needs of all risk management actors at European, National and Regional levels, and combined the use of satellite observation data with exogenous data and modelling techniques.

The RISK-EOS services were developed and qualified in close synergy with operational users of five European countries, federated by the National Civil Protection services of France, Germany, Italy, Spain and Sweden.

The main flood related topics were:

- Production of dynamic risk maps (containing flood hazard maps, dynamic failure scenario calculation, creation of animation movies, setup of assets maps, damage potential calculation)
- Evaluation of different planned protection measures
- Setup of flood information system
- Data integration into local IT-system
- Training of local water authorities and rescue services
- Further information is available at www.risk-eos.com.

Using a study area, the potential flood hazard areas for an extreme 100 year flood were calculated. In addition, damage potential for this extreme event were derived and levee failure scenarios also simulated at various locations.

3.10. SAFER (FP7)

SAFER is a follow-up project of PREVIEW and RISK-EOS within the funding scheme of FP7. It is concentrating on different rapid mapping products with the driving priority of quick information delivery - notably:

- Gradual increase of activations: 30-45-60 events per year.
- Reference maps available in less than 6 hours.
- Anticipation of new acquisitions, based on events monitoring, to speed-up assessment mapping.

On top of this, the following additional information and services are offered:

- Reference mapping prepared in advance with more than 6.8 million km^2 covered during the project;
- Progressive enrichment of the service with thematic maps (assets and population maps, risk maps, historical damage maps) for the different types of hazards.

Services are provided via:

- An internal focal point which provides a single point of contact available 24 hours a day, 7 days per week to manage service delivery;
- a service gateway for efficient access to products;
- "in-field GIS" light solutions (geo-information delivered up to the intervention field).

In order to prepare a fully operational service, the following work steps have been implemented:

- Service development and validation according to standard process;
- Set-up of service infrastructure to allow seamless integration between service partners and with end-users;
- Written processes and methods, quality organisation, and training of service providers;

- Training courses for users.

The flood services platform covers both the plain floods and the flash floods risks analysis. This platform provides services at European level.

The **Plain Flood Risk Management service** provides decision-making tools from mapping to modelling, including damage assessment, as a complement to the Core Service. The service is suited to be delivered on large territories and will bring benefit to the users involved in emergency response. In order to broaden the European dimension, this interoperable service will also be applied to test sites in Romania and Bulgaria. The service meets the requirements stated in the European flood directive and includes:

- Mapping of Past Flood Events;
- Potential Flood Damage Maps;
- Flood Information Service.

Due to the spatial focus of events on a regional scale, the operations of the **Flash Flood Risk management service** are kept under the control of the local, regional or national authorities concerned. Flash Flood services developed in the context of PACTES, RISKEOS and PREVIEW projects should therefore be considered as demonstration services to be implemented within the framework of each local or national hydro-meteorological operator with specific responsibilities in a country, region or basins prone to flash floods. Flash Flood services may also extend to the risk management of intense runoff in medium or large rivers watersheds that trigger hydraulic and damaging effects close to a typical Flash Flood response with similar associated impacts.

In the context of damage assessment, a multi-risk approach is followed for the underlying assets map. The Basic European Assets Map (BEAM) provides an assets layer that can be used for all types of natural hazards, giving the information in Euro/m^2 and the population density. The service is designed to be applicable all over Europe and is mainly based on CORINE land cover and Eurostats data. More detailed information layers can be provided for smaller regions.

Further information is available via www.emergencyresponse.eu.

3.11. Floodrisk – HORA

The Federal Ministry of Agriculture, Forestry, Environment and Water Management and the association of Austrian insurance companies launched the project "Flood risk zoning in Austria – HORA" in autumn 2002. This is an Austria-wide risk zoning system for natural disasters which focuses on floods.

In recent years Austria has been stricken by numerous severe flood disasters, most recently in spring 2006 along the Morava River (Lower Austria). Following the disastrous damage caused by that flood, the goal has been to record and better assess such major damage potentials in the future. Consequently everybody can now use the HORA internet platform to obtain a first assessment of the flooding risk of over 25 000 river kilometres by entering a relevant address.

One pivotal conclusion of the "FloodRisk" project has been that, in addition to enhancing people's hazard awareness, informing them about the limits of active control measures and the need for an appropriate use of areas at risk, future handling of this issue will require an intensified risk sharing between the state, insurance companies and private persons.

The "HORA" project has an important role to play in this interaction since it specifically focuses upon cooperation between the state and the private sector, and is therefore unparalleled in Europe. For example, Austrian citizens can benefit from this cooperation for the provision of important information about the flooding risk to which their apartments, industrial enterprises or infrastructural facilities are exposed. Apart from the quick and easy retrieval of information about potential flooding risks from a digital risk map provided on the internet (which permits a first risk assessment), the flood control measures required for communities, national and provincial governments can also be optimised and prioritised.

For the Federal Ministry of Agriculture, Forestry, Environment and Water Management, the "HORA" project is not only a milestone in risk communication, but illustrates Austria's pioneer role in the water sector in general. The project anticipates parts of the planned EU Floods Framework Directive which requires better information for the population, whilst also serving the interests of the insurance industry by both heightening people's risk awareness and enhancing identification and assessment of potential risks as a basic prerequisite of insurability.

4. Harmonisation and joint definition of requirements

Harmonisation is not only needed regarding different nations, but also regarding different user groups who have both different expectations and uses for map content. The bottom line is that the river must be conceived like a system which does not respect any border. Flood risk management has to be one piece of this puzzle. The national requirements are summarized in the "Report on national requirements on the flood mapping procedures for the Danube River".

5. Harmonisation of data

Data are the heart of the risk modelling process. Inconsistencies or quality deficits may lead to insufficient results.

5.1. Data needs and minimum quality requirements (resolution, accuracy, up-to-datedness)

5.1.1. Overview of data needs

In the context of flood hazard and risk modelling the following data is needed and should be collected in a central database. If not possible (see national requirements report), meta data should be delivered. This relates especially to input data not acquired with DFRP funds such as DTM, cross-sections, roughness coefficients, hydrological data, but also to input data for risk considerations. Additionally, depending on the level of detail and the type and size of catchment, one or the other data set might be of smaller or no relevance.

Background data (multi-use):

- Catchment outline, here the Danube corridor
- Digital terrain model
- Land cover or land use

Hydraulic data:

- River network
- Cross-sections
- Longitudinal profile
- Gauging stations (geo-position and H historical, H(t), Q(H) Rating curves and Q(t) discharges); Q(t) and Z(t) time series are required for calibration and validation purposes (year 2002 and 2006 floods are

recommended for this purpose for as many internal gauging stations as available)
- Bridges
- Hydropower Dams
- Polders
- Spillways
- Bottom outlets
- Dykes
- Dyke weak zone
- Historical records of dyke breaches:
  - The width and depth of historical dyke breaches recommended if available
- Dewatering canals
- Pumping stations
- High Waters Diversions
- Bank protection (rip-rap)

Hydrological data:
- Time series:
  - time series are required by the Hydrology Sub-group for statistical processing of the flood waves

Vulnerability and damage assessment can be split into different sections. One part covers all the information needed for estimating the monetary assets, as well as the affected population.
- Number of affected persons
- Net fixed assets of agriculture, industry, service, trade
- Number of employees in agriculture, industry, service, trade
- Net fixed assets private houses
- Number of cars and motorbikes
- Average value of cars and motorbikes
- Number of dwellings and average living area per dwelling Þm^{2}Ý
- Average construction costs and depreciation rate
- Average value of household and depreciation rate
- Number of different types of livestock (cattle, pigs, horses, sheep/goats, poultry)
- Market price of different types of livestock (cattle, pigs, horses, sheep/goats, poultry)

The other part is more dedicated to the vulnerability and description of non-monetary goods:
- enterprises
- bridges
- roads and railways
- hydrotechnical works
- Infrastructural networks (electricity, water, gas, oil)
- Cultural heritage
- Critical (hazardous) infrastructure
- Recreation areas

Validation data:
- Retention areas / floodplains (delimitations from neighbouring sciences like ecology, geomorphology or soil science)
- Occurred floods (outline, water depth, recurrence interval and description of event)

- Dyke breach information including breach characteristics (dyke breaches are included in the section dealing with hydraulic data). Areas effected and information about flood progression

5.1.2. Extract of data to be integrated in the project data base

As not all of this data are relevant at the scale of the Danube River, and also due to national concerns as well as copyright limitations only the most relevant data should be gathered in the central data base. Main usage is to print the atlas and to provide background information for the map web service.

The following data sets are needed:

- Rivers and channels (line)
- Rivers, channels and lakes including islands (polygon)
- Dykes (line)
- Settlements (polygon)
- Roads and railroads (line)
- Gauging stations (point)
- Historic flooding extent (polygon), only if relevant and available for publication
- Special risk objects (point), the following classifications might be used: hospitals, airports, main train stations, cultural heritage, national protection sites, industrial sites and waste water treatment plants (IPPC).

For damage assessment calculation the following data is needed in relation to the statistical special unit – the NUTS region (polygon). The data should be collected in the best level of detail available. In EUROSTAT the following NUTS level 2 data is usually available:

- NumberOfCars
- NumberOfMotorbikes
- NumberOfCattle
- NumberOfPigs
- NumberOfHorses
- NumberOfSheepsAndGoats
- NumberOfPoultry
- Population
- NumberOfEmployeesInAgriculture
- NumberOfEmployeesInIndustry
- NumberOfEmployeesInService
- NumberOfDwellings (preferable instead is TotalLivingArea)
- TotalLivingArea (in square meters, to be provided if no data for NumberOfDwellings exist)
- NetFixedAssestsAgriculture (Euro)
- NetFixedAssetsIndustry (Euro)
- NetFixedAssetsService (Euro)
- NetFixedAssetsTrade (Euro)
- NetFixedAssetsPrivateHouses (Euro)
- AverageValueOfCar (Euro)
- AverageValueOfMotorbike (Euro)
- AverageConstructionCosts (Euro/Square meter)

- AverageValueOfHousehold (Euro/Square meter)
- AverageLivingAreaPerDwelling (square meters)
- MarketPriceOfCattle (Euro/t)
- MarketPriceOfPigs (Euro/t)
- marketPriceOfHorses (Euro/t)
- MarketPriceOfSheepsAndGoats (Euro/t)
- MarketPriceOfPoultry (Euro/t)

5.1.3. Digital Terrain model

According to the project proposal, a 5 meters grid seems to be enough for LiDAR scanning and this implies 1 terrain point per 3-4 m^2 with a precision of 10-15 cm each. The tributaries of the Danube have been also considered and have been taken into account in LiDAR scanning by measuring them until the backwaters. The tributaries have to be LiDAR surveyed up to the end of the floodplain that is in connection with the Danube and the tributary. If the tributary has a floodplain that is separated from the Danube by a higher ground, then that floodplain is not the subject of our project.

If no data are available of the requested precision, then the data that comes closest to the requirements should be used and a description of the precision available should be added.

The ground GPS total stations network can be mixed with the Bathymetrical measurements as landmarks for cross sections.

- Accuracy is the same as for the cross-sections.

- The density of the LiDAR points can be defined by the survey company to achieve required grid density for the modellers.
- Linear structures should be defined as break lines including information on openings as well.

5.1.4. Transversal cross-sections

Regarding the bathymetric measurements, in the project proposal it is stipulated that the cross sections should be done at 100 metres distance. This issue has been discussed with the hydraulics team and they have affirmed that for modelling they don't need more than one cross section per kilometre. So, it has been decided that the cross sections will be done at each 1 000 metres and a detailed interval of 250 metres will be applied for special hydraulic conditions (islands, dead branches etc.) to have a better control. In certain cases, where hydraulically justified, the site data could be collected even at 100 metres. For the site survey, the following criteria were defined:

- cross sections measured from dyke to dyke;
- the maximum distance between the cross sections is 4-5 times of the main channel;
- add extra cross sections where necessary;
- vertical accuracy for vegetation covered area is ±30 cm and ±10 cm elsewhere. Normally the LiDAR data are obtained during early spring or late autumn, thus the accuracy should be the same everywhere (15-20 cm).
- horizontal accuracy required is ±1 m (radius).

The common projection of the bathymetric maps is Lambert Azimuthal Equal Area in the ETRS89 datum, the vertical reference system is the EVRS 2007 (European Vertical Reference System 2007) while the national projection can be whatever is appropriate.

Concerning the bathymetric measurements, it is known from experience that the single beam echo sounders which all countries are using for this modelling cannot pass water vegetation and therefore the depths recorded will not be correct. It is therefore proposed that bathymetrical measurements should be done during high waters and LiDAR scanning during the low waters. Indeed, the results for modelling will benefit from double data on the two banks of Danube one from LiDAR and one from Bathymetric measurements. But this is only a proposal since it has also been concluded that on the Danube the water vegetation is almost insignificant to the bathymetric measurements and that this problem is only relevant in the Danube Delta.

Romania and Bulgaria agreed to make alternative cross sections of 500 metres in between thus the density of the resulting network of cross section will be 250 metres, so that the same work should not be done twice plus the costs are lower. The same procedure can be done for the rest of the participating countries with common border over the Danube.

5.1.5. Roughness coefficient

The roughness coefficient can be estimated as a minimum requirement based on Corine Land Cover (CLC) data. If more detailed land cover data sets are available, then they should be referenced to the CLC system by a lookup table so that the values used can be better interpreted. Derivation for model calibration purposes should be documented.

Field trips are recommended to check the density of the vegetation.

5.1.6. Hydrological data

- In case of non-homogenous data series, both the series jumps and differences between hydrologic parameters by splitting series of data should be presented. If it is the case, only recent hydrological data should be used, despite the fact that long series of data exist. This issue will be solved after having the results of the homogeneity tests on all sections along the Danube River. Related to this topic, the possible effects of the New Vásárhelyi Plan implementation in Hungary for the future evolution of the maximum discharges on the downstream countries was mentioned, but no final conclusions were reached.

- Concerning the time step for the flood hydrograph, it was decided to use daily data both for the Danube River and its tributaries.
- As hydrological boundary conditions for steady state calculations, the rating curves at gauging stations and the hydrological longitudinal profile of the peak discharge are needed.
- The discharge values are examined concerning:

– Data inaccuracy (read fault, lack of data, resolution,…);

– Control of the sample (consistency, independency, homogeneity, outliers, representativeness, …);

– Plausibility check (analysis and data balance), if necessary correction of rating curve (stage-discharge relation) and surveying of bed profile.

5.1.7. Discharge data

Time series of Q (t) and H (t) are required for calibration and validation purposes of the hydraulic simulations. The year 2002 and 2006 floods are recommended as high water level data are available for many gauging stations. Other time series may be required for parts of the catchment.

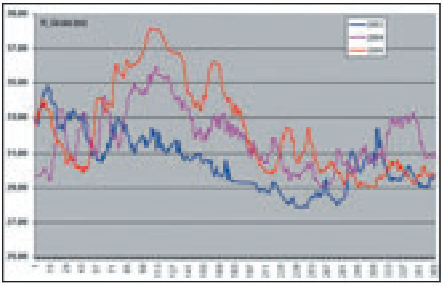


Figure 1: Example for discharge data from Gruia, Romania
Source: Prof. Drobot, TUCEB

For the major structures that can modify the flood regime of the rivers, geometry and operational rules (during floods) will be required. The simulations will be made for fixed bed.

Historical records of the dyke breaches are necessary, including the location, width and depth of historical dyke breaches.

5.1.8. Meta data (minimum content):

- Projection information
- Height system used (if applicable)
- Data Source, way of data generation, processing
- Accuracy information
- Owner of the data, copyright limitations
- Detailed description of the classes used, preferable already adjusted to INSPIRE
- Property rights (copyright)

5.2. Projection and reference systems

The ETRS89 reference system was adopted in 2003 by the European Commission and is recommended to be used by the EuroGeographics – the organization that unifies all the cadastre agencies across Europe. This reference system is described at the moment by EUREF according to ISO19111 standard – Spatial Referencing by Coordinates. All European countries adopted the ETRS89 reference system and provide tools for transformations between ETRS89 and the national systems. Therefore ETRS89 should be applied in DFRP.

5.2.1. Vertical reference systems

During the last ten years significant progress has been achieved in the definition and realization of the European Vertical Reference System, especially by the IAG Sub-commission EUREF. At the EUREF Symposium 2000 in Tromsø, the conventions for the European Vertical Reference System 2000 (EVRS2000) were approved and the realization of the European Vertical Reference Frame 2000 (EVRF2000) based on the UELN 95/98 solution was adopted.

Following the EUREF Symposium 2007 in London, the new realization of the EVRS - the European Vertical Reference Frame 2007 (EVRF2007) - was elaborated based on a combination strategy of three elements: the network, the vertical datum and the observation of the time evolution of the reference frame.

5.2.2. Differences between local vertical systems and EVRS2007

Each European country has the possibility to transform from local (national) coordinate systems to EVRS2007.

In a specific case like EU projects for the Danube River, a demand for the creation of a common spatial database exists and it is recommended to use the following coordinate systems:

- ETRS89 as the reference system, and;

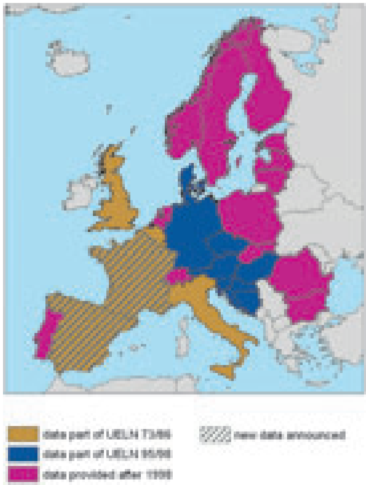


Figure 2:
Participant countries at the EVRF2007 realization
see: www.bkg.bund.de/nn_164706/geodIS/EVRS/EN/EVRF2007/evrf2007__node.html__nnn=true

Figure 3:
Differences between local vertical coordinate systems and EVRS2007
see: http://www.bkg.bund.de/nn_164776/geodIS/EVRS/EN/Projects/03HeightDatumRel/height-datum-rel__node.html__nnn=true

- EVRS2007 for the vertical coordinate system.

In countries like Germany where the differences between the local vertical reference systems and EVRS2007 is only +1cm this difference can be ignored. On the other hand, in countries like Austria a transformation from local vertical reference systems to EVRS2007 must be realised.

Further information can be found at: http://www.bkg.bund.de/evrs/

6. Harmonisation of methods for processing of hazard maps

The methods used for the processing of hazard map data predetermine the quality of the results. The application of different methods might be appropriate if carefully assessed, but more usual

is the harmonisation of methods which covers: quality management, damage assessment, modelling techniques and model border conditions, scenario definition and simulation methods.

6.1. Hydraulic modelling techniques

There was a discussion on using steady or unsteady hydraulic models for the flood hazard mapping. Austria and Slovakia intend to use steady models 1D and 2D models in most of the cases. The other riparian countries downstream of Gabcikovo will use 1D and 2D unsteady models for simulation.

The conclusions of this discussion were:

1.) For high (1:30 years) and medium (1:100 years) probability floods:

– Use of 1D steady backwater curve calculations are recommended (it is agreed that these floods will be contained between dykes)

– 2D steady models can be used where appropriate (wide floodplain, high damage potential, detailed study etc.)

2.) For low (e.g. 1:300 years; 1:1000 years) probability floods:

– General recommendations for the 2D hydraulic models

= Flooding & drying option needed

= Option to represent linear structures

= Present references on reproduction of velocity distribution

= Prove that a dense enough grid size is used (e.g. presenting series of results of systematic grid refining)

– For the simulation of the inundation of the protected floodplain use of a combined unsteady "1D-Breach-2D model system" is recommended

– For the 2D unsteady hydraulic model the ability of handling flooding and drying processes is a prerequisite.

– For Austria and Slovakia:

= The use of 2D steady models on the floodplains are recommended

= 1D steady model can be used on the floodplain depending on the financial and human resources, low damage potential etc.

– For Hungary:

= For medium and high probabilities of exceedance, the floods will remain between dykes.

= For 0.1% probability of exceedance a combined unsteady "1D-Breach-2D model system" will be used.

– For Serbia:

= 1D steady model can be used.

= Quality requirements for the 2D hydrodynamic model (See General recommendations above)

– For Romania and Bulgaria:

= 1D unsteady model will be used all along the Danube. In areas with high vulnerability a quasi-2D unsteady model is recommended.

6.2. Boundary conditions for the hydraulic modelling

6.2.1. General principles

For hydraulic simulations, the hydrologic data represent boundary conditions. According to the type of the hydraulic simulations (steady or unsteady state) only the maximum discharge $Q_{P\%}^{max}$ corresponding to a given probability of exceedance (P% = 33%; 1% and 0.33/0.1%) or the whole hydrograph $(Q(t))_{P\%}$ of the flood wave for the same probabilities are necessary.

The statistical values $Q_{P\%}^{max}$ can be obtained by selecting each year the maximum annual discharge, or keeping only the maximum discharges over a threshold. In the latter case, in some years more than one flood will be selected, while in other years without significant floods no value will be kept for statistical processing.

In the case of unsteady simulations, the whole hydrograph $(Q(t))_{P\%}$ is necessary. A family of floods $(Q(t))_{P\%}$ for the same probability of exceedance P% can be obtained using either a Markov chain based generation algorithm or a classic statistical processing. Even if the mathematical approach is different, the philosophy behind the family of floods is the same: more than one synthetic flood $(Q(t))_{P\%}$ can be defined for the same return period. According to their characteristics, some of the synthetic floods will be run for flood propagation, while others will be used for the seepage computation.

In Hydrology two types of uncertainty can be identified:

- Stochastic uncertainty (natural variability of maximum discharges and volumes)
- Epistemic uncertainty (incomplete knowledge of the system: measurement errors, Plotting Position formulae, selection of data and partial series, selection of distribution functions, parameter estimation for distribution functions). In the frame of the latter, there are different sources of uncertainty:

– Hypothesis concerning the extreme values (stationarity, homogeneity, independence);

– Data sampling (period selection, selection of the maximum discharges)

– Theoretical Distribution function (Pearson III, log-normal, Weibull, GEV, GPD etc)

– Empirical Distribution Function (Weibull, Cunnane, Blom, Gringorten, Hazen, Cegodaev)

– Parameters estimation (method of moments, maximum likelihood, principle of maximum entropy)

– Stage-discharge relation: hysteresis during a flood wave; changes in river channel /over time, measurements errors, parameters estimation, error in model selection, arbitrary prolongation of the stage-discharge relation for maximum stages.

Severe problems may occur when the uncertainty is ignored (especially for low probabilities).

6.2.2. Hydrological methodology

6.2.2.1. Generation of daily discharges

Hungary presented a model based on the generation of the daily discharges. (See Annex I and references: Szilágyi J., Bálint G. and Csík A. (2006): Hybrid, Markov Chain-Based Model for Daily Streamflow Generation at Multiple Cachtment Sites. Journal of Hydrological Engineering, Vol.11., Issue 3., pp. 245-256.; Szilágyi J., Bálint G., Csík A., Gauzer B. and Horoszné Gulyás M. (2005): Simulation of the Superimposition of Floods in the Upper Tisza Region. NATO Sciences Series, Vol.72., pp. 171-182.). Using daily data for a period of minimum 30-50 years, daily discharges for 10 000 years will be generated. The given approach also requires data sets (water level and discharge data for flood routing stations 2-10 years). From the simulated set of data, the floods with different return periods will then be selected.

6.2.2.2. Statistical processing

If only one distribution function is used in the statistical processing (for instance GEV distribution like in Austria) unique values are provided for the maximum discharges corresponding to different return periods. This approach is used extensively, mainly due to the fact that in current practice the design prescriptions have to be very clear. The design values (for instance the maximum discharge for 100 years return period) are considered as certain and unique values (like being deterministic values).

For the Austrian Danube the currently most suitable and used method is the AMS method – Annual Maximum Series (See Figure 4). For this analysis there is only the highest annual maximum in use.

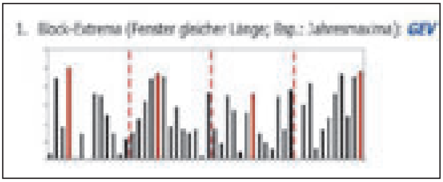


Figure 4: Annual maximum series (AMS) – for each year one maximum value
Source: via donau

For the analysis the generalized extreme value distribution – GEV method, with three different types (I-III), is in use (See Figure 5). Type I (k=0) is the equivalent of the Gumbel distribution and provides good and rational results.

Figure 5: Generalized extreme value distribution – GEV (I-III)
Source: via donau

The data series of some selected gauge stations are going to be adapted to this distribution function and thereby the probability can be related to the discharge.

Another, more complex, approach is proposed by TUCEB team, by using different cumulative distribution functions that fit well the empirical distribution of the maximum discharges. Different values of the maximum discharges corresponding to the same probability of exceedance are obtained. The lowest and the highest values of these discharges define an interval of hydrologic uncertainty, denoted by $(Q_L^{max} ; Q_U^{max})_{P\%}$ where L and U mean the lower and the upper limits of the interval. This approach represents in fact a generalization of the current practice based on a single distribution. Even if only one statistical distribution is used (GPD for instance) by increasing the threshold value for the selection of the maximum discharges an uncertainty interval will also be obtained. Of course, further statistical considerations should lead to a reasonable interval of uncertainty.

Similar considerations as for the uncertainty intervals of the maximum discharges may be made for the volumes of the flood waves. As a result, uncertainty intervals will be defined both for the discharges and the volumes of the flood waves: $(Q_L^{max} ; Q_U^{max})_{P\%}$ and $(V_L^{max} ; V_U^{max})_{P\%}$ respectively.

At the same time, different shapes of the synthetic floods may be obtained based on a clustering procedure applied to registered floods (See Annex 2). Thus, the floods corresponding to a given return period are characterized not only by the maximum discharges, but by the whole hydrograph which has a shape and a volume. The hydrograph $(Q(t))_{P\%}$ is necessary in the case of unsteady simulations.

By using the uncertainty intervals of the maximum discharges and volumes a family of hydrographs corresponding to the same probability of exceedance P% can be obtained. The dykes' failure mechanisms produced by the flood waves are mainly: the crest overtopping and the dyke or foundation internal erosion. The crest overtopping occurs during high levels, corresponding to the maximum discharges $Q^{max}_{P\%}$, irrespective of the flood volume. The internal erosion develops during long duration floods, which means high volumes of the flood waves, even if the maximum discharge is lower than the $Q^{max}_{P\%}$.

In order to take into account the mentioned failure mechanisms, at least two flood scenarios should be provided for the probability of exceedance P%: the flood characterized by the upper limit of the maximum discharge and the lower value of the volume $(Q^{max}_{U} ; V_L)_{P\%}$ and the flood corresponding to the upper limit of the volume and the lower value of the discharge $(Q^{max}_{L} ; V_U)_{P\%}$ respectively. In both cases, the upper and the lower limits of the intervals for discharges and volumes are computed for the same probability of exceedance P%. This approach will be called the Synthetic Flood Procedure in the following section.

In conclusion, the hydrological processing can be performed at different degrees of complexity, depending on the future utilization of the results.

6.2.2.3. Synthesis of the hydrologic methodology

The main steps of the statistical processing are the following:

1) Selection of the time series of the maximum discharges:

a) Either the maximum annual discharges, or

b) The maximum discharges exceeding a certain threshold value.

2) Statistical processing of the selected discharges.

a) If maximum annual discharges were selected, then:

- only one distribution function is used for statistical extrapolation, obtaining a unique value $Q^{max}_{P\%}$, or
- a set of distribution functions can be used for fitting the empirical data, resulting an interval of uncertainty. In this case, some of the distribution functions can be discarded based on statistical tests (Kolmogorov-Smirnov, Anderson-Darling etc). The extreme values (lowest and highest limits) for a probability of exceedance P% represent in fact the uncertainty interval of the maximum discharge: $(Q^{max}_{L} ; Q^{max}_{U})_{P\%}$. It should be mentioned that the uncertainty interval is not similar with the confidence interval.

b) If the maximum discharges exceeding the threshold value were selected, then by modifying the threshold value a different uncertainty interval for maximum discharges will be obtained.

3) After defining the interval of uncertainty for the maximum discharges

a) Either the Markov chain generation procedure is used to obtain the flood hydrographs

b) Or the Synthetic Flood Procedure is used for the same purpose, based on the following steps:

- Obtaining the uncertainty interval $(V^{max}_{L} ; V^{max}_{U})_{P\%}$ of the flood volume for the same probability of exceedance P%.
- Clustering of the flood shapes
- Preparing data for hydraulic simulations. If the hydraulic simulations will be in steady state, the hydrological data are already obtained. If the hydraulic simulations are in unsteady state, the whole hydrograph $(Q(t))_{P\%}$ is necessary. In the latter case, the hydrograph corresponding to the upper limit of the maximum discharges and the hydrograph having the maximum volume will be selected for further simulations.

The flowchart of the hydrological methodology is presented in Figure 6.

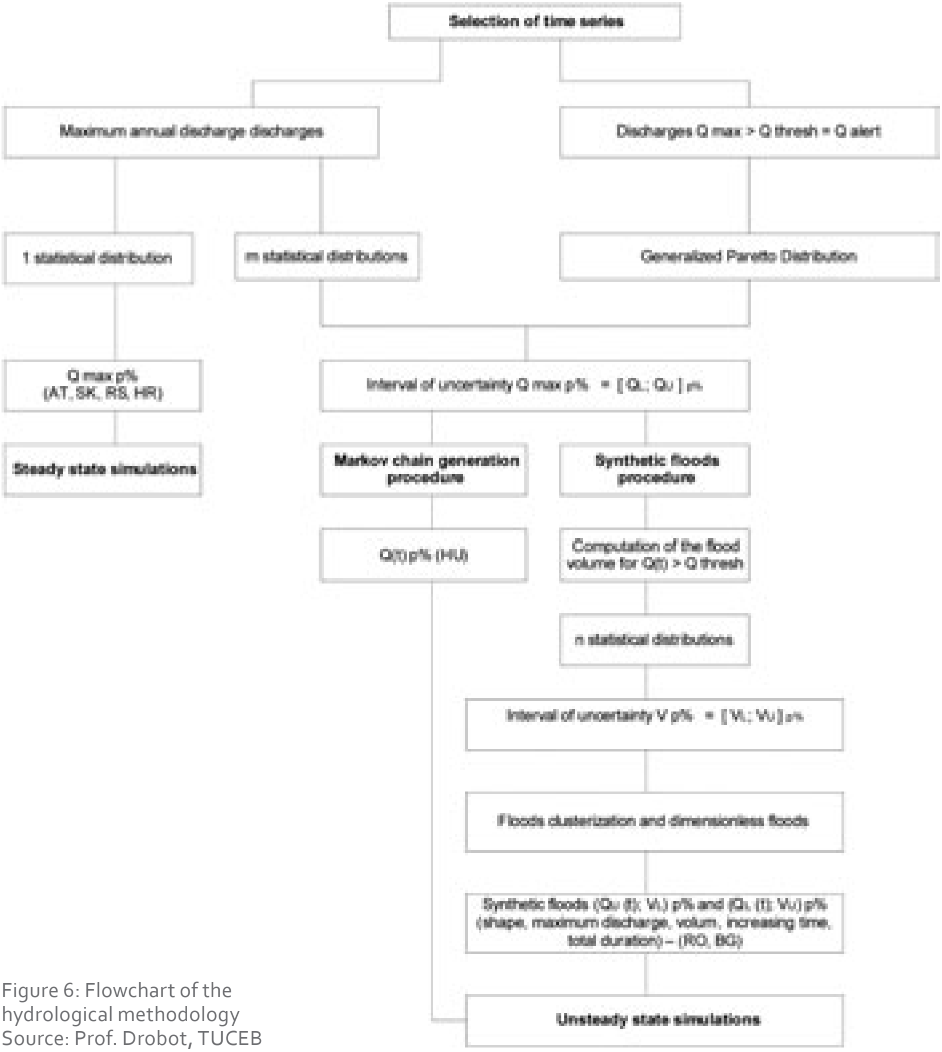


Figure 6: Flowchart of the hydrological methodology
Source: Prof. Drobot, TUCEB

6.3. Scenario definition for the hydraulic modelling

Mountainous regions: Simulate using a 1D-steady state approach.

Flat regions, use either coupled 1D/2D or complete 2D approach, for dyke protected areas dyke failure scenarios need to be included.

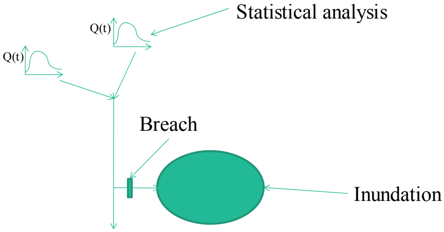


Figure 7
Source: Péter Bakonyi, VITUKI

6.4. Quality management

Detailed descriptions of all assumptions, are all result data complete, are all meta data available?

The following tests on the result data should be performed:

- Do the different data sets fit at the national borders?
- Are the different recurrence intervals consistent with each other?
- Are the former inundated areas (event data) covered by the extent of the extreme event?
- Visibility tests concerning artefacts of the DTM generation process?
- Are there implausible islands in the inundation area which correlate to land use patterns?
- General plausibility of the inundated area, check by external experts and local water authorities.

7. Harmonisation of methods for vulnerability and damage assessment

7.1. Requirement towards vulnerability indices

The methodology for vulnerability index / indicators determination will take into account that vulnerability indicators must be developed based on some well-defined criteria.

The vulnerability index/indicators must be: measurable, relevant, understandable and easy to interpret, sensitive, reproducible and policy relevant.

In the same time the construction of vulnerability index must be based on:

- key-elements,
- use of analytically and statistically sound data,
- easy understandable and interpretable,
- sensitivity.

Standard criteria for indicator development (see EEA 2004; Birkmann 2004; NZOSA 2004; Berry, 1997; Parris 2000)

- Measurable
- Relevant i.e. represent an issue that is important to the relevant topic
- Policy-relevant
- Only measure important key-elements instead of trying to indicate all aspects
- Analytically and statistically sound
- Understandable
- Easy to interpret
- Sensitivity i.e. be sensitive and specific to the underlying phenomenon
- Validity/accuracy
- Reproducible
- Based on available data
- Data comparability
- Appropriate scope
- Cost effective

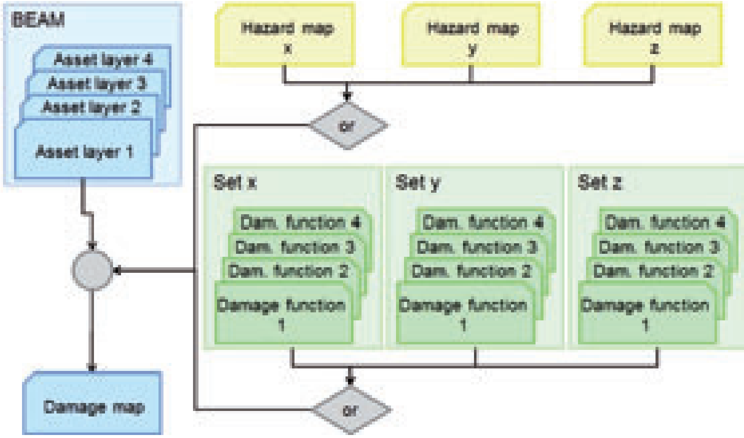
7.2. BEAM-methodology

The following methodology has been provided by the FP7-project SAFER, It has been developed from the approaches used in the risk mapping projects at Rhine, Elbe, Weser and Odra, as well as other projects like RISK-EOS and FP6 PREVIEW.

7.2.1. How to apply BEAM

Damage assessment can follow two different ways, either applying damage functions that give a direct output of losses in money or following a two-step approach by first calculating the assets and then applying damage functions that give the losses in a percentage.

BEAM is following the second approach because in this way the underlying asset layers can be used for various types of hazards (e.g. in a multi-risk analysis) and the damage functions don't need to be adopted for new regions. For example, the damage function for an average car will be similar in each country, no matter what will be the age and value of an average car there.



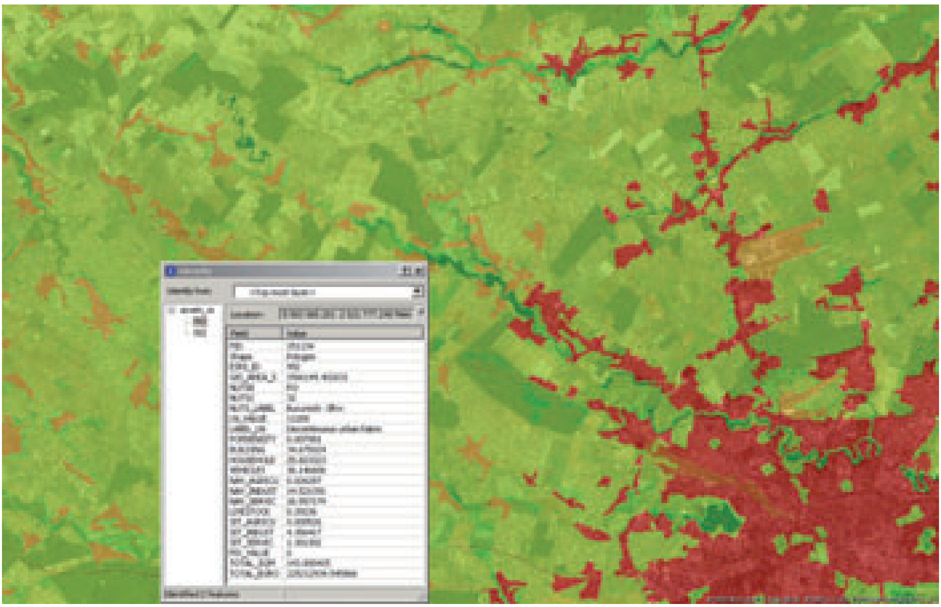
Source: André Assmann

The damage functions are not part of the BEAM product itself, but can be taken in an adjusted version from other large scale risk projects (e.g. Rhine).

7.2.2. Technical specifications

Projection and coordinate system: Lambert Azimuthal Equal Area, ETRS 1989 LAEA, others and on request.

BEAM consists of the following set of



asset layers:

- Population density
- Private housing: buildings and equipment (urban immobile)
- Household goods (urban mobile)
- Vehicles
- Industry: buildings and equipment (net asset value, immobile)
- Industry: stock in trade (mobile)
- Service and trade: buildings and equipment (net asset value, immobile)
- Service and trade: stock in trade (mobile)
- Agriculture: buildings and equipment (net asset value, immobile)
- Agriculture: stock in trade without livestock, mobile)
- Agriculture: livestock

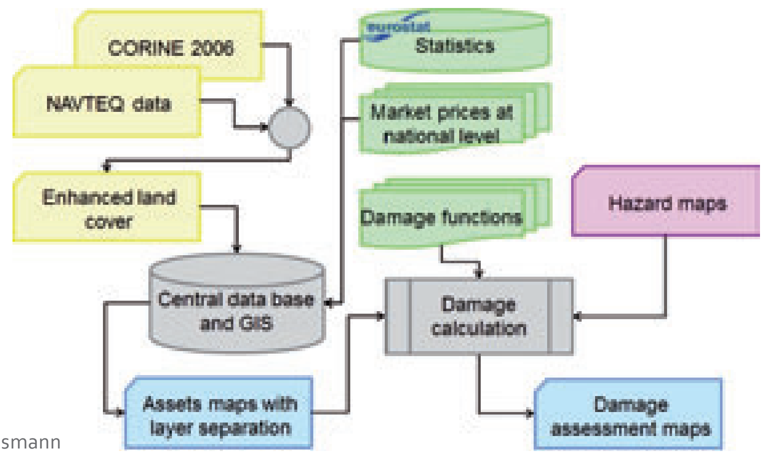
Additionally, BEAM contains one combined layer that covers asset values for:

- Arable land
- Grassland
- Forest
- Road network
- Green urban areas and sport areas

This aggregated layer can easily be related to the single land use classes as this information is contained in another column of the data file.

7.2.3. General remarks

BEAM is composed of two major components: the asset volume taken from the statistics and the land use data which are needed to disaggregate these values. As this does not always work directly, in some cases the addition of statistical data is needed to perform intermediate steps. Details of this process are described below for each layer.



Source: André Assmann

7.2.4. Data used for BEAM

The basis for the background land use information is the CORINE land cover information. This is subsequently enhanced by additional data sources (NAVTEQ). These enhancements relate mainly to the introduction of small settlement areas as well as the traffic infrastructure (roads, railways, etc.).

To cover the social-economic data needs, data from the EUROSTAT data base are processed and analysed. Additional values are being gathered from the national statistical institutes as well as from other sources.

7.2.5. Production background

Data processing and analysis are carried out based on a geo-enabled relational database system, compatible to OGC standards. The data is also ready for INSPIRE related activities and projects.

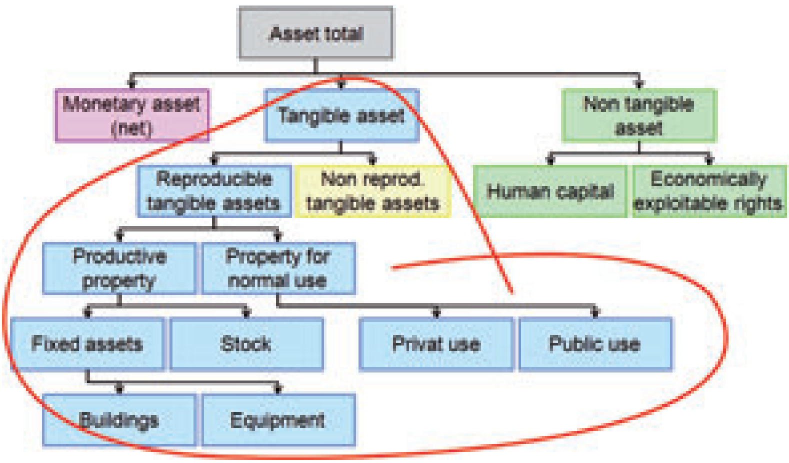
The set of baseline data follows the same standards for each country covered in the BEAM database system. Data for additional countries can easily be created by processing the spatial land used data model and by entering the basic statistical figures.

7.2.6. Assumptions and definitions

Due to the complexity of the topic and the area covered, it is not feasible to integrate all types of assets. In view of the fact that the product is related to risk assessment in the context of natural hazards, the following assumptions have been made:

- Only direct assets (tangible) are taken into account (see diagram below).
- The product is based on the so-called net concept, which reflects the current market value of an asset (not restoration costs or insured assets).
- No costs for the building ground are included as it is assumed that the value assigned to it will not change in the case of an event.
- No external planning costs are included (i.e. building permits) as they will not apply for a simple restoration after an event.
- No costs due to production downtimes are taken into account.

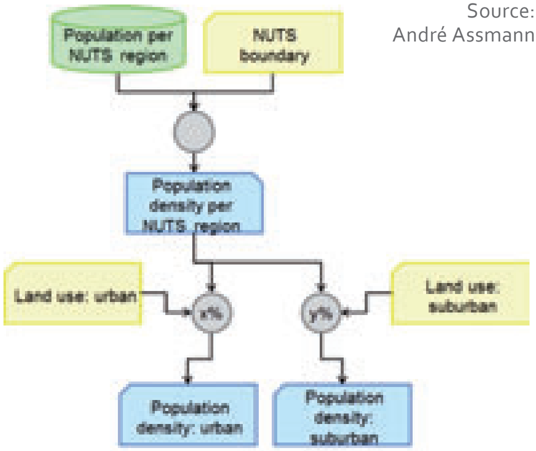
Further estimations are implied in the different calculation models by the values used to perform the calculation.



Source:
André Assmann

7.2.7. Population density

In case of a hazardous event the estimation of figures for the potentially affected population is of highest priority. Because the data availability is quite good, the statistical base figures only need to be allocated according to land use, under consideration of different density classes.

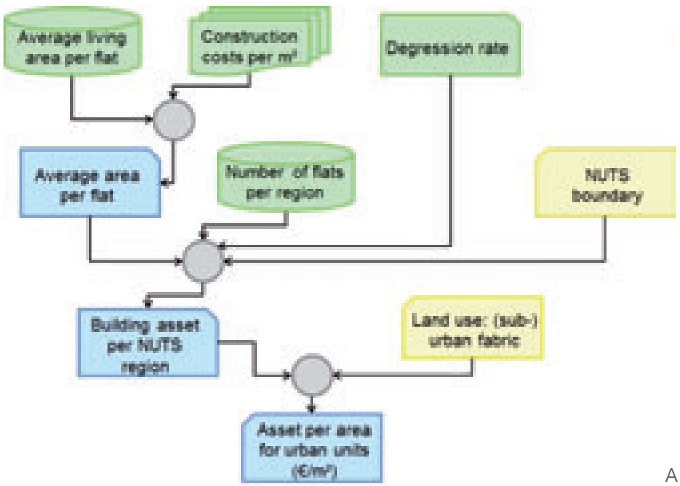


Source: André Assmann

7.2.8. Private housing

Private housing accounts for the largest portion of the total asset. The details of the processing are schematically displayed in the diagram below. The parameters are chosen mainly due to their general availability across Europe. Tests performed comparing the output with results from the more detailed input data (i.e. living area per NUTS region) have showed only little deviation.

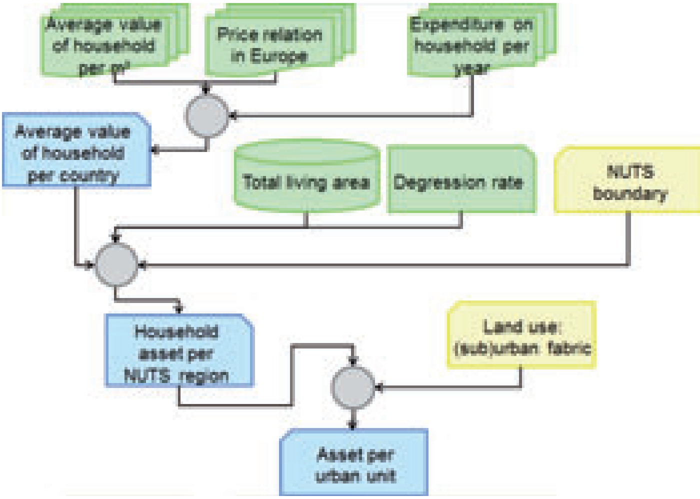
The approach considers only construction costs, additional values based on special locations (e.g. city centre) are not taken into account since they will endure natural disaster. Also the added value of a building could be considered to include the asset of the building ground, but this has been excluded in this approach.



Source: André Assmann

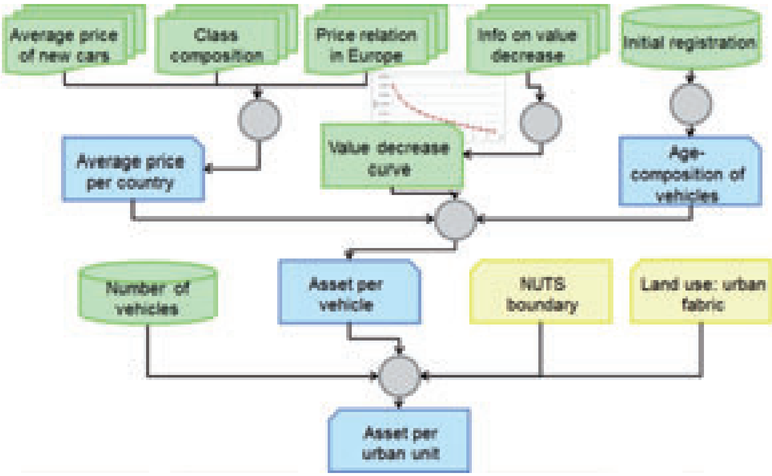
7.2.9. Household

Household assets are very difficult to capture as there is only little information available. The values that can be found for some countries (e.g. from the insurance sector) need to be transferred to other countries where this information is not available. Therefore the price index relation and the average expenditure on household goods are used for this purpose. The allocation is done by using the available information on the total living area under the assumption that the size of dwellings relates directly to the value of household assets - an assumption also made by the insurance industry.



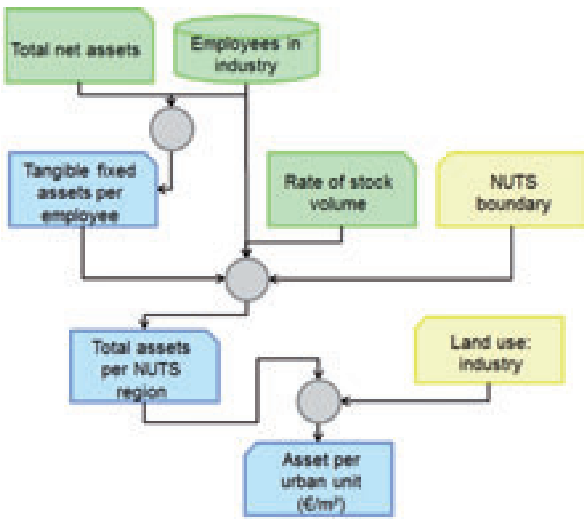
7.2.10. Vehicles

The vehicle assets layer covers cars and motorbikes. Other vehicles are mostly covered within the net asset value of the applicable economic sector. In this field of analysis the availability of data in the official statistics data is very poor. Therefore, the data (especially prices and information for the value decrease curve) had to be compiled from various other sources. Further details can be taken from the diagram below.



7.2.11. Industry: Buildings and equipment (net asset value, immobile)

For the buildings and equipment the total net asset value is provided by the national statistics accounts, generally only on national level. This value is distributed to the desired NUTS level by using the number of employees as an indicator and then in a further step by the land use. Here, not only the designated industrial areas are considered but also (to a lesser extent) the settlement area as some of the industry is located there.



7.2.12. Industry: Stock in trade (mobile)

As the stock in trade is no longer covered directly by the official statistics (as it was the case at least in some countries in the past), it has to be derived and updated from the last available figures and is now calculated as a percentage of the net asset value.

7.2.13. Service and trade: Buildings and equipment (net asset value, immobile)

The methodology is analogous to the one followed for the industrial assets, i.e. the totals for each country are collected from the statistics and subsequently disaggregated spatially based on land use information.

7.2.14. Service and trade: Stock in trade (mobile)

Again due to the non-availability of direct data the stock volume has to be estimated based on the net asset value. As the overall service sector has only a very little stock volume but the subsection of the trade-sector a quite large one, the relation of trade to the other services influences needs to be taken into account for the stock estimation. This relation ranges from about 3 to 10%.

7.2.15. Agriculture: Buildings and equipment (net asset value, immobile)

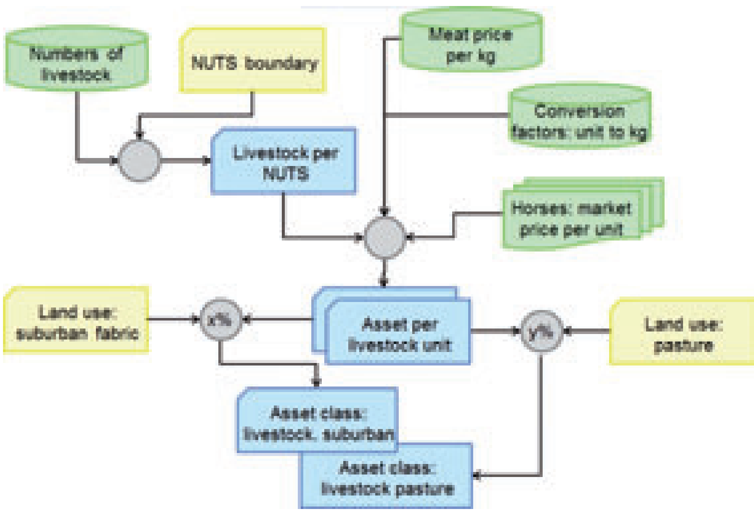
Also in the agricultural sector the asset disaggregation is performed using the employees' figures in this sector. The scheme is identical to the one used for the industry and service sector assets.

7.2.16. Agriculture: Stock in trade without livestock (mobile)

The agricultural 'stock in trade' can be divided into livestock and further stock. As the livestock covers the major share of the mobile assets and has to be allocated to different land use classes it needs to be separated from the other stock assets.

7.2.17. Agriculture: Livestock

Due to the very detailed agricultural statistics the livestock distribution is well

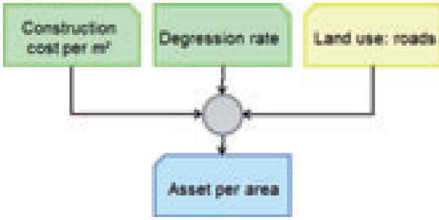


documented. By using national market prices which differ quite a lot between the countries the number of livestock can be converted into a monetary asset value. The disaggregation process is considering the relation between indoor breeding and grazing by assigning part of the asset to rural settlement areas and another part to the grassland.

7.2.18. Constant assets

Types of land use where the corresponding assets are not (or only partially) covered by the statistics figures are estimated by average construction or maintenance costs. For each land use class an appropriate value in €/m² has been derived from different publications and previous studies. External costs like planning costs, ecological compensation costs, construction permit etc. are not included.

All constant values are combined in one column of the value table, if needed they can be reallocated according to the underlying land use class.



7.3. Implementation of damage model in DFRP

It is proposed to use the BEAM methodology in the DFRP. Where available, national geo-referenced data may be used, otherwise the asset calculations as proposed here shall be applied.

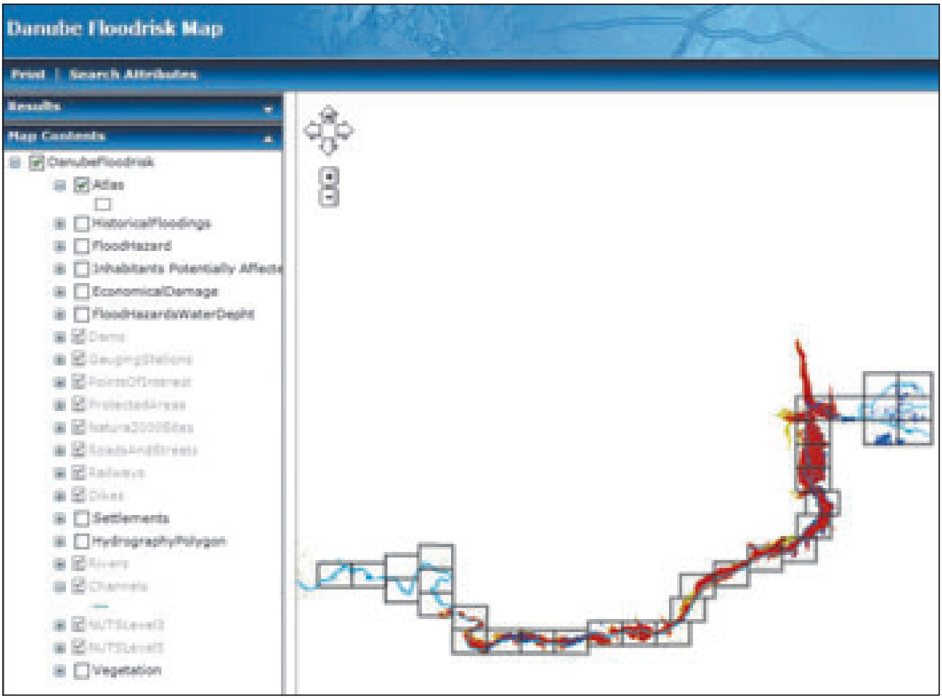
8. Geodatabase, outputs for the common methodology – application for the Danube Floodplain

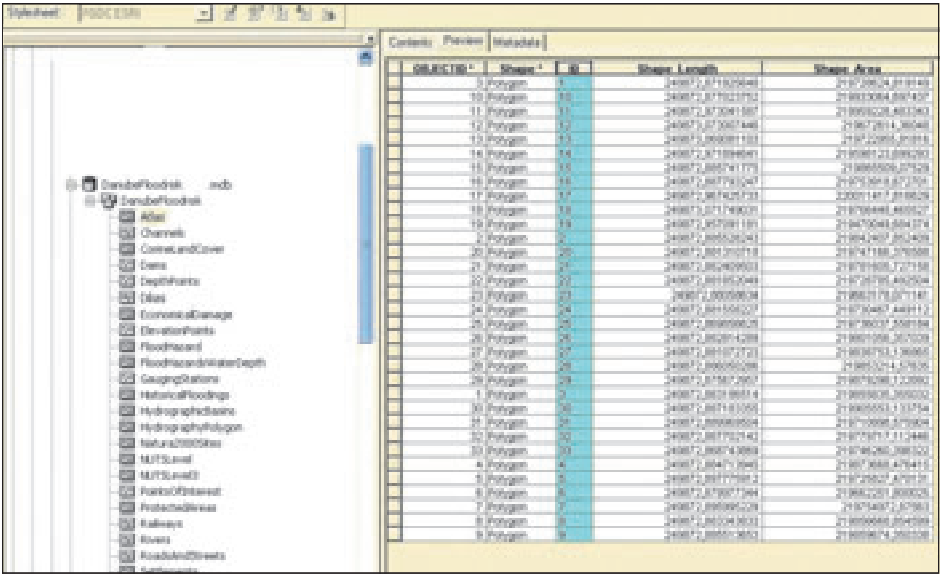
The common methodology defines all datasets needed as ESRI file Geo-databases in ETRS89 datum, with a significant buffer along the Danube river in order to be able to print on A3 format at 1:100.000 scale in LAEA5210 projection on ETRS89 datum. All the heights are provided in meters above the EVRS 2007 – European Vertical Reference System 2007. It is essential that no topological errors are allowed, as the spatial datasets need to be related to each other (i.e.: the dikes should not cross the rivers or lakes, rivers segments must be connected, etc). The methodology follows the INSPIRE Metadata Regulation 1205/2008, in relation to the scale/precision of the respective datasets.

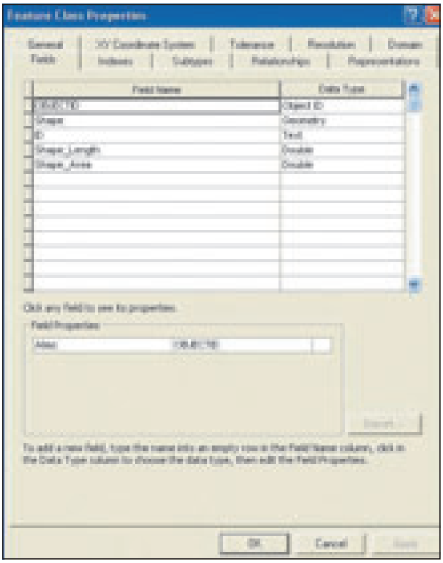
8.1. FEATURE CLASSES AND ATRIBUTES

Atlas – mandatory, polyline representing the Atlas A3 paper format at 1:100.000 scale in LAEA5210 projection on ETRS89 datum
– ID of Atlas page

Example: Atlas
Table preview
Feature Class Properties, filed name, data type







Rivers – polyline representing the "center" of the rivers, mandatory, provided as separate segments between tributaries (at least all those that are shown in the 1:100.000 national topographic map), digitised in the sense of flow; all the segments of the rivers must be connected; even if there is a lake on the river, the river must be represented as a continous feature on the bottom of the lake; the rivers dataset will include all the tributaries used to separate the segments.
– Name (in Latin script, mandatory; if the river is an arm of the river, than the name of the arm will be provided as name)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)

Channels – polyline representing the „center" of channels, mandatory; channels are considered all the linear hydrographical features, other than the rivers, that are usualy either disconnected from the rivers, or connected trough a weir or sluice, usualy used for dreinage or irrigations, sometimes for transportation or for diverting the water to another hydrographical system (usualy for producing energy or for water supply);

– Function (one of the following “N/A” – not assessed, “irrigation”, “drainage”, “transport”, “water adduction”)

HydrographyPolygon – polygon, mandatory for rivers, channels, arms and channels that are wider than 20 meters as well as the lakes that are shown in the 1:100.000 national topographic map. All the poligons should be topologicaly correct in the sense that they should not overlap and they should share the same lines if a common border exist. The lines from the HydrographicNetwork spatial dataset must be inside the HydrographyPolygon spatial dataset except if there is no corresponding polygon based on the rules set to create the poligons.
– Name (name of the river in own language but in Latin script, mandatory)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
– Type: “River” or “Channel” or “Lake” or “Islet”

Dams – point, large dams are mandatory, small dams are optional; partners shoud agree how to define large/small dams (can be in relation with height and length); for common understanding the dams are structures perpendicular to the rivers
– Name (in Latin script, mandatory if exist)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
– Height (optional)
– Length (optional)
– Material (one of the following values: “riprap” , “concrete” , “wood” , “earth” , “concrete steel” , “clay earth core” , “masonry”, “other material” , “unknown”), optional

Settlements – polygon, mandatory; all the settlements must be provided
– Name (in Latin script, mandatory)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
– Town (Yes/No – “Yes” if it is town, otherwise “No”, mandatory) N/A
– Population (mandatory, used to automatically estimate the number of inhabitants potentially affected)

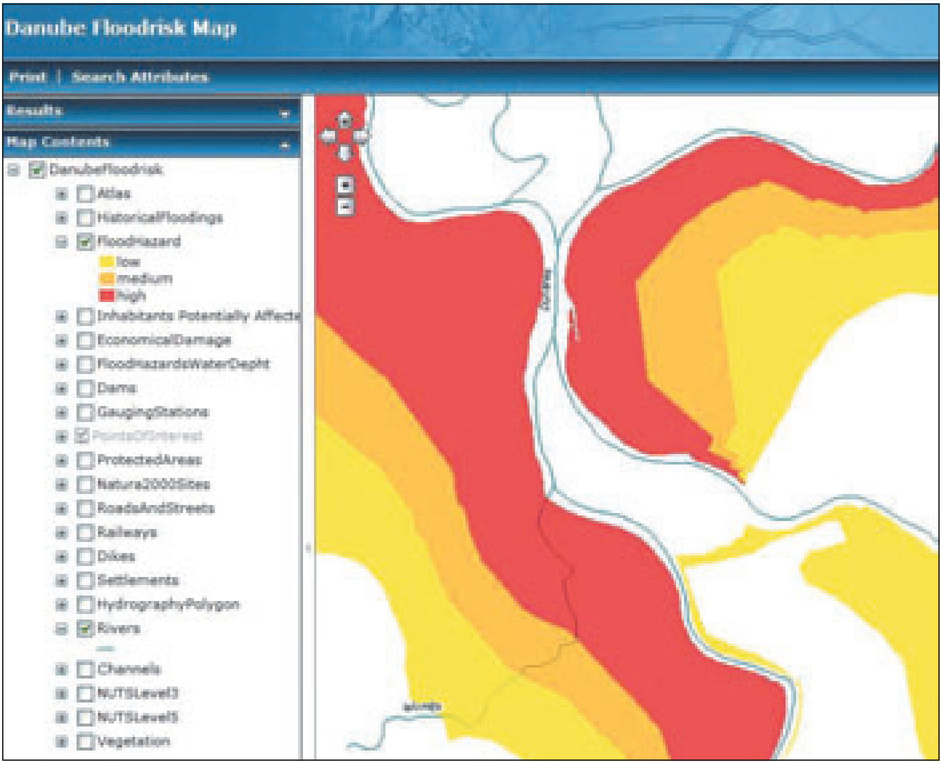
RoadsAndStreets – polyline, roads are mandatory, streets inside settlements are optional
– InternationalCode (i.e: “E81”, mandatory if the road has an international code)
– Code (i.e: “N7”, mandatory if the road has a national/regional/county code)
– StreetName (in Latin script, optional)
– StreetNameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
– Type (N/A, street, local, regional, national, international)

Railways – polyline, mandatory
– Main (Yes/No – “Yes” if the railway is a main railway, otherwise “No”, optional)

GaugingStations – point, mandatory, to be used for web-map, but not for printing atlas
– ZeroElevation (in meters, mandatory)
– Name (mandatory if exist)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)

HistoricalFloodings – poligon representing the maximum extent within the provided period, mandatory; if relevant, there can be provided different maximal extents of the same flood for different periods of time in order to ilustrate the evolution of the flood (in this case the EndFloodingDate must be the BeginFloodingDate for the next ilustration of the evolution of the flood)
– BeginFloodingDate (date, mandatory)
– EndFloodingDate (date, mandatory)

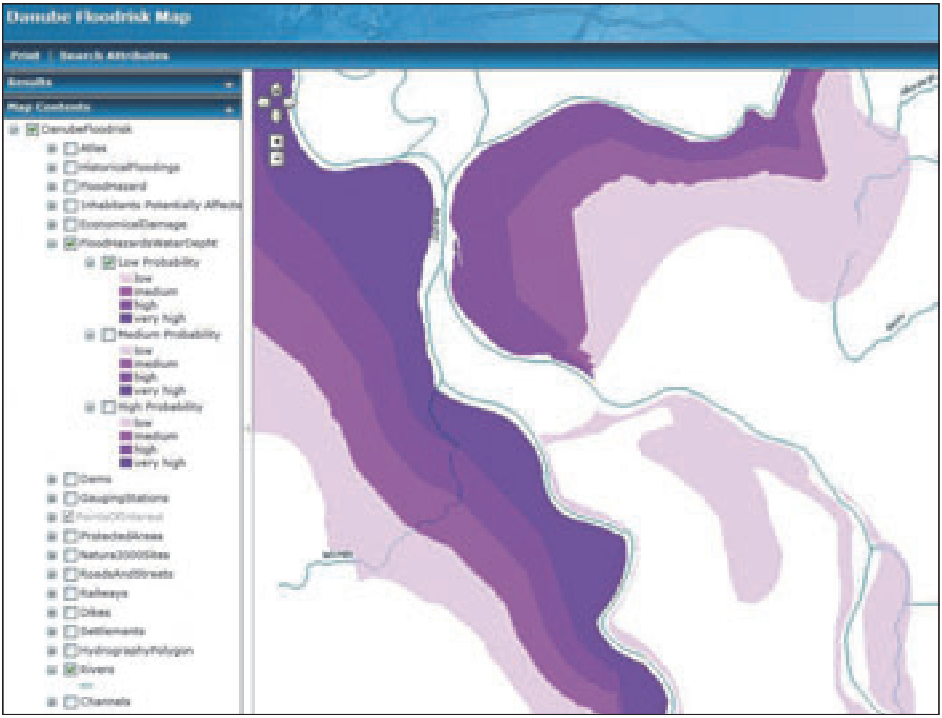
FloodHazards – polygons representing the maximal extent of the floodings mod-



Example: FloodHazard

eled based on the each flooding scenario, mandatory, one polygon or multipart polygon for each flooding
– Probability (one of the following values: “low”, “medium”, “high”, mandatory, partners will need to agree on a common understanding for these three categories of probabilities, i.e.: “medium” = 100 years)
– InhabitantsPotentiallyAffected (integer number – indicative number of inhabitants potentially affected, mandatory for each of the scenarios with probability “low”, “medium”and “high”)
– EconomicalActivitiesAffected (text listing the NACE codes of all economical activities potentially affected, separated by coma followed by a space. i.e.: “A1.02.07, A1.04.03”)

FloodHazardsWaterDepth – mandatory, same polygons as those from FloodHazards spatial dataset but splited based on water depth intervals (for each probability);
– Probability (one of the following values: “low”, “medium”, “high”, mandatory, partners will need to agree on a common understanding for these three categories of probabilities, i.e.: “medium” = 100 years)
– WaterDepth (one of the following values: “low”, “medium”, “high”, “very high”, mandatory, partners will need to agree on a common understanding of these four categories, i.e.: “low” = “<0.5m”)



Example: FloodHazardWaterDepht

Points Of Interest – points indicating the location of various points of interest, obligatory
– Name (optional)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
– Type (one of the following domain values: IPPC installation, airport, archeological site, children's home, cemetery, church, court, elderly peoples home, exhibition hall, fire brigade, freight terminal, gas tank, gas works, heating or cooling system, hospital, hotel, jail, kindergarten, library, livestock breeding, logistic hub, long-distance heating, monuments, museum, nuclear facilities, oil tank, oil/gas production, petrol station, police station, port areas, post office, power plant, production site with dangerous goods, pumping station, pumping station for water supply, radio/television station, recycling station, refinery, relay station, research institute, residential home, sanatorium, school, slaughterhouse, telecommunication, theater/opera, town hall, toxic release inventory sites, train station, underground mining, underground station, university, vehicle depot, waste disposal site, waste water treatment plant, water protection area, water sewage plant, water works, youth hostel, zoo.)

EconomicalDamage – polygons derived from isolines, mandatory, same polygons as those from FloodHazards spatial dataset but splited based on economical damage impact intervals (for each probability);

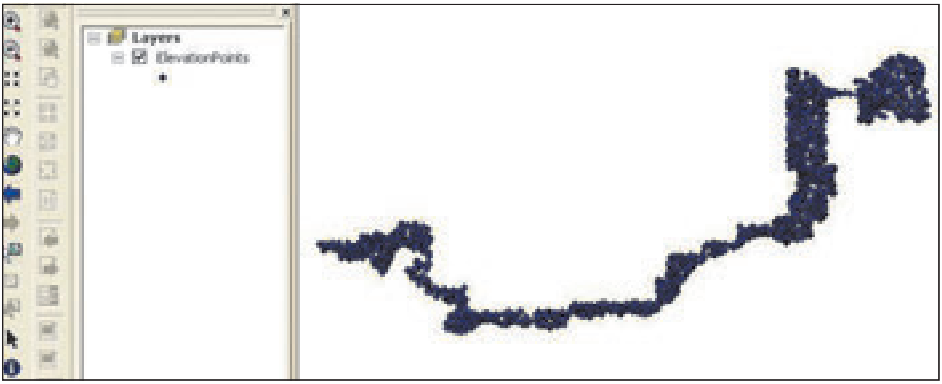
Example: EconomicalDamage

– Probability (one of the following values: "low", "medium", "high", mandatory, partners will need to agree on a common understanding for these three categories of probabilities, i.e.: "medium" = 100 years)
– EconomicalDamageImpact (one of the following values: "low", "medium", "high", "very high", mandatory, partners will need to agree on a common understanding of these four categories, i.e.: "low" = "<10 Euro/sqm")

The domain of the values can be extended and the list of types of the points of interest is decided for only those which are needed for the modeling. The location of all IPPC installations, is also an useful information to be used for the flood risk maps.

8.2 DATASETS FOR MODELLING

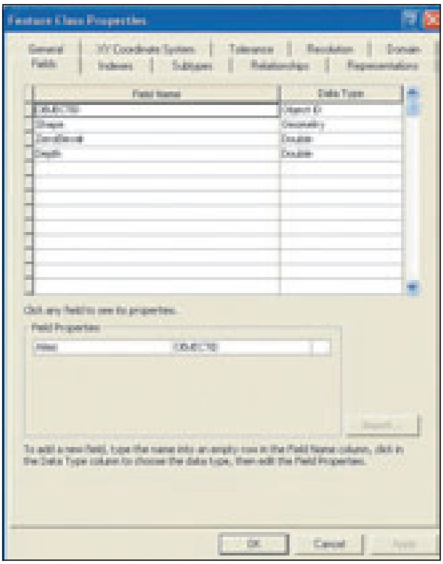
These type of datasets are not be publicly displayed, and are needed for the modelling.
– Elevation (in meters, mandatory)
– Name (in Latin script, mandatory if exist)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
* Elevation points on dikes and elevations along the country borders are important information.



Example: ElevationPoints

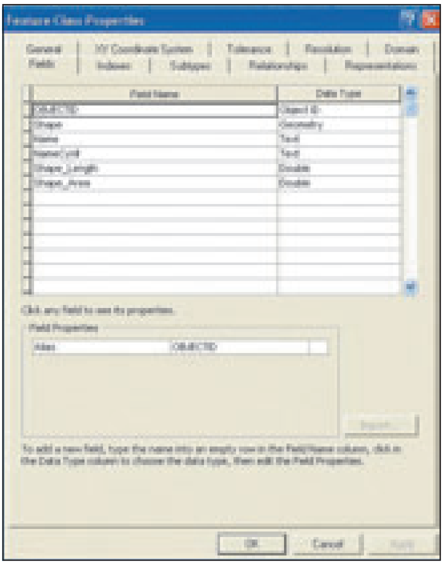
DepthPoints – point, optional for modelling, not for public display
– ZeroElevation (in meters, mandatory)
– Depth (in meters, mandatory, as difference between the Zero Elevation and the elevation of the bottom of the river or lake)

Example: DepthPoints



HydrographicBasins – polygon, optional, to be used for modelling, not for public display
– Name (in Latin script)

Example: HydrographicBasins



– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)

NUTSMaxLevel – polygon, mandatory at the highest level where statistical data exist (i.e.: In Romania Level 5)
– Name (in Latin script, mandatory)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
– Code (optional, according to http://simap.europa.eu/codes-and-nomenclatures/codes-nuts/codes-nuts-table_en.htm)

NUTSLevel3 – polygon, mandatory, sharing the same border with the NUTSMaxLevel spatial dataset
– Name (in Latin script, mandatory)
– NameCyrillic (in Cyrillic script for countries that are writing in Cyrillic, optional)
– Code (optional, national code if exist)

8.3. ADDITIONAL DATASETS

These type of datasets are available at the European Environmental Agency (EEA).

CorineLandCover – polygon, mandatory
– CLCcode (mandatory)
The spatial dataset from LandUse2010 where field ITEM is Forests, Green urban areas in Major Cities and from Corine Land Cover 2006 where field "Code_06" is 311, 312, 313 will be used as background (vegetation) in web-map and Atlas.

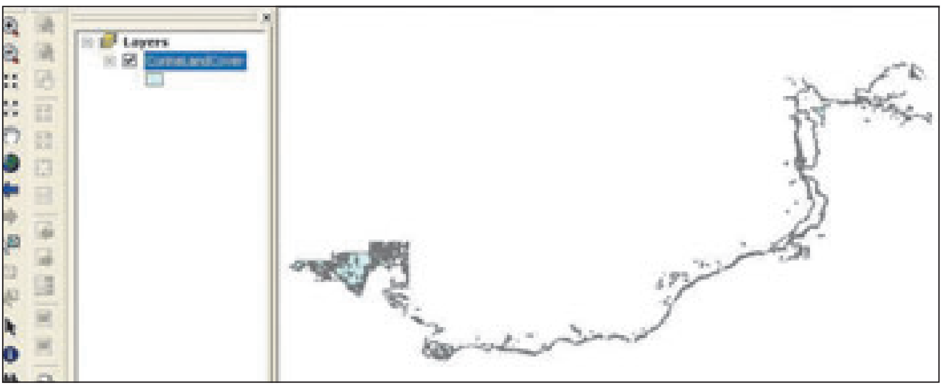
Natura2000Sites – polygon, mandatory
– SiteCode(mandatory)
– SiteName (in Latin script, mandatory)
– Type (one of the following values "SCI", "SPA","SCISPA", mandatory)

ProtectedAreas – polygon, mandatory
– Name (mandatory)
– Category (one of the following values indicating the IUCN category: I, II, III, IV, V, BiosphereReserve, RamsarSite)

As a conclusion, the described geodatabase will be used for the hazard and risk maps.

The printed format will also include information about roads, localities, symbols of the protected areas, critical infrastructure, economy and important cultural objectives.

Example: CorineLandCover



9. ANNEXES

Annex 1
SUB-WORKING GROUP HYDROLOGICAL ANALYSES
PROPOSED SCHEME OF STATION NETWORK OF THE DANUBE RIVER FOR FLOOD SIMULATION STUDIES

The proposed method is described in the listed references below. The given approach is proposed for national use in Hungary, as the result of the „Hydrological and Hydraulic Methodological Bases of Flood Hazard Mapping" project 2008-2011:

– Szilágyi J., Bálint G. and Csík A. (2006): Hybrid, Markov Chain-Based Model for Daily Streamflow Generation at Multiple Cachtment Sites. Journal of Hydrological Engineering, Vol.11., Issue 3., pp. 245-256.;

– Szilágyi J., Bálint G., Csík A., Gauzer B. and Horoszné Gulyás M. (2005): Simulation of the Superimposition of Floods in the Upper Tisza Region. NATO Sciences Series, Vol.72., pp. 171-182.).

Data requirements

Three types of hydrological stations compose the simulation scheme, with different data needs, namely:

– Upstream stations for Markov Chain Monte Carlo (MCMC) type of simulations of daily discharge series:

– Long observed daily discharge series are required with minimum length of 30-50 years.

– Flood routing stations:

– Observed 2-10 years of discharge and water level series, preferably covering the entire range of observed water levels, discharges, i.e. high and low water years. Additionally rating curve representing present day or designed future conditions. In case of sufficient station density observed water level time series can also be utilized to create "interpolated" rating curves and/or discharge series.

– Target stations, selected flood routing stations, which simulated discharge and/or water level "design" hydrographs are used as input and boundary conditions for hydrodynamic models:

– Data requirements are as at flood routing stations – minimum requirement. To check and validate flood frequency estimates received for simulated series additional long observed daily discharge series are beneficial (at least 30-50 years). In most cases monthly (or at least annual) maxima are sufficient.

The overall scheme

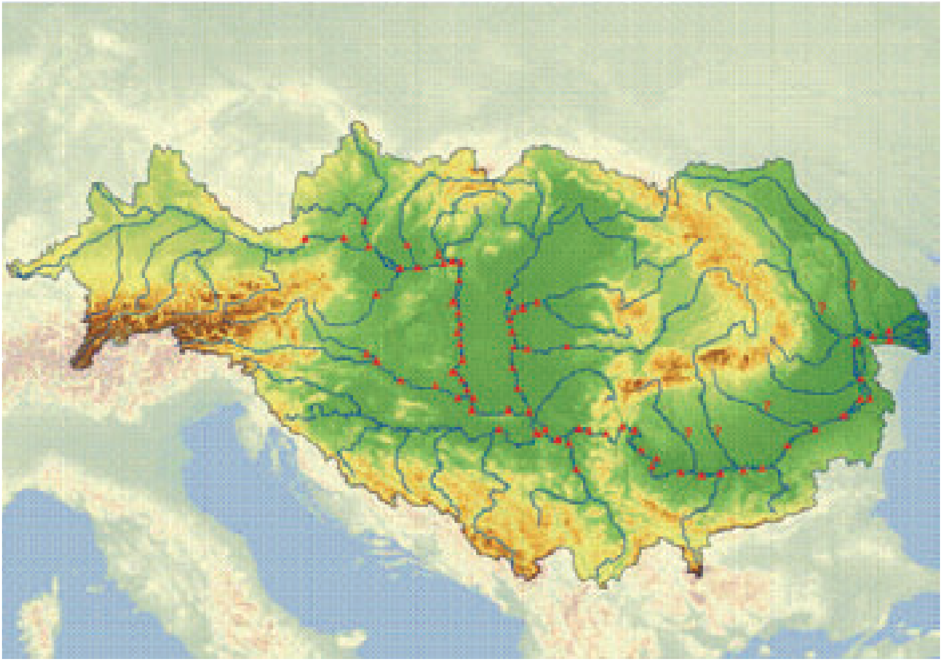


Figure 1: General scheme of the proposed station network for central and lower Danube reaches and tributaries

A consultation took place during the WG meeting and a preliminary agreement was reached regarding Austrian, Slovak (i.e. Austrian-Slovak, Slovak and Slovak–Hungarian) and Hungarian Danube reaches and river Drava. Although the Danube backwater does not influence the entire Drava downstream of the Mura confluence (a criterion set by the sub-group on hydraulic modeling), it was suggested that coincidence and superposition of floods on the two major streams of the Drava basin are to be also investigated to define design flood hydrographs. Some details of station network for tributary Tisza have been already discussed. Confirmation of the proposed network would be possible together with Serbian Danube reaches and tributaries Sava and Velika-Morava only after Serbian Republic Hydrometeorological Institute (RHMZ) actively joins the WG.

Based on the preliminary discussion it is proposed that only some of the tributaries of the Lower Danube are to be included. No details, like station selection on tributaries were defined, however it is clear that gauging sites outside of Danube backwater are needed (in the piedmont regions of Carpathians - and Balkan/Stara Planina if Bulgarian tributaries are also considered). The general scheme of the proposed station network for central and lower Danube reaches and tributaries is presented on *Fig. 1*. Hydrometric stations in international near real-time data exchange were mostly considered.

The central Danube and Drava scheme

A scheme of the proposed station network for the central Danube and Drava and tributaries is presented on *Fig. 2* and *Table 1*. The upper limit can be set at Kienstock or Vienna (Korneuburg).

The Tisza scheme

A scheme of the proposed station network for the lower Tisza and tributaries is presented on *Fig. 3* and *Table 2*. Downstream boundary conditions can be simulated directly to Titel station, while the other option is based on Danube stations, either or both on Novi Sad and Zemun.

The Danube scheme upstream of the Iron Gate

A scheme of the proposed station network for the Danube upstream of the Iron Gate is presented on *Fig. 4* and *Table 3*. Downstream boundary conditions can be given at the Iron Gate.

The lower Danube scheme

A scheme of the proposed station network for the lower Danube is presented on *Fig. 5* and *Table 4*. Only tributaries are named no stations are proposed. A separate scheme can be created downstream of the Olt mouth.

Figure 2 Scheme of the proposed station network for the central Danube and Drava and tributaries

Table I Scheme of the proposed station network for the central Danube and Drava reaches and tributaries

HYDRA code	Station	River	River/ chainage km	Type of station Y- yes; N - no; P - possible			Remarks
				Upstream	Routing	Target	
242011	Kienstock	Danube	2015.2	Y	N	N	
242013	Korneuburg	Danube	1941.4	P	Y	N	
142301	Devin	Danube	1879.8	P	Y	N	
142306	Medvedov	Danube	1806.3	P	Y	P	/Nagybajcs
442502	Nagybajcs	Danube	1801.0	P	Y	P	/Medvedov
442514	Ragyogóhíd	Rába	73.4	Y	N	N	
442522	Komárom	Danube	1768.3	P	Y	P	
142479	Sala	Váh	33.9	Y	N	N	
142538	Kamenin	Hron	10.9	Y	N	N	or else ? Nova Bana?
442025	Esztergom	Danube	1718.5	N	Y	P	
442527	Nagymaros	Danube	1694.6	P	Y	Y	
442026	Vác	Danube	1679.5	N	Y	Y	
442027	Budapest	Danube	1646.5	P	Y	Y	
442535	Adony	Danube	1597.8	N	Y	Y	
442028	Dunaújváros	Danube	1580.6	N	Y	Y	
442029	Dunaföldvár	Danube	1560.6	N	Y	Y	
442030	Paks	Danube	1531.3	N	Y	Y	
442540	Dombori	Danube	1506.8	N	Y	Y	
442031	Baja	Danube	1478.7	P	Y	Y	
442032	Mohács	Danube	1446.8	P	Y	Y	
542010	Bezdan	Danube	1425.5	N	Y	P	
542015	Apatin	Danube	1401.4	N	Y	P	
446501	Letenye	Mura	35.6	Y	N	N	
446198	Őrtilos	Dráva	235.9	Y	Y	P	'Dummy' station only Drava flow without Mura is accounted alternative station: Botovo
446199	Barcs	Dráva	154.1	N	Y	P	/Terezino Polje
446502	Szentborbás	Dráva	133.1	N	Y	P	
446503	Drávaszabolcs	Dráva	77.7	P	Y	P	/Donji Mihojlac
546090	Osijek(Belisce)	Dráva	19.2	P	Y	P	
542020	Bogojevo	Danube	1367.4	P	Y	Y	

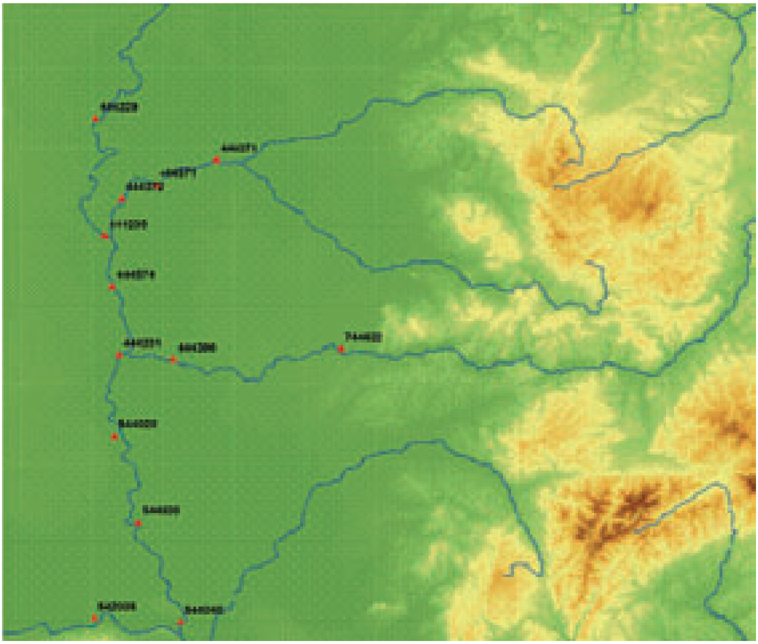


Figure 3
Scheme of the proposed station network for the lower Tisza and tributaries

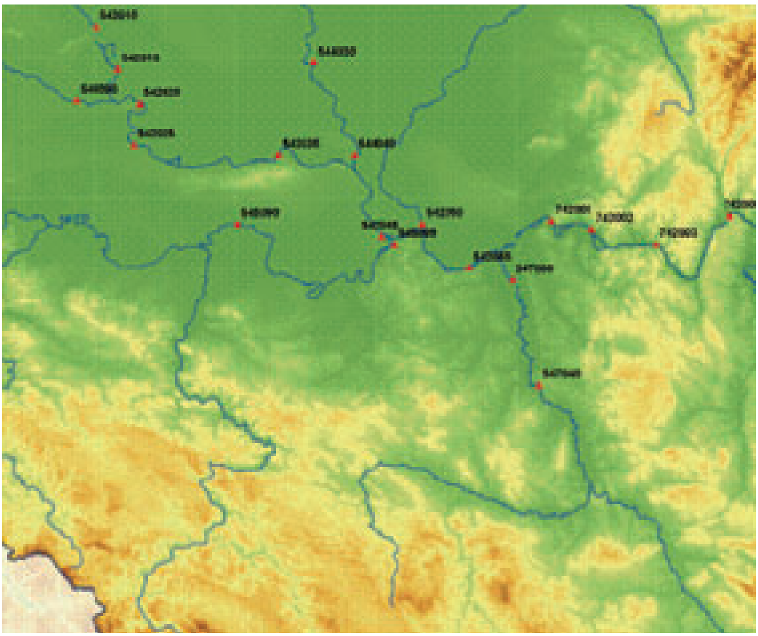


Figure 4
Scheme of the proposed station network for Danube and tributaries upstream of the Iron Gate

Table 2 Scheme of the proposed station network for river Tisza and tributaries

HYDRA code	Station	River	River/ chainage km	Type of station Y- yes; N - no; P - possible			Remarks
				Upstream	Routing	Target	
542035	Novi Sad	Danube	1255.1	Y	N	N	
444229	Szolnok	Tisza	334.6	Y	N	N	
444230	Csongrád	Tisza	246.2	N	Y	Y	
444371	Gyoma	H-Körös	79.2	Y	N	N	
444571	Békéssztandrás	H-Körös	47.48	N	Y	P	
444372	Kunszentmárton	H-Körös	21.1	N	Y	P	
444574	Mindszent	Tisza	217.7	N	Y	Y	
744622	Arad	Mures	97.0	Y	N	N	
444396	Makó	Maros	24.5	P	Y	N	
444231	Szeged	Tisza	173.6	P	Y	Y	
544020	Senta	Tisza	123.4	P	Y	Y	
544030	Novi Becej	Tisza	65.1	N	Y	Y	
544040	Titel	Tisza	9.5	P	Y	P	
542045	Zemun	Danube	1172.9	P	Y	N	

Table 3 Scheme of the proposed station network for the Danube reaches upstream of the Iron Gate and tributaries

HYDRA code	Station	River	River/ chainage km	Type of station Y- yes; N - no; P - possible			Remarks
				Upstream	Routing	Target	
442031	Baja	Danube	1478.7	P	N	N	
442032	Mohács	Danube	1446.8	P	Y	N	
542010	Bezdan	Danube	1425.5	P	Y	P	
542015	Apatin	Danube	1401.4	N	Y	P	
446503	Drávaszabolcs	Dráva	77.7	P	Y	P	/Donji Mihojlac
546090	Belisce	Dráva	19.2	P	Y	P	
542020	Bogojevo	Danube	1367.4	P	Y	P	
542025	Vukovar	Duna	1336.5	N	Y	P	
542035	Novi Sad	Danube	1255.1	N	N	P	
444231	Szeged	Tisza	173.6	P	Y	N	
544020	Senta	Tisza	123.4	P	Y	N	
544030	Novi Becej	Tisza	65.1	N	Y	N	
544040	Titel	Tisza	9.5	N	Y	P	
542045	Zemun	Danube	1172.9	P	Y	P	
545090	Mitrovica	Sava	136	Y	N	P	or Sabac
	Sabac	Sava		P	Y	P	
545099	Belgrad	Sava	0.5	N	Y	P	
542050	Pancevo	Danube	1153.3	N	Y	P	
542055	Smederevo	Danube	1116.2	N	Y	P	
547040	Bagrdan	V Morava	154	P	N	N	or Ljubicevski Most
547090	Ljubicevski Most	V Morava	34.8	Y	P	N	
742001	Bazias	Danube	1072.5	N	Y	P	
742002	Moldova Veche	Danube	1049	N	Y	P	
742003	Drencova	Danube	1015.8	N	Y	P	
742005	Orsova	Danube	955	N	N	P	

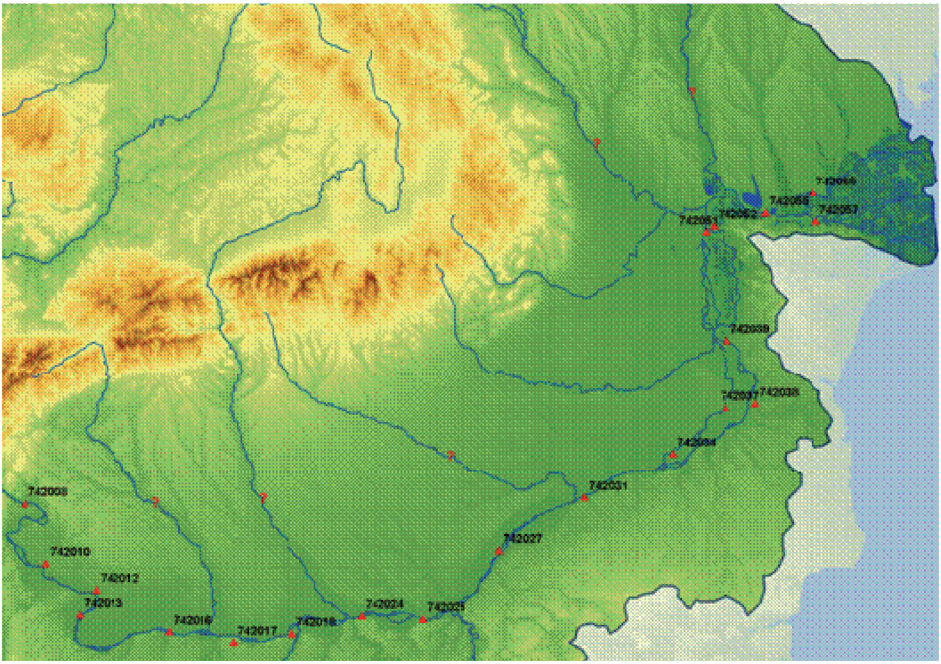


Figure 5 Scheme of the proposed station network for the lower Danube and tributaries

Table 4 Scheme of the proposed station network for the lower Danube reaches and tributaries

HYDRA code	Station	River	River/ chainage km	Type of station Y- yes; N - no; P - possible			Remarks
				Upstream	Routing	Target	
742005	Orsova	Danube	955.0	Y	N	N	or Turnu Severin
742008	Turnu Severin	Danube	931.1	P	Y	P	
742010	Gruia	Danube	851.0	N	Y	P	
742012	Cetatea	Danube	811.0	N	Y	P	no measurements
742013	Calafat	Danube	795.0	N	Y	P	
742016	Bistret	Danube	725.0	N	Y	P	no measurements
742231	Podari	Jiu	77.0	Y	N	N	
742017	Bechet	Danube	679.0	N	Y	P	
742018	Corabia	Danube	630.0	N	Y	P	
	?	Iskar		Y	N	N	
9124	Stoenesti	Olt	68.0	Y	N	N	no measurements
742024	Turnu Magurelle	Danube	597.0	N	Y	P	
742025	Zimnicea	Danube	554.0	N	Y	P	
742027	Giurgiu	Danube	493.0	N	Y	P	
742514	Budesti	Arges	31.0	Y	N	N	
742031	Oltenita	Danube	430.0	P	Y	P	
742034	Calarasi	Danube	365.0	P	Y	P	
742038	Cernavoda	Danube	300.0	P	Y	P	
742036	Fetesti	Danube	43.0	P	Y	P	
742615	Slobozia	Ialomita	77.0	Y	N	N	
742039	Hirsova	Danube	252.0	N	Y	P	
742051	Braila	Danube	170.0	N	Y	P	
742714	Lungoci	Siret	76.0	Y	N	N	
742659	Banita	Buzau	135.0	Y	N	N	
742052	Galati	Danube	150.0	N	Y	P	
742967	Oancea	Prut	79.0	Y	N	N	
742055	Isaccea	Danube	102.0	N	Y	P	
742057	Tulcea	Danube	72.0	N	Y	P	
742058	Ceatal Ismail	Danube	0.0	Y	N	N	

ANNEX 2

I. Case Study – Mohács Gauge Station

Using the Synthetic Flood Procedure, a statistical processing of the floods registered at Mohács gauge station (Hungary) was performed. To obtain the uncertainty interval the maximum annual discharges were analysed, while for obtaining the synthetic floods (characterized not only by the maximum discharge, but also by their shape, duration, increasing time and volume) only the floods over a threshold (discharges corresponding to the warning level) were taken into consideration. The computer code FloodUTCB realized in UTCB was used for the separation of the significant floods. The flood characteristics (maximum discharge, volume, increasing time and total duration of the floods) for the registered floods were computed automatically.

The maximum annual discharges for the period 1924-2008 are presented in Figure 8. One can notice that the registered values are in the range 2720 m^3/s (in 1934) and 8240 m^3/s.

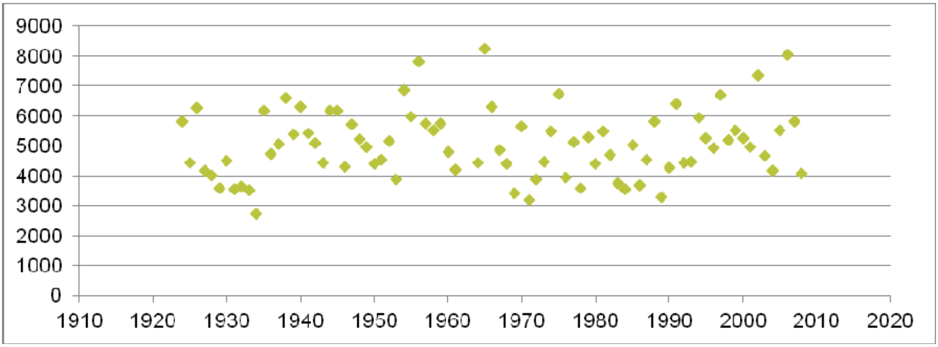


Figure 8 Maximum annual discharges at MohacsMohács gauge station

The uncertainty intervals for the maximum annual discharges and the corresponding volumes were computed using 10 distribution functions (Figure 9 and Figure 10).

P%	Discharges [mc/s]										Interval	
	LogGamma	JohnsonSB	GenGamma	FatigueLife	Gamma(3P)	Lognormal	GenExtreme	Weibull	FatigueLife	Pearson5 (2P)	Min	Max
0.1	9991	9257	9343	9653	9579	9807	9359	8964	9653	10667	8964	10667
0.5	8851	8487	8493	8664	8628	8744	8565	8281	8664	9238	8281	9238
1	8349	8112	8096	8216	8193	8271	8173	7950	8216	8635	7950	8635
3	7527	7446	7412	7465	7459	7489	7475	7360	7465	7678	7360	7678
5	7127	7099	7064	7092	7092	7105	7114	7049	7092	7228	7049	7228
10	6555	6578	6547	6550	6555	6552	6577	6573	6550	6599	6547	6599
20	5929	5975	5954	5945	5951	5940	5966	6004	5945	5931	5929	6004
25	5708	5755	5739	5728	5734	5722	5746	5791	5728	5700	5700	5791
30	5517	5563	5551	5540	5545	5534	5555	5602	5540	5503	5503	5602
40	5189	5229	5222	5215	5218	5209	5225	5267	5215	5170	5170	5267
50	4902	4932	4930	4928	4929	4923	4933	4961	4928	4882	4882	4961
60	4632	4650	4651	4656	4654	4653	4656	4666	4656	4616	4616	4666
70	4360	4367	4369	4381	4377	4380	4376	4364	4381	4351	4351	4381
75	4217	4218	4220	4236	4231	4236	4228	4204	4236	4213	4204	4236
80	4064	4059	4061	4079	4074	4081	4069	4033	4079	4067	4033	4081
90	3689	3672	3673	3695	3690	3699	3674	3623	3695	3713	3623	3713
95	3408	3388	3388	3405	3404	3411	3373	3334	3405	3451	3334	3451
97	3237	3220	3221	3230	3232	3236	3189	3173	3230	3294	3173	3294

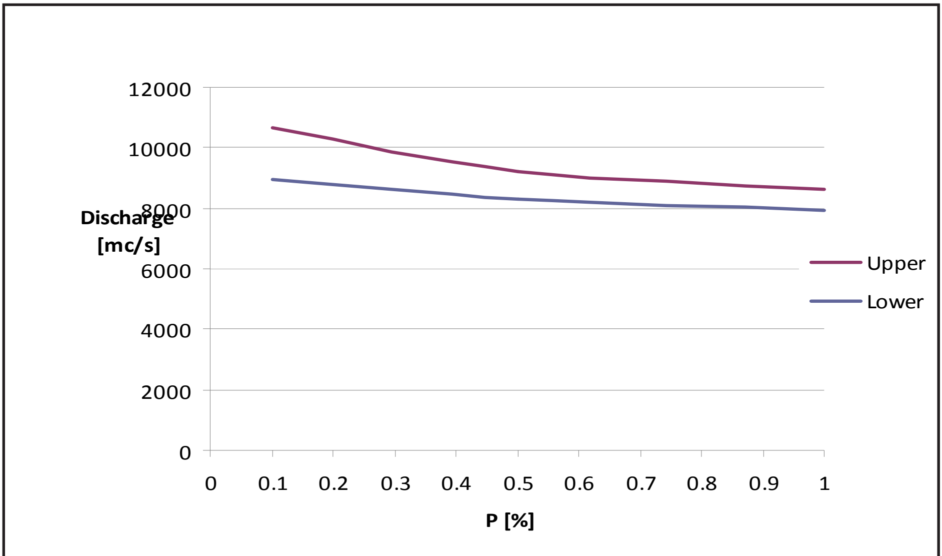


Figure 9
Uncertainty interval of the maximum annual discharges

P%	Volume [Million cubic meters]								Interval	
	LogGamma	GenExtreme	Pearson6	Pearson5	Lognormal	Lognormal	Burr	InvGaussian	Min	Max
0.1	98629	92220	92070	92071	81378	74206	101852	73810	73810	101852
0.5	63863	58299	58521	58515	56081	52335	60029	54551	52335	63863
1	51929	47287	47554	47548	46817	44165	47632	46621	44165	51929
3	36118	33160	33397	33392	33912	32589	32669	34629	32589	36118
5	29899	27724	27915	27910	28589	27729	27195	29341	27195	29899
10	22449	21261	21367	21363	21979	21604	20874	22514	20874	22514
20	15980	15623	15636	15634	15985	15939	15478	16143	15478	16143
25	14072	13935	13921	13920	14164	14190	13870	14196	13870	14196
30	12566	12587	12552	12551	12706	12779	12580	12643	12551	12779
40	10266	10484	10427	10427	10443	10565	10556	10256	10256	10565
50	8521	8836	8774	8774	8693	8831	8948	8446	8446	8948
60	7090	7432	7380	7380	7237	7369	7556	6975	6975	7556
70	5841	6147	6121	6122	5948	6058	6261	5710	5710	6261
75	5253	5516	5511	5512	5336	5428	5618	5123	5123	5618
80	4672	4872	4895	4895	4728	4799	4957	4552	4552	4957
90	3450	3417	3535	3536	3438	3443	3468	3378	3378	3536
95	2701	2426	2642	2642	2643	2589	2486	2681	2426	2701
97	2310	1862	2149	2148	2228	2137	1960	2325	1862	2325

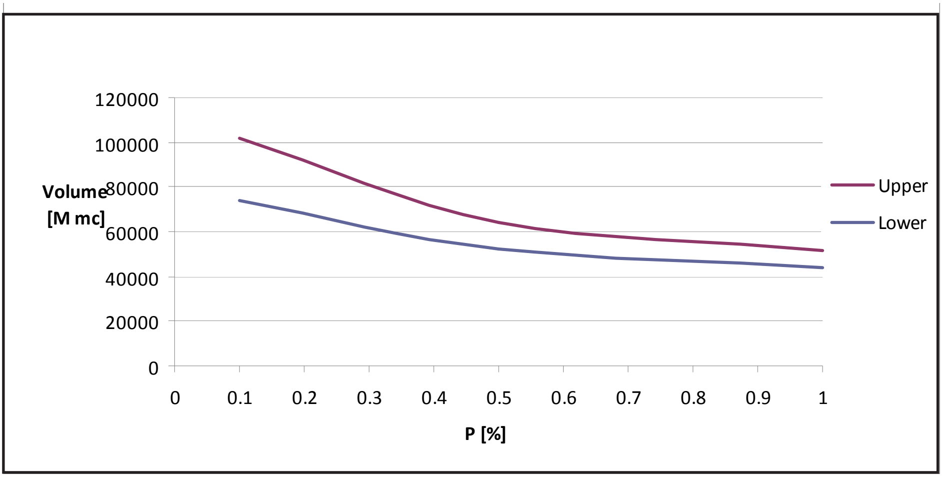


Figure 10
Uncertainty interval
of the floods volume

Using the software FloodUTCB, the daily data discharges during floods were selected. The warning threshold was considered 3900 m^3/s, while all selected floods in order to define the shape of the flood hydrograph have their peak values greater than 4800 m^3/s. As mentioned, the floods characteristics are computed automatically. The obtained results are presented in the Table 1.

Table I – Floods parameters

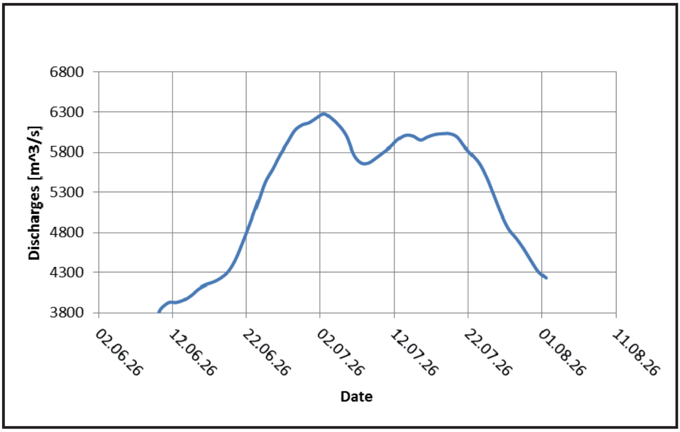
Nr.Flood	Date	Discharge Max[mc/s]	Volume [M mc]	Tg [day]	Tt [day]	Class
1	5/4/1924 8:12	5810	14321.5	13.15789	34.15789	2
2	6/11/1926 1:42	6280	32526.81	21.42858	72.47206	6
3	2/19/1935 23:08	6170	1134.155	1.535486	2.610752	4
4	3/4/1937 23:00	5060	20389.67	15.54167	52.65278	6
5	1/18/1938 0:19	6600	3571.148	3.486481	8.653148	3
6	5/26/1939 18:21	4910	4896.888	4.735289	12.4972	2
7	12/3/1939 8:18	5370	7096.164	7.153843	17.48718	3
8	3/8/1940 4:36	6310	17503.54	13.3077	39.52992	7
9	6/4/1940 4:48	5850	7048.814	7.3	16.3	3
10	2/20/1941 13:07	5120	4017.997	0.953125	10.35313	1
11	3/8/1941 15:33	5420	7161.37	8.851852	17.16764	4
12	3/30/1941 15:16	4890	13341.26	7.863634	34.11363	2
13	3/11/1942 15:41	5080	14836.2	17.84616	38.22116	8
14	4/11/1944 16:48	6160	12215.4	14.8	26.8	4
15	6/20/1944 12:00	5060	6564.318	8	17.18182	3
16	2/10/1945 11:34	6160	8487.481	4.017859	20.01786	2
17	3/17/1947 18:47	5720	10522.98	11.71698	24.18365	3
18	1/7/1948 12:00	4830	7003.975	6	18.72727	9
19	2/12/1948 20:00	4970	4916.512	6.666667	12.48148	4
20	7/14/1948 3:00	5210	9330.057	11.375	23.03289	3
21	8/20/1949 9:32	4960	2958.895	4.102569	7.542569	4
22	3/28/1952 20:16	5170	13817.37	10.65517	34.56426	9
23	7/8/1954 14:40	6860	12153.23	14.88889	26.07639	4
24	3/30/1955 10:20	5440	4005.967	5.06897	9.56897	4
25	4/14/1955 8:00	5300	5105.904	5.166667	12.61111	3
26	7/13/1955 9:10	5970	8969.095	7.11765	21.00654	9
27	8/4/1955 20:00	4940	6592.32	11.66667	17.33333	5
28	3/10/1956 15:40	7810	4310.584	2.84662	7.933576	2
29	7/27/1957 23:24	5760	5263.049	7.525	11.93963	5
30	2/20/1958 8:48	5020	6450.612	4.133333	16.29333	9

Nr.Flood	Date	Discharge Max[mc/s]	Volume [M mc]	Tg [day]	Tt [day]	Class
31	7/3/1958 11:36	5520	4957.927	4.016667	11.85	2
32	6/18/1959 2:49	5410	3976.825	4.38235	9.735289	3
33	7/5/1959 0:34	5060	3149.85	3.476192	7.930741	3
34	7/22/1959 6:40	4830	3010.574	5.222222	8.042731	5
35	8/18/1959 7:48	5740	3939.408	4.174606	9.080266	3
36	7/29/1960 6:54	4800	2794.509	3.503785	7.299074	3
37	5/18/1962 2:24	5130	11014.57	13.69167	27.28	7
38	3/17/1963 6:47	4810	5370.69	9.216829	13.71683	10
39	3/26/1965 17:45	5190	8282.228	9.551667	21.01	3
40	4/26/1965 0:28	8240	55259.39	54.27167	111.1467	8
41	2/12/1966 8:18	5130	4739.265	5.153843	11.77289	3
42	7/1/1966 7:00	6320	31338.54	33.5	74.20833	11
43	6/4/1967 14:24	4870	9313.618	12.69167	24.9	10
44	3/27/1970 14:34	5080	8852.365	4.892859	23.05953	2
45	4/21/1970 7:08	5420	17065.01	11.49405	41.83875	9
46	6/5/1970 16:14	4950	9245.175	12.6152	24.37909	10
47	8/14/1970 14:56	5650	7905.646	5.168854	19.12719	9
48	12/10/1974 6:40	5500	6770.117	7.055556	16.64328	3
49	1/1/1975 13:36	5030	5141.764	4.926389	13.21905	2
50	7/2/1975 2:24	6740	14567.69	10.525	32.44167	2
51	2/12/1977 2:40	5120	13467.24	6.222222	34.18889	12
52	6/22/1979 5:13	5280	5061.73	5.073715	12.55478	3
53	3/15/1981 8:55	5490	5491.598	5.419873	13.12821	3
54	7/25/1981 3:51	5460	4511.125	5.130949	10.77519	3
55	8/11/1985 21:20	5040	2992.152	3.402778	7.555556	3
56	3/24/1988 9:00	5800	14741.53	10.41667	34.83928	9
57	8/4/1991 7:00	6400	5784.12	7	12.83333	5
58	4/17/1994 2:20	5950	7237.272	6.694444	16.58333	3
59	6/5/1995 3:00	5260	13841.59	8.541667	34.29167	14
60	9/3/1995 22:00	4890	2785.758	3.75	7.138889	4
61	5/17/1996 10:00	4940	3387.204	2.875	8.875	2

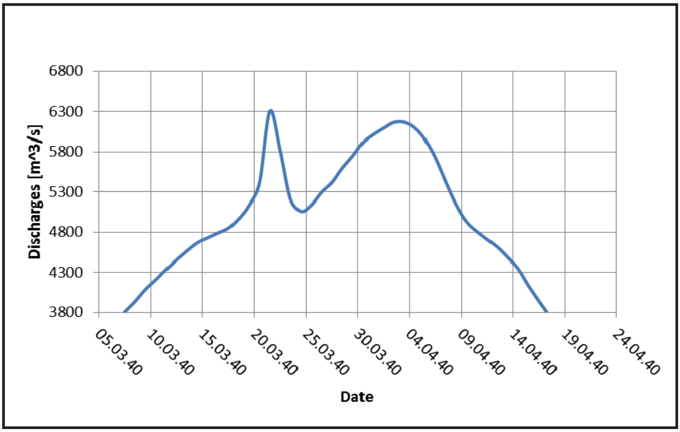
Nr.Flood	Date	Discharge Max[mc/s]	Volume [M mc]	Tg [day]	Tt [day]	Class
62	10/25/1996 17:00	4800	1812.552	1.958333	4.694444	3
63	7/10/1997 9:00	6690	13532.97	16.91667	28.74167	10
64	11/2/1998 4:00	5190	7738.533	14.16667	19.5625	13
65	2/24/1999 12:30	4870	2313.86	2.9375	5.947917	3
66	3/5/1999 6:24	5370	6525.965	4.525	16.025	2
67	5/12/1999 5:15	5530	11599.41	18.61458	28.57292	10
68	3/12/2000 19:30	5270	13389	24.10417	32.95833	13
69	3/26/2001 4:30	4960	3490.506	3.604167	8.791667	3
70	3/24/2002 9:15	6300	4526.507	4.697917	9.795139	3
71	8/11/2002 4:32	7370	7956.66	10.06079	16.2703	5
72	11/7/2002 18:58	4800	5748.166	9.500833	15.50083	10
73	3/21/2005 21:45	5320	6957.197	2.885417	16.45486	1
74	7/14/2005 1:20	5310	2654.025	3.361111	6.465278	4
75	8/26/2005 8:20	5530	3399.078	4.319444	7.972222	4
76	3/29/2006 8:15	8050	21141.36	9.40625	44.26042	9
77	5/31/2006 5:00	5800	6024.822	8.5	13.93056	5
78	8/10/2006 15:15	5060	2001.377	2.15625	5.045139	3
79	9/10/2007 0:30	5810	4334.046	4.895833	9.576389	4

Some of the selected floods are presented in Figure 11 in order to show the shape differences of the registered hydrographs.

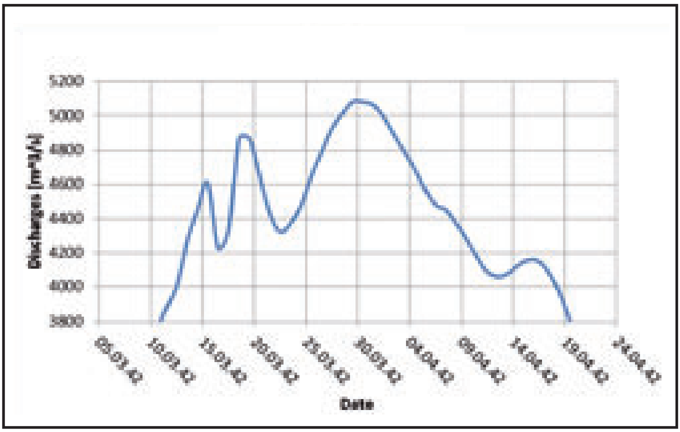
1926



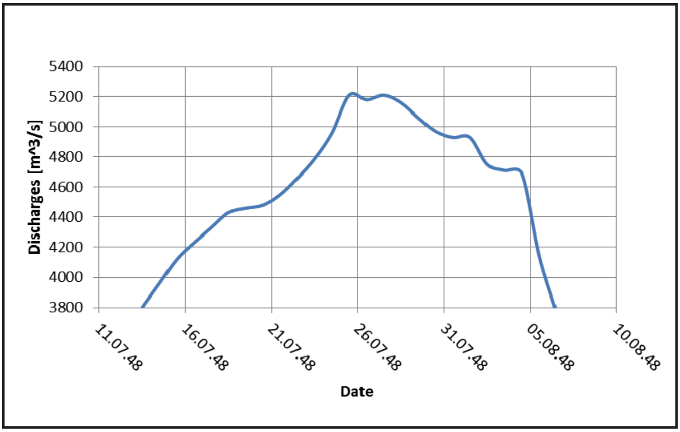
1940



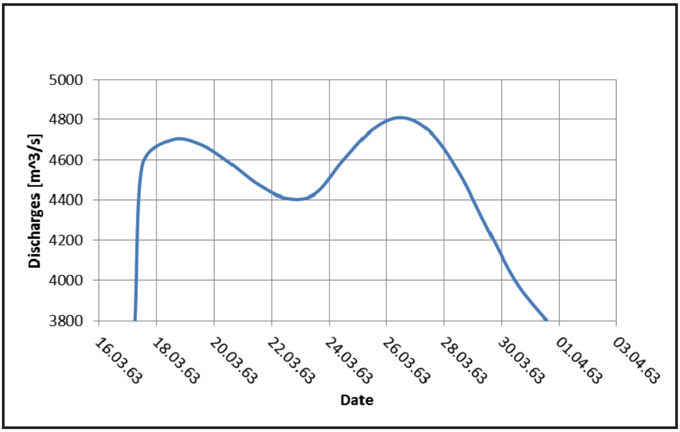
1942



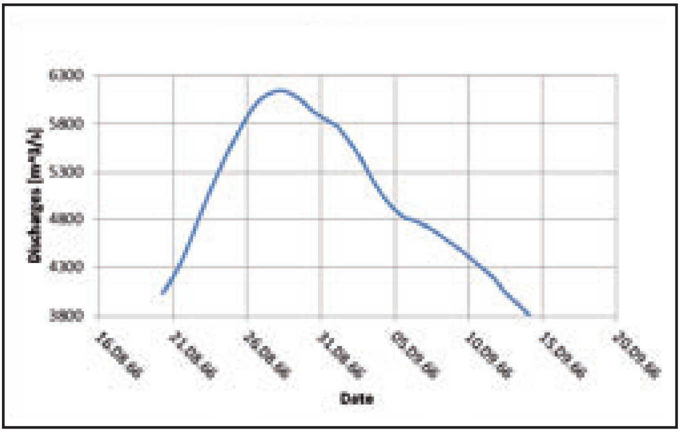
1948



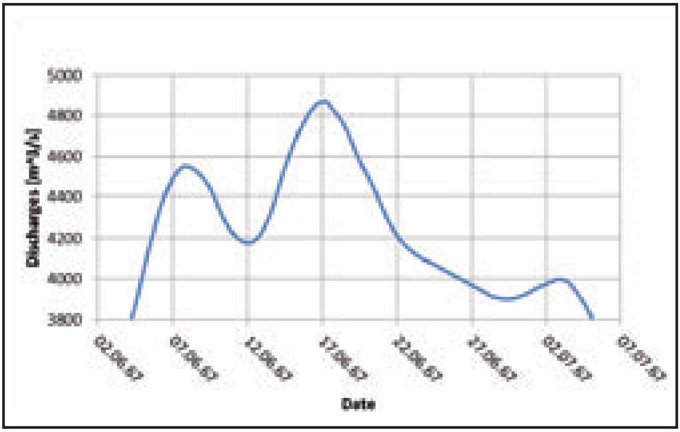
1963



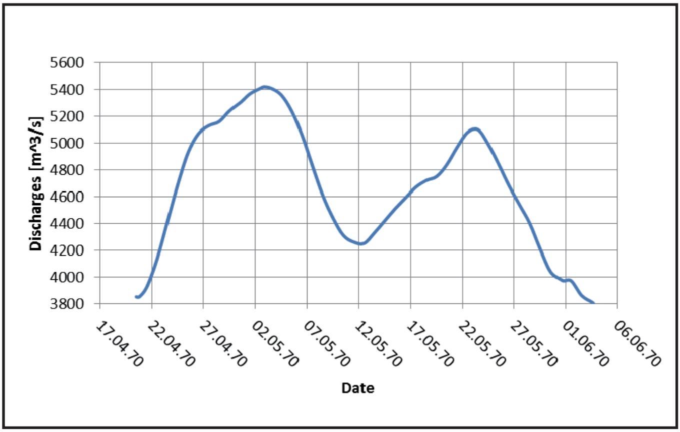
1966



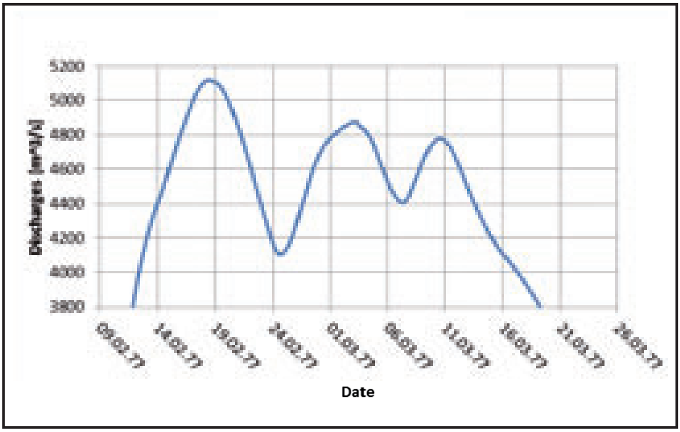
1967



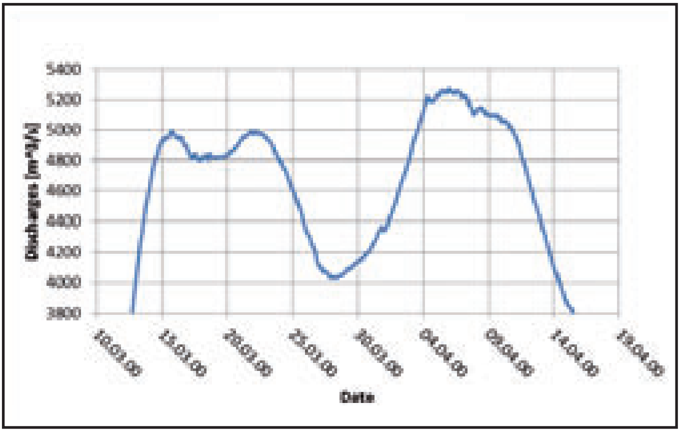
1970



1977



2000



2006

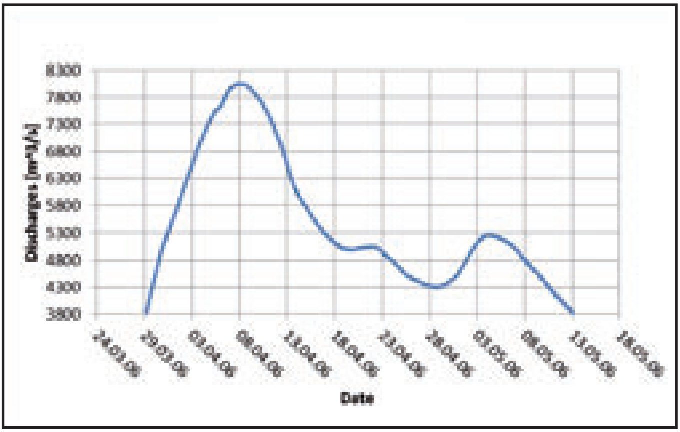
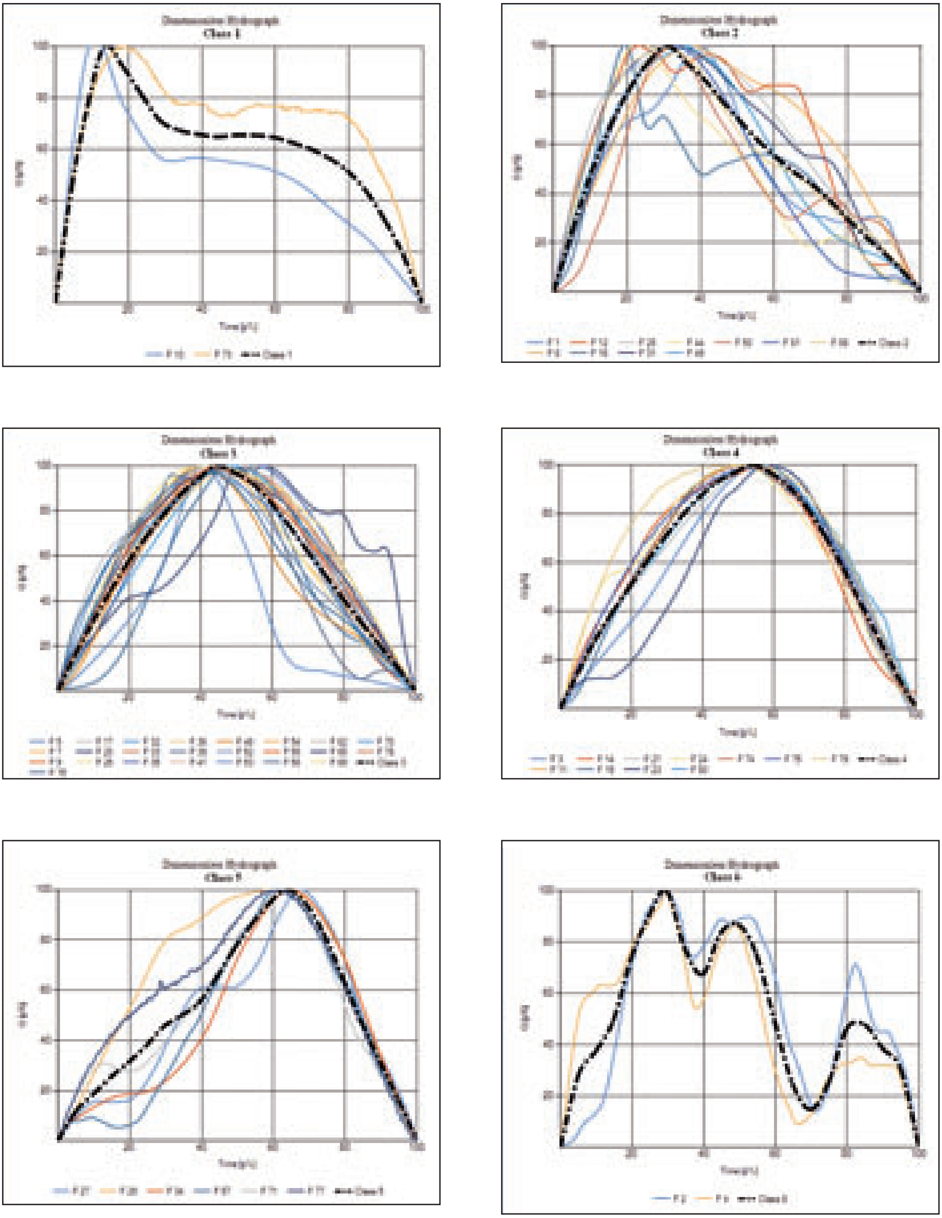
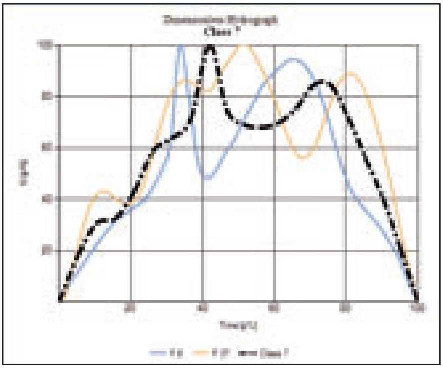
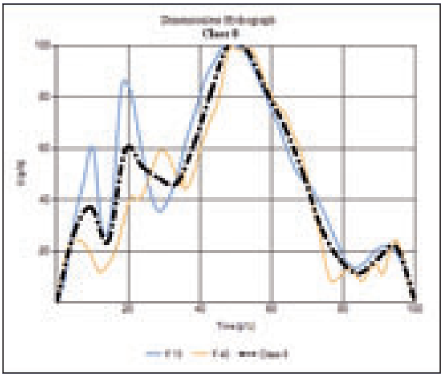


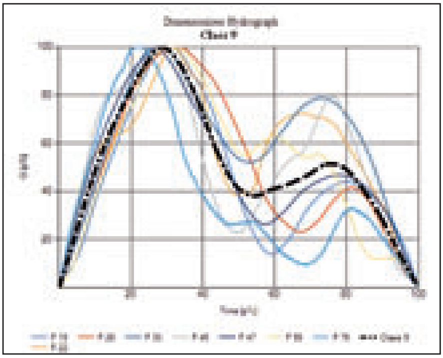
Figure 11 Some examples of the shape of the registered floods

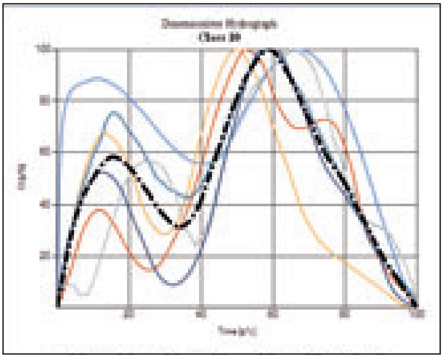
The next step is to obtain dimensionless hydrographs from the set of the selected floods. They were clustered into 14 classes of equivalence, as it is presented in Figure 12.

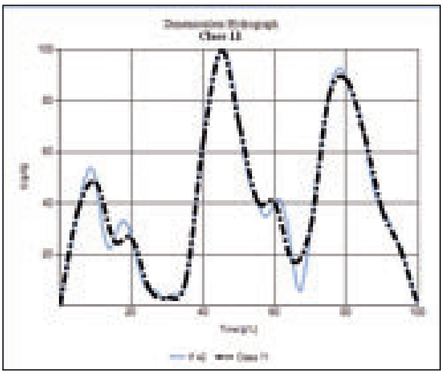


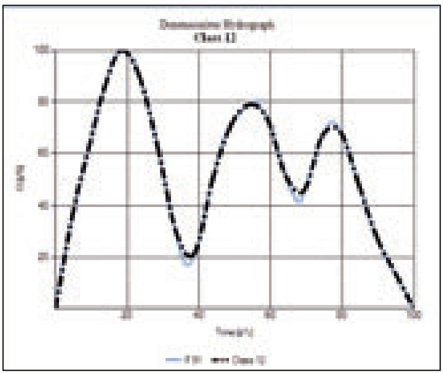












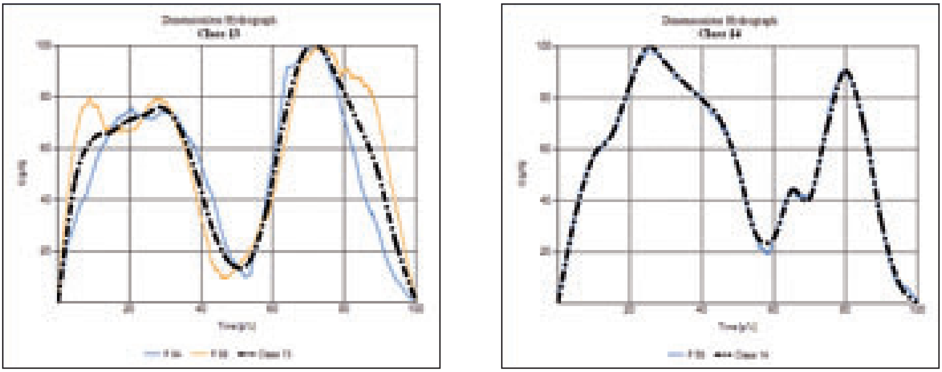
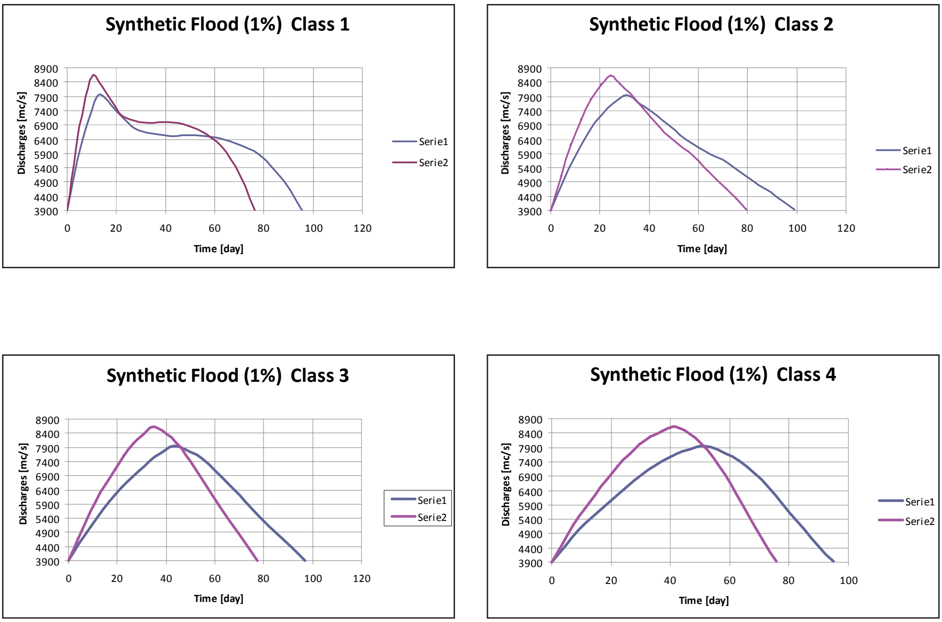
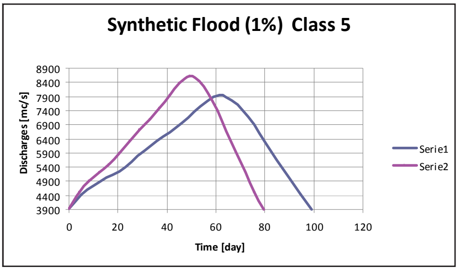


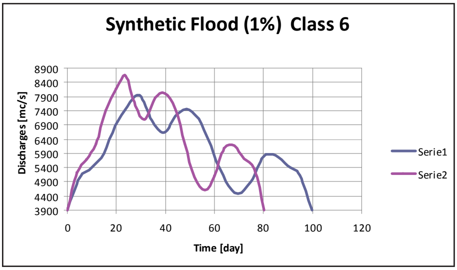
Figure 12. Dimensionless hydrographs

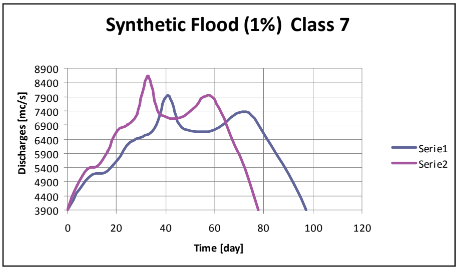
Based on the dimensionless floods, 14 synthetic floods were obtained. For each class, the floods with a return period of 100 years corresponding to maximum discharge (series 2), respectively to maximum volume (series 1) are presented in Figure 13.

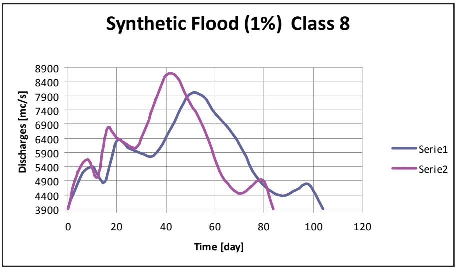
P= 1% Q=[7950, 8635] V=[44165, 51929]

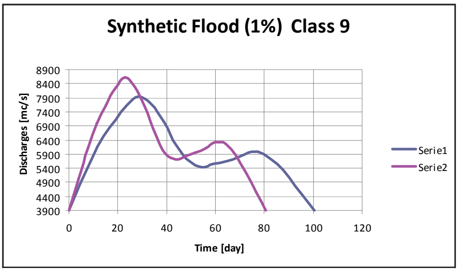


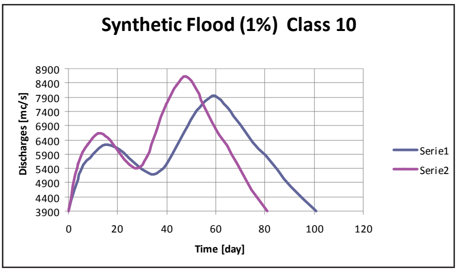

Synthetic Flood (1%) Class 5
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2

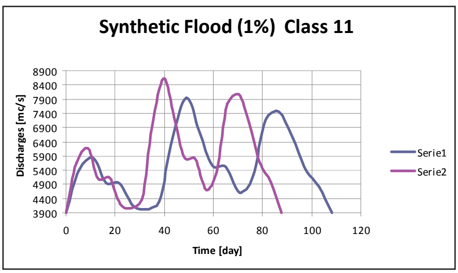

Synthetic Flood (1%) Class 6
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2

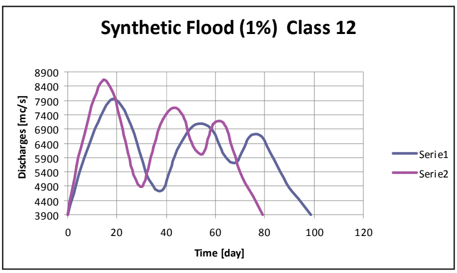

Synthetic Flood (1%) Class 7
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2


Synthetic Flood (1%) Class 8
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2


Synthetic Flood (1%) Class 9
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2


Synthetic Flood (1%) Class 10
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2


Synthetic Flood (1%) Class 11
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2


Synthetic Flood (1%) Class 12
8900
8400
7900
7400
6900
6400
5900
5400
4900
4400
3900
Discharges [mc/s]
0
20
40
60
80
100
120
Time [day]
Serie1
Serie2

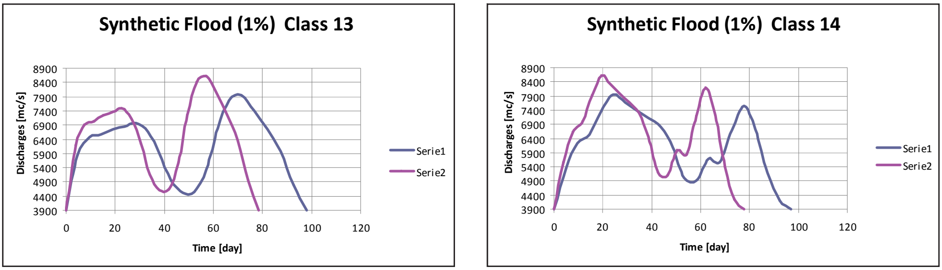


Figure 13. Synthetic floods corresponding to the probability of exceedance 1%

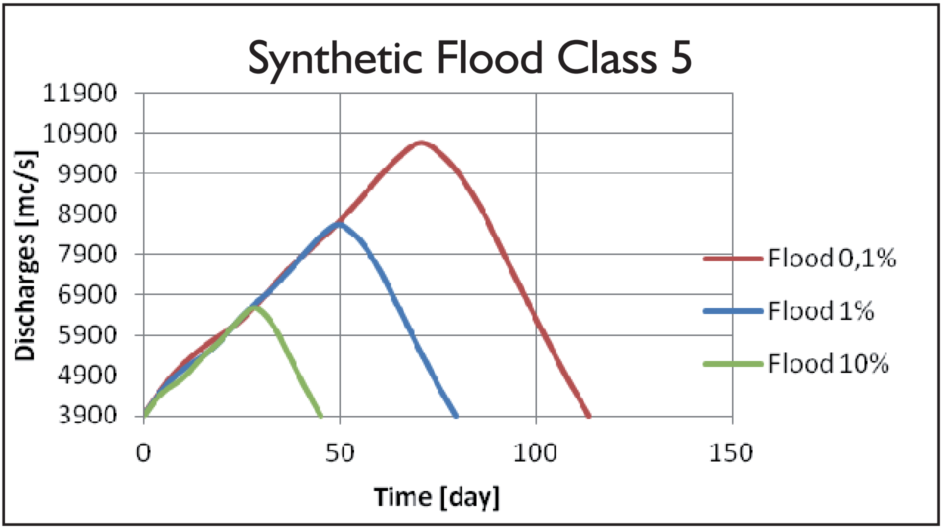
Legend:

Series1 Maximum volume

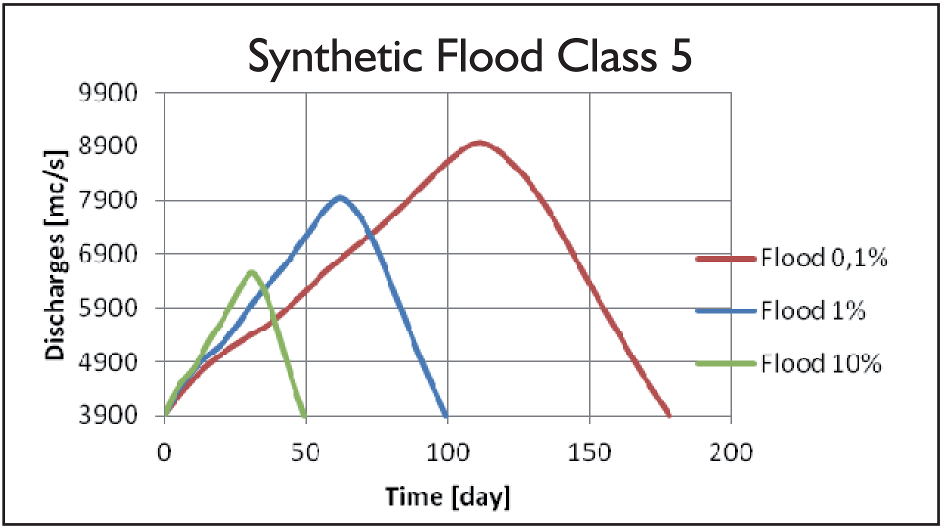
Series2 Maximum discharge

In order to make a comparison, some floods corresponding to different probabilities of exceedance (10%; 1% and 0.1%), but belonging to the same class are presented in Figure 9.

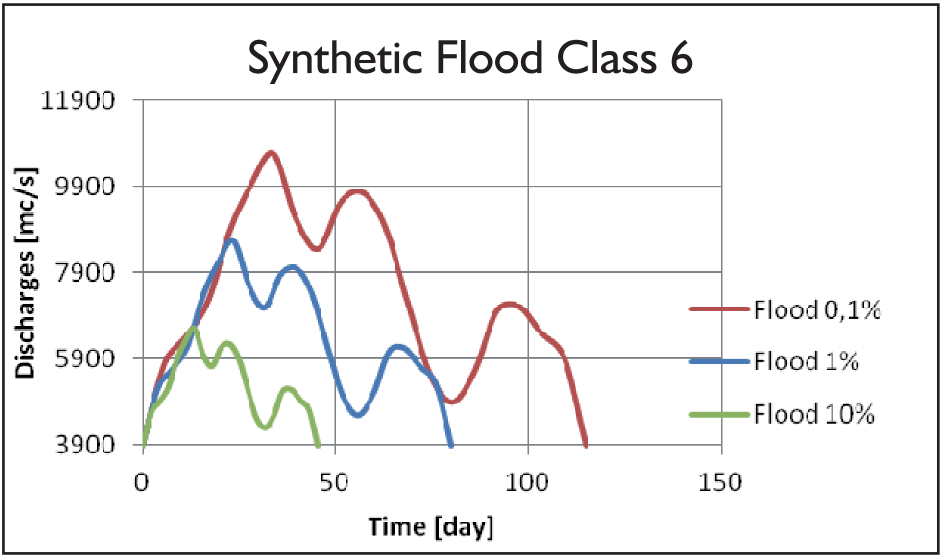
Q – upper; V – lower



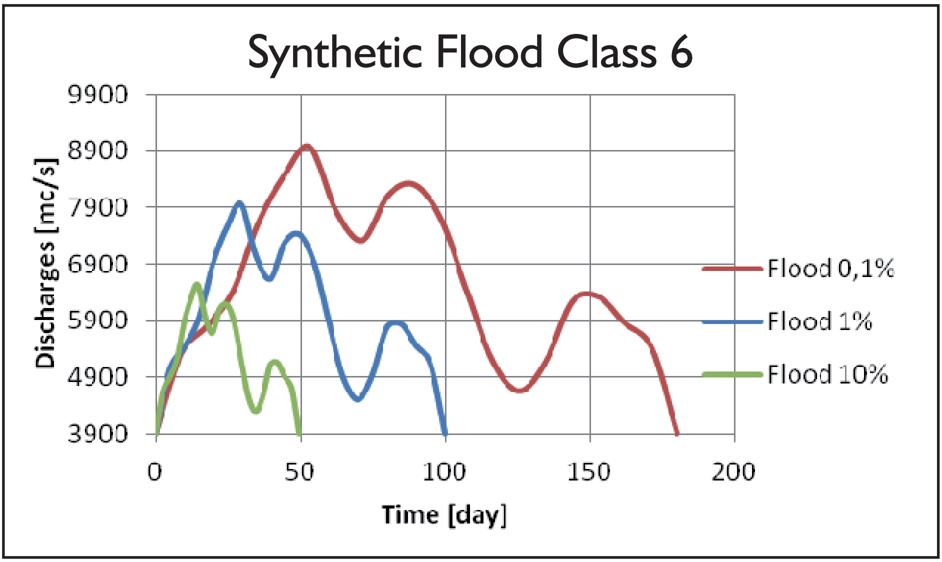
Q – lower; V – upper



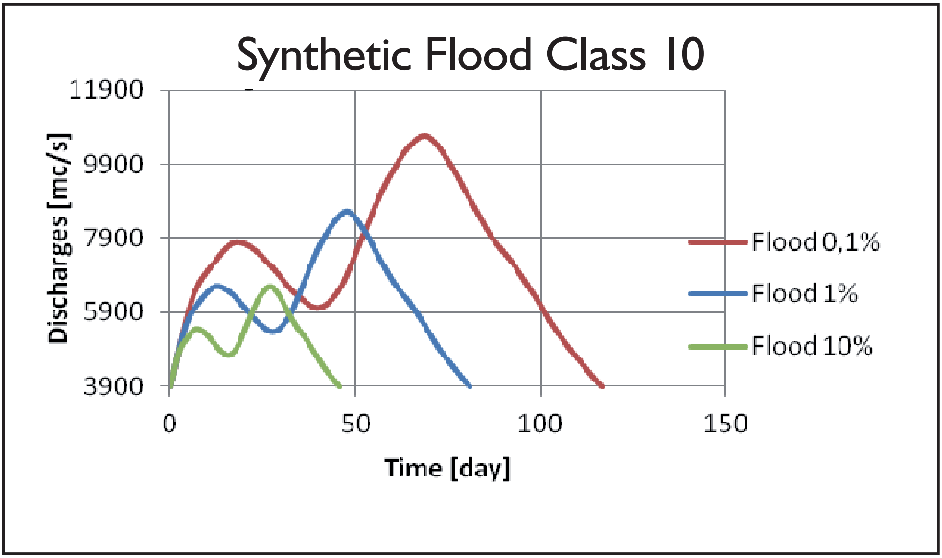
Q – upper; V – lower



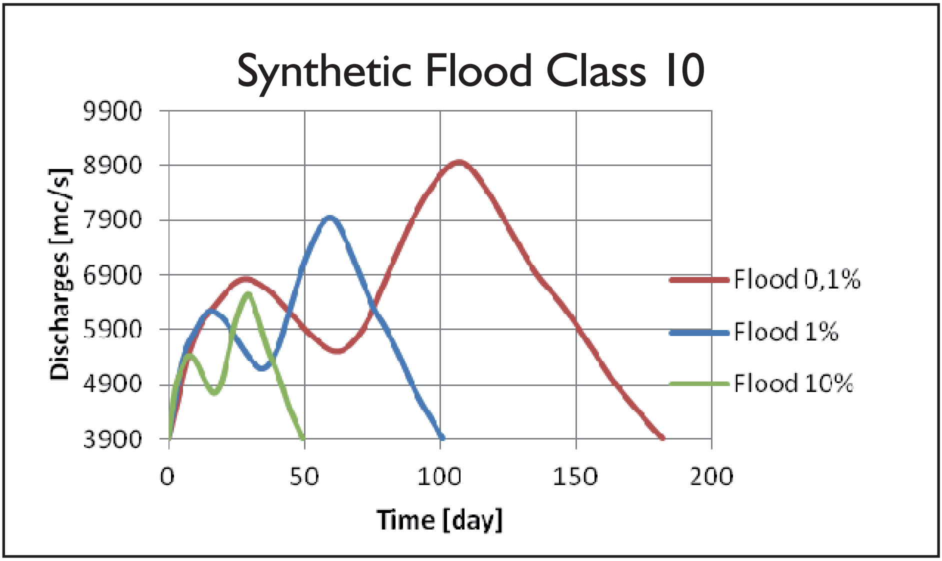
Q – lower; V – upper



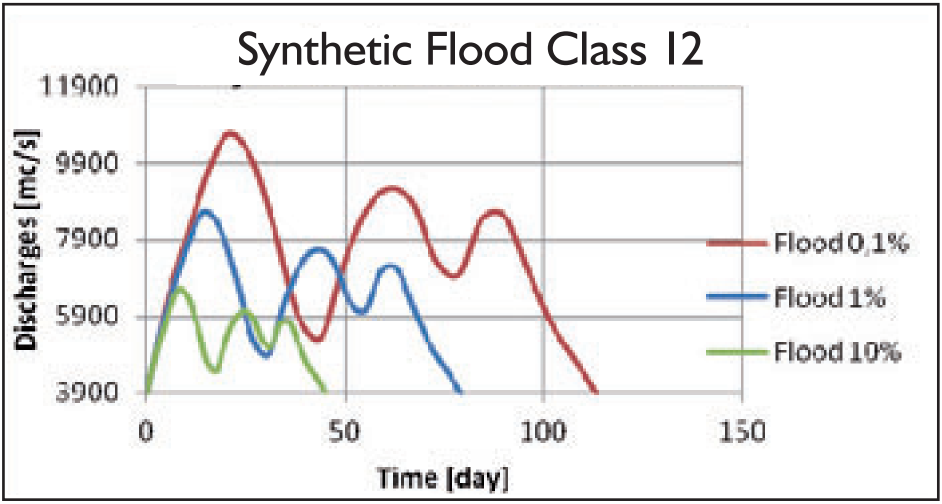
Q – upper; V – lower



Q – lower; V – upper



Q – upper; V – lower



Q – lower; V – upper

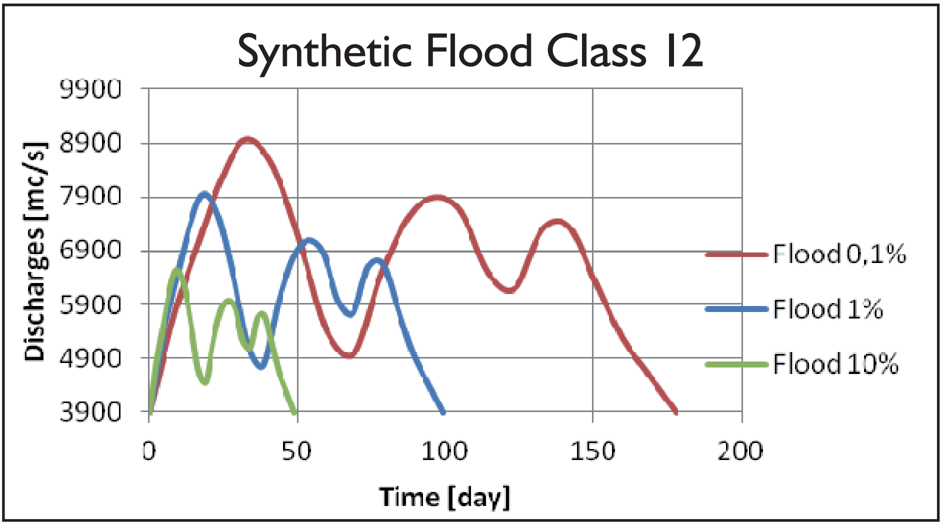


Figure 9. Synthetic floods corresponding to the probability of exceedance 10%; 1% and 0.1%

ANNEX 3

THE COMMON DATABASE

1. The Conceptual Data Model

A conceptual data model (CDM) is a collection of data interrelated into a logical flux of information. Data become objects into a CDM and they are organized by thematic modules. The objects are characterized by attributes that store their thematic features and have a spatial representation (point, line and polygon) except those in table format. Several types of relationships are used to link the objects into a module or between several modules.

In order to identify all needed data in the CDM the assessment of the needs of the stakeholders was done in three steps:

1) inventory of their assignments or missions,
2) inventory of available and lacking data, and
3) inventory of requested functionalities.

The CDM created for flood management has 11 main modules:

– Danube corridor
– River network
– Hydraulic structures
– Critical infrastructure
– Measurements and processed data
– Operation rules
– Administrative organization
– Recorded damage
– Vulnerability (damage functions)
– Potential losses
– Risk assessment

In order for the model to be easily understood and used by all stakeholders a dictionary was created with all objects classified on modules. The short name of each object is specified and explanations regarding storage (what the object means and its spatial representation) are given. Each object is then characterized by attributes with names, the type of the stored data (e.g. Text, Float and Short Integer) and the explanation of what it means (Table 1).

Table 1: Danube CorridorModule

Danube_corridor	Polygon	It represents the Danube corridor (larger than the flooded area for the extreme flood) plus the range extention of the backwater effects on the main tributaries
Danube_corridor	Line	It represents the Danube corridor (larger than the flooded area for the extreme flood) plus the range extention of the backwater effects on the main tributaries
Digital terrain model	GRID	min 10 m - max 25 m cell size Grid
Value	Float	The elevation of each cell of the grid
NOTA BENE!!!: elevation source should be the equivalent of 1:10000 scale map		
Land Cover	Polygon	Corrine land cover on the whole extention of the Danube corridor.
IDLU	Text	Unique identifier of the land use surface in the geodatabase
Name	Text	The name of the lakes and wet areas
Code1	Text	Code 1 of a surface with a certain type of coverage (e.g.agricultural, artificial surfaces, forests and semi natural areas, wetlands and water bodies)
Code2	Text	Code 2 subdomain of code 1 description (e.g. forests)
Code3	Text	Code 3 subdomain of code 2 description (e.g. type of forests)
Natural attenuation areas	Polygon	
IDZona	Text	Unique identifier of the natural attenuation area in the geodatabase
Details	Text	Suplimentary details if needed
Occurred floods (Feature class)	Polygon	
IDflood	Text	Unique identifier of a flooded area
StartDate	Date	It specifies the date when the flood occurred (dd/mm/yyyy)
EndDate	Date	It specifies the date when the flood ended (dd/mm/yyyy)
Cause	Text	The cause which generated the flood (e.g. overtopping, dyke failure etc)
p_100	Float	Probability of the maximum discharge
Occurred floods (Table)	Table	
IDflood	Text	Unique identifier of a flooded area
StartDate	Date	It specifies the date when the flood occurred (dd/mm/yyyy)
EndDate	Date	It specifies the date when the flood ended (dd/mm/yyyy)
Cause	Text	The cause which generated the flood (e.g. overtopping, dyke failure etc)
p_100	Float	Probability of the maximum discharge
Flooded areas_p_100	Polygon	Results of the mathematical modelling
IDfloodP	Text	Unique identifier of a flooded area corresponding to P% probability of exceedance
p_100	Float	Probability of the maximum discharge
Water depth P%	Grid	Results of the mathematical modelling Several grids correponding to each value of the exceedance probability P%
Value	Float	The maximum depth of the water during floods with a return period
Flow velocities P%	Grid	Results of the mathematical modelling
Value	Float	The mean velocities in the flood prone area at a certain probability
Flow directions P%	Grid	Results of the mathematical modelling
Value	Float	The coded values for flow direction which indicates the direction of the flood current
Flood duration	Grid	The duration in hours of the flooded areas registered as observations in the field
Value	Short Integer	The values in hours for the duration in different zones (raster cells)

River Network Module

Rivers	Line	Danube river and the main tributaries
IDR	Text	Unique identifier of a river in the geodatabase
Rcode	Text	Cadastral code of the river from the cadastral atlas
NameR	Text	Name of the river
Top_Scheme	Blob	Topological scheme inside the Danube corridor stored as an image

Cross-sections	Point	Obtained from the batimetric measurements and the Digital Terrain Model or classical survey; it includes compulsory the crest elevation of the dykes
IDCS	Text	Unique identifier of the cross section in the geodatabase
IDR	Text	Unique identifier of a river in the geodatabase where the cross section is located
Name	Text	Name of the cross section if any
CS_no	Short Integer	Cross section number on a river
PointEl_no	Short Integer	Point elevation number in a cross section
Elevation	Float	Elevation of the point in the cross section [m]
X	Float	X coordinate
Y	Float	Y coordinate
MeasType	Text	The way how the point in the cross section was measured (type of measurement)
Coord_pj_syst	Text	Horizontal projection system used for reference of the coordinates (e.g.Stereographic 1970 for Ron
Nota Bene: The vertical reference system will be mentioned as metadata of the cross-section object		

Longitudinal profile	LineZ	Only for Danube river
IDprofile	Text	Unique identifier of the longitudinal profile in the geodatabase
Year	Short Integer	Year for which the longitudinal profile is valid
Type	Text	Thalweg, left bank, right bank
X	Float	X coordinate
Y	Float	Y coordinate
ErosionKmStart	Float	The kilometer where an erosion/deposition process starts
ErosionKmEnd	Float	The kilometer where an erosion/deposition process ends
Ersosion_type	Text	The way the erosion/deposition occured (natural or regresive)
IDlake	Text	Unique identifier of a reservoir created by a dam
Details	Text	Additional specifications (if necessary)
Nota Bene: The vertical reference sytem and the horizontal projection system will be mentioned as metadata of the longitudinal profile		

Gauging stations	Point	Along Danube river and the tributaries in the range of the backwater effects
IDGS	Text	Unique indentifier of a gauging station
IDR	Text	Unique identifier of a river in the geodatabase where the gauging station is located
X	Float	X coordinate
Y	Float	Y coordinate
Type	Text	Type of the gauging station (automated, manually operated)
NameGS	Text	Name of the gauging station
NameR	Text	Name of the river
0_UD	Double	Stage gauge elevation of "0" point [m]
Year	Short Integer	The year since the measurements are taken [yyyy]
S	Double	The surface of the river basin the gauge station covers [km^2]
Nota Bene: The vertical reference sytem and the horizontal projection system will be mentioned as metadata of the gauging stations		

Bridges	Point	On Danube river and the tributaries in the range of the backwater effects
IDbridge	Text	Unique indentifier of a bridge in the geodatabase
IDR	Text	Unique identifier of a river in the geodatabase which is crossed by the bridge
X	Float	X coordinate
Y	Float	Y coordinate
Type	Text	Type of bridge (e.g. : concrete, metal, suspended etc)
Scheme	Blob	The bridge scheme (cross-section)- inlcudes number of piers, mean width between piers, mean distance between lower deck and discharge
Obs	Text	Observations if any
Year	Short Integer	Year of construction [yyyy]
Ren_year	Short Integer	year of renovation[yyyy]

Hydraulic Structures Module

Hydropower_dams	Point	
IDam	Text	Unique identifier of a dam into the geodatabase
IDlake	Text	Unique identifier of the reservoir created by the dam in the geodatabase
Name	Text	The name o ffhe dam
Observations	Text	Suplimentary observations regarding the dam (if necessary)
Profile	Blob	Dam profile
Nota bene: Characteristics of the dam shall be stored as meta-data		
Polders	Polygon	
IDpolder	Text	Unique identifier of the polder in the geodatabase
IDR	Text	Unique identifier in the geodatabase of the river to which the polder is connected
Surface	Double	The surface of the water extent at the minimum crest elevation [ha]
H_spill	Double	The level above which the water spills into the polder
Q	Double	Discharge in river when flooding of the polder begins
Spillways	Table	No geometric representation
IDspillway	Text	Unique identifier of the spillway in the geodatabase
IDdam_polder	Text	Unique identifier of a dam/ polder into the geodatabase
Type	Text	Type of spillway (free, with breakwater , etc.)
CrestEl	Double	The elevation of the crest of the spillway [m]
Dimens	Text	The spillway dimensions
Details	Text	Suplimentary details if necessary
Bottom outlet	Table	No geometric representation
IDbott_outlet	Text	Unique identifier of the bottom outlet in the geodatabase
IDdam	Text	Unique identifier of the dam which has the bottom outlet in the geodatabase
Shape_sect	Text	The shape of the bottom outlet depending on which Dimens, Adm_el and Evac_el attributes will be filled
Dimens	Text	The bottom outlet dimensions (D for circular bottom outlet and L / for rectangular bottom outlet)
Details	Text	Suplimentary details if necessary
Dykes	Line Zd	The dykes along Danube and main tributaries as long as the backwater effects are taken into account
IDdyke	Text	Unique identifier of a dyke in the geodatabase
IDR	Text	Unique identifier of the river in the geodatabase which is protected by the dyke
Bank	Text	The bank of the river where the dyke is located
ImpClass	Text	The design probability of the dyke
Type	Text	Type of the dyke : if it is flood protection dyke along Danube or a backwater dyke in impoundments of hydropower plants reservoirs)
FB	Short Integer	Information about the freeboard [cm]
Dyke_weak_zone	Point	
IDzone	Text	Unique identifier of a weak zone of the dyke
IDdyke	Text	Unique identifier of a dyke in the geodatabase
X	Double	X coordinate corresponding to the geometrical centre of the weak zone of the dyke
Y	Double	Y coordinate corresponding to the geometrical centre of the weak zone of the dyke
L_zone	Double	The length of the weak zone along the dyke [m]
Characterization	Text	The reason why that is considered to be a weak zone in the dyke (e.g. lower crest elevation, animal dens, undercrossing of pipes or over crossings , etc.)
Dewatering_canals	Line	
IDDC	Text	Unique identifier of a dewatering canal
IDR	Text	Unique identifier of the river in which the drained discharge is evacuated
Name	Text	Name of the drainage canal
Cross_section	blob	Cross_section of the drainage canal
Qcap	Double	The maximum discharge which can be evacuated by the pumps
X	Double	X coordinate of the evacuation point of the drainage canal into the river
Y	Double	Y coordinate of the evacuation point of the drainage canal into the river
State	Text	The state of the canal (e.g. in use, deteriorated etc.)
Pumping stations	Line	
IDPS	Text	Unique identifier of the pumping station
IDDC	Text	Unique identifier of the drainage canal on which the pump is located
Qcap	Double	The maximum discharge which can be evacuated by the pumps
High Waters Diversions	Table	No geometric representation
IDHWD	Text	Unique identifier of a high water diversion
IDR1	Text	Unique identifier of the river from which the discharges are diverted
IDR2	Text	Unique identifier of the river in which the water discharges are diverted
Name	Text	The name of the diversion
Q_cap	Double	The maximum discharge which can be transported through the diversion
Long_profile	Blob	Longitudinal profile of the diversion
CrossSection	Blob	A cross section of the diversion
Intakes	Table	No geometric representation
IDintake	Text	Unique identifier of an intake into the geodatabase
IDDam	Text	Unique identifier of a dam into the geodatabase
ElAxis	Double	Elevation of the intake's axis [m]
D	Double	Diameter of the intake [cm]
Equip	Text	This attribute mentions the hydromechanical equipments of the intake
Details	Text	Suplimentary details if necessary

Critical infrastructure Module

Roads	LineZM	The roads in the area of interest (inside the Danube corridor)
IDroad	Text	Unique identifier of the road in the geodatabase
Name	Text	Name of the road (e.g. E70 - european number 70)
Type	Text	Type of road (highway, county road, national road, etc)
NrLanes	Short Integer	Total number of lanes on both directions
Railways	LineZM	The railways in the area of interest (inside the Danube corridor)
IDrailway	Text	Unique identifier of a railway in the geodatabase
Networks	Line	The networks in the area of interest (inside the Danube corridor)
IDntk	Text	Unique identifier of a network in the geodatabase
Type	Text	Type of network (gas, water, electricity, oil)
Intakes	Point	
IDIntake	Text	Unique identifier of an intake into the geodatabase
IDR	Text	Unique identifier of the river into the geodatabase
Details	Text	Suplimentary details if necessary
Water treatment plants	Point	
IDWtp	Text	Unique identifier of a water treatment plant into the geodatabase
Details	Text	Suplimentary details if necessary
Waste water treatment plants	Point	
IDWwtp	Text	Unique identifier of a waste water treatment plant into the geodatabase
Details	Text	Suplimentary details if necessary
Industry	Point	
IDInd	Text	Unique identifier of the industrial area into the geodatabase
Type	Text	Type of industry
Details	Text	Suplimentary details if necessary
Livestock farms	Point	
IDLf	Text	Unique identifier of the livestock farm into the geodatabase
Type	Text	Type of livestock farm
Details	Text	Suplimentary details if necessary
Landfills deposits	Point	
IDLd	Text	Unique identifier of the landfill deposit into the geodatabase
Type	Text	Type of landfill deposit (industrial, domestic)
Details	Text	Suplimentary details if necessary
Recreational areas	Polygon	
IDRa	Text	Unique identifier of the recreation area into the geodatabase
Details	Text	Suplimentary details if necessary

Measurements and Processed Data Module

H_historical	Table	No geometric representation
IDH	Text	Unique identifier of a estimated historical level (other levels than the ones recorded at the gauge statio
NameR	Text	The name of the river
Date_H	Text	The date/period when the event occurred
H	Double	The value of the estimated level [m] in absolute elevation
X	Double	X coordinate where the historical level was estimated
Y	Double	Y coordinate where the historical level was estimated
Observations	Text	Suplimentary observations regarding a measured level if necessary

H(t)_gauge stations	Table	No geometric representation
IDh	Text	Unique identifier of the hydrograph
IDGS	Text	Unique identifier of the gauge station
NameGS	Text	The name of the gauge station where the level measurement took place
NameR	Text	The name of the water course where the measured level was registered
Date_h	Date	The date when the level measurement took place (dd/mm/yyyy)
Hour	Text	The hour the measurement took place [hh:mm]
h	Double	The value of the recorded level [m] in absolute elevation
Observations	Text	Suplimentary observations regarding level recording, if necessary

Q(H)_Rating curves	Table	No geometric representation
IDRC	Text	Unique identifier of a rating curve
IDGS	Text	Unique identifier of the gauge station
NameGS	Text	The name of the gauge station where the level measurement took place
NameR	Text	The name of the water course where the measured level was registered
Time_span	Text	The time span when the recordings took place and for which the rating curve is valid
H	Double	The value of the level that is corresponing to a discharge
Q	Double	The value of the discharge that is corresponding to a specific level
Observations	Text	Suplimentary observations regarding the rating curves, if necessary

Q(t)_discharges	Table	No geometric representation
IDQt	Text	Unique identifier of a discharge hydrograph
IDGS	Text	Unique identifier of the gauge station
NameGS	Text	The name of the gauge station where the level measurement took place
NameR	Text	The name of the water course where the measured level was registered
Date_Q	Date	The date (dd/mm/yyyy)
Hour	Text	The hour [hh:mm]
Q	Double	Discharge value [cm/s]
Observations	Text	Suplimentary observations regarding level recording, if necessary

Breach_characteristics	Table	No geometric representation
IDzone	Text	Unique identifier of a weak zone of the dyke where the breach occurred in the past
IDdyke	Text	Unique identifier of a dyke in the geodatabase
Length	Double	The length of the breach
V_ext	Double	Vertical extention of the breach
Failure_mechanism	Text	The way the breach was created (by overtopping, internal or foundation erosion or sliding)

Operation Rules Module

V(H)_permanent reservoirs	Table	No geometric representation
IDLake	Text	Unique identifier of the permanent reservoir
Year	Short integer	The year when the lake capacity curve was ploted
V	Double	The volume in the permanent reservoir that corresponds to a certain level [mc]
H	Double	The water level in the permanent reservoir corresponding to the water volume from above [m]
Observations	Text	Observations regaring the reservoir capacity curve if necessary

V(H)_polders	Table	No geometric representation
IDpolder	Text	Unique identifier of a polder
V	Double	The volume of the polder corresponding to a certain water level [mc]
H	Double	The water level corresponding to the water volume from above [m]
Observations	Text	Observations regaring the polder's capacity curve, if necessary

Spillways and bottom outlets rating curves	Table	No geometric representation
IDSpillway	Text	Unique identifier of the spillway
IDbott_outlet	Text	Unique identifier of the bottom outlet
IDRating_Curve	Text	Unique identifier of the rating curve of a spillway/bottom outlet for dams or polders (individual rating curve)
Gate_position	Text	The gate position for which the spillway's rating curve is valid
H	Double	Water level in the lake for reservoirs or in the river for polders [m]
Q	Double	The spilled discharge [mc]

Reservoirs_operation_rules	Table	No geometric representation
IDLake	Text	Unique identifier of the permanent reservoir
Lake_Name	Text	The name of the permanent reservoir
H1	Double	The water level in the reservoir above which the discharge is evacuated downstream for a certain type of spil
H2	Double	The water level in the lake for which the discharge of the same type of spillway is stopped
Observations	Text	Observations regarding the exploitation rules, if necessary

Polders_operation_rules	Table	No geometric representation
IDpolder	Text	Unique identifier of a polder
Spillway_el	Double	The elevation of the spillway crest
Vmax	Double	The maximum volume accumulated in the polder [mc]
Start_date_ev	Date	The date when the water evacuation from the polder starts (dd/mm/yyyy)
Start_hour_ev	Text	The hour when the water evacuation from the polder starts [hh:mm]
Observations	Text	Observations regarding the exploitation rules, if necessary (for bottom outlet)

Administrative Organization Module

Settlements	Polygon	The settlements inside the Danube corridor
ID	Text	Unique entifier of the settlements in the geodatabase
IDcounty	Text	Unique identifier of a county in the geodatabase
IDHB	Text	Unique identifier of the hydrographic basin in which the settlement is positioned
Name	Text	The name of the settlement
Type	Text	The type of the settlement (village, town, city, municipality etc.)
Pop	Short integer	The total number of inhabitants of the settlement
Obs	Text	Observations regarding a settlement, if necessary

Countries/State	Polygon	The country polygon to which the Danube corridor
IDcountry	Text	Unique identifier of the country in the geodatabase
Name	Text	Name of the country

Counties/Province	Polygon	The counties that intersect the area of interest (Danube corridor) or are totally inlcuded in it
IDcounty	Text	Unique identifier of a county in the geodatabase
IDcountry	Text	Unique identifier of the country in the geodatabase
Name	Text	Name of the county

Data from the CDM was split into two categories: data needed and obtained in the first stage after hydraulic modelling and assessment of the flood prone areas and data needed to assess the risk in the analysed perimeter. Following data from the first category will be presented in the frame of the first seven modules.

The Danube corridor module gives information regarding the extension of the analysed area along the Danube River (called the Danube corridor), the digital terrain model, land cover and occurred floods as well as important results of the modelling for risk assessment like flooded area, water depth and mean velocities (see Table 1). These results can be obtained after running a complex 2D hydraulic modelling where data from all modules are used.

The River network module stores information related to the Danube River and the main tributaries for which modelling is relevant in order to assess the flood prone area. Data regarding the river bed morphology (cross sections and longitudinal profiles) are stored also together with the gauging stations and bridges which are positioned on the river (see Table 1).

The Hydraulic structure module takes into consideration all structures that can be found along the Danube River and can influence the assessment of the flood area. The reservoir exploitation is not taken into account because the dams have a minor role in the flood attenuation along the Danube River. For this reason the characteristics of the dams were not taken into account. Thus, most of the objects are inventorised in the CDM as a support in the risk assessment (see Table 1).

The Critical infrastructure module inventorises all assets that can be affected by floods, like communication means (roads and railways), networks, treatment plants, farms, industries and landfills deposits. The objects in this module are positioned and inventorised through their attributes, but do not offer any information regarding their asset values (see Table 1).

Besides the Danube corridor and River network modules, the Measurement and processed data module is one of the most important modules for modelling as it stores input data for the hydraulic model. For the boundary conditions of the hydraulic model it was necessary to store water levels (measured data) and rating curves (processed data) from the gauge stations along the Danube River and the main tributaries. Historical water levels are also useful as they offer added valuable information regarding former floods and allow for a better image upon floods along the Danube River (see Table 1).

The Operation rules module refers only to the exploitation of the polders along the Danube, respectively to the reservoirs and their spillways and bottom outlets on the main tributaries. The objects attributes store characteristic data in operation like water level, discharge and volume (see Table 1).

The Administrative organization module has a secondary role and is meant to delineate country territories inside the flood areas as well as to allow the identification of the affected settlements (see Table 2).

The other four modules Recorded damage, Vulnerability (damage functions), Potential losses, Risk assessment contain the same objects and are characterized by the same attributes, but there is a big differentiation among the meanings of each object in the four modules. For example the object *Houses* in the *Recorded damage* module gives information about the magnitude of the losses (euro) which were already recorded during previous floods. In the *Vulnerability* module the same object offers information regarding the number of vulnerable houses located in the flood prone area. The object *Houses* in the *Potential losses* module gives information about the value (euro) of the vulnerable houses in the flood prone area. In the *Risk assesment* module, by combining hazard, exposure, potential losses and vulnerability information the risk can be evaluated for the object *Houses*. In a similar way the rest of the objects from the four modules can be interpreted.

Table 2

Danube_corridor	Danube_corridor
	Digital terrain model
	Land Cover
	Retention areas / floodplains
	Occured floods (Feature class)
	Occured floods (table)
	Flooded areas P%
	Water depth
	Flow velocities
	Flow directions
	Flood duration
River network	River network
	Cross-sections
	Longitudinal profile
	Gauging stations
	Bridges
Hydraulic structures	Hydropower Dams
	Polders
	Spillways
	Bottom outlets
	Dykes
	Dyke_weak_zone
	Dewatering_canals
	Pumping stations
	High Waters Diversions
	Bank protection (rip-rap)

Critical Infrastructure	Roads
	Railways
	Networks (electricity, water, gas, oil)
	Intakes
	Power Plants
	Water treatment plants
	Waste water treatment plants
	Industry
	Livestock farms
	Landfills deposits
	Recreational areas
	Cultural objectives
	High vulnerable buildings (schools, hospitals, military bases, administration buildings, etc)
Measurements and processed data	H_historical
	H(t)_gauge stations
	Q(H)_Rating curves
	Q(t)_discharges
	Breach characteristics
Operation rules	V(H)_permanent reservoirs
	V(H)_polders
	Spillways and bottom outlets rating curves
	Reservoirs_operation_rules
	Polders_operation_rules
Administrative organization	Settlements
	Countries
	Counties

All these objects are related with each other by relation classes. These relations can be of different types depending on the number of items related to each object. In this CDM the relation *one to many* was used to link several objects. Several examples can be seen as follows:

– Rivers are related to gauging stations and gauging stations are related to water levels; this means that for each water level one can identify where it was measured;

– Dykes are related to rivers and weak zone dykes are related to dykes; in this way one can identify where a risk of dyke failure is and look which settlements close to that particular river reach could be affected

This CDM was created in such a way that covers all data needed for flood modelling and includes also the results of this modelling. In such a way it is more than a flux of information but can be used as a Decision Support System for flood risk management.

2. The Geodatabase Structure

The purpose of the Geodatabase is to put together the necessary data for modelling and its results in a common structure and a spatial reference system. It represents an important step in data harmonization and shall contribute to the success of the modelling stage through the accuracy and homogeneity of the modelled data.

A database structure represents a basic method for the harmonization of the data. The conceptual data model of all the information that is needed for flood delineation and risk assessment along the Danube River represented the basis for the physical creation of the database.

The physical structure of the database has been developed in ArcGIS v.9.3. so that it may be referenced from now on as the geodatabase as it includes spatial or geographical reference of all the objects. The creation process followed the layout of the conceptual data model of modules, objects and attributes.

There are two types of data that will be stored in the geodatabase: spatial reference data and attribute data related to these former objects. The spatial referenced data can be also divided into data characterized by altitude information and data which is represented only in the x and y plan. For all data objects containing elevations a unique Vertical coordinate system was defined: European Vertical Reference Frame 2007 (See Chapter 6.2.1.). As a planimetric coordinate system ETRS1989 (See Chapter 6.2) has been used for all objects in the geodatabase (Figure 1).

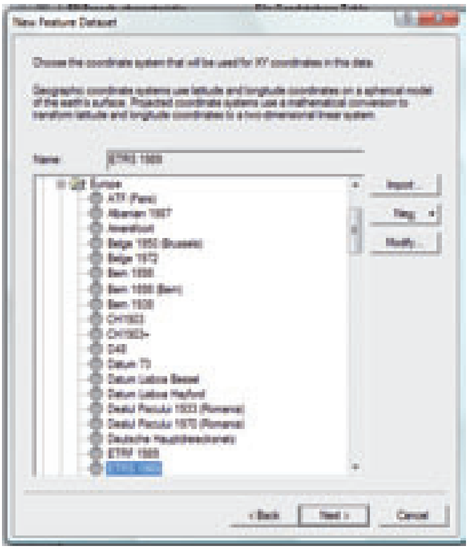


Figure 1. Selection of the unified planimetric reference system

The correspondence between the conceptual data model and the geodatabase structures is the following:

– Conceptual data model → Geodatabase
– Modules → Feature dataset
– Objects → Feature Classes, Attribute tables
– Attributes → Attributes according to the description from the Data Dictionary
– Relations → Relation classes
– Additional comments and information → Meta data

A special attention was paid to the creation of the River Feature Class as it has to offer the possibility to determine the flow direction [3] and to build a chainage in order to make the correspondence with the milestones in the field. M option is used to enable such advantages when creating the River Feature Class.

An added value to any geodatabase structure is the possibility of the validation of data that will be stored. This can be done by adding to the basic structure (Figure 2) a Topology structure with validating geometry rules. This is very important as it guarantees the correctness of the data that need to be used further for other purposes, like mathematical modelling in our case.

An example of such topology rules used for the created geodatabase is that the gauging stations points should be located on the river course line. If there are gauging stations that are located by mistake at a certain distance from the river they are symbolized as errors on the map and they should be placed under the correct coordinates. Another example is that dykes should never intersect river courses. If they do so, it is a mistake probably from the digitization phase and it has to be removed either by correcting the river course or the dyke line using as a background the aerial photographs.

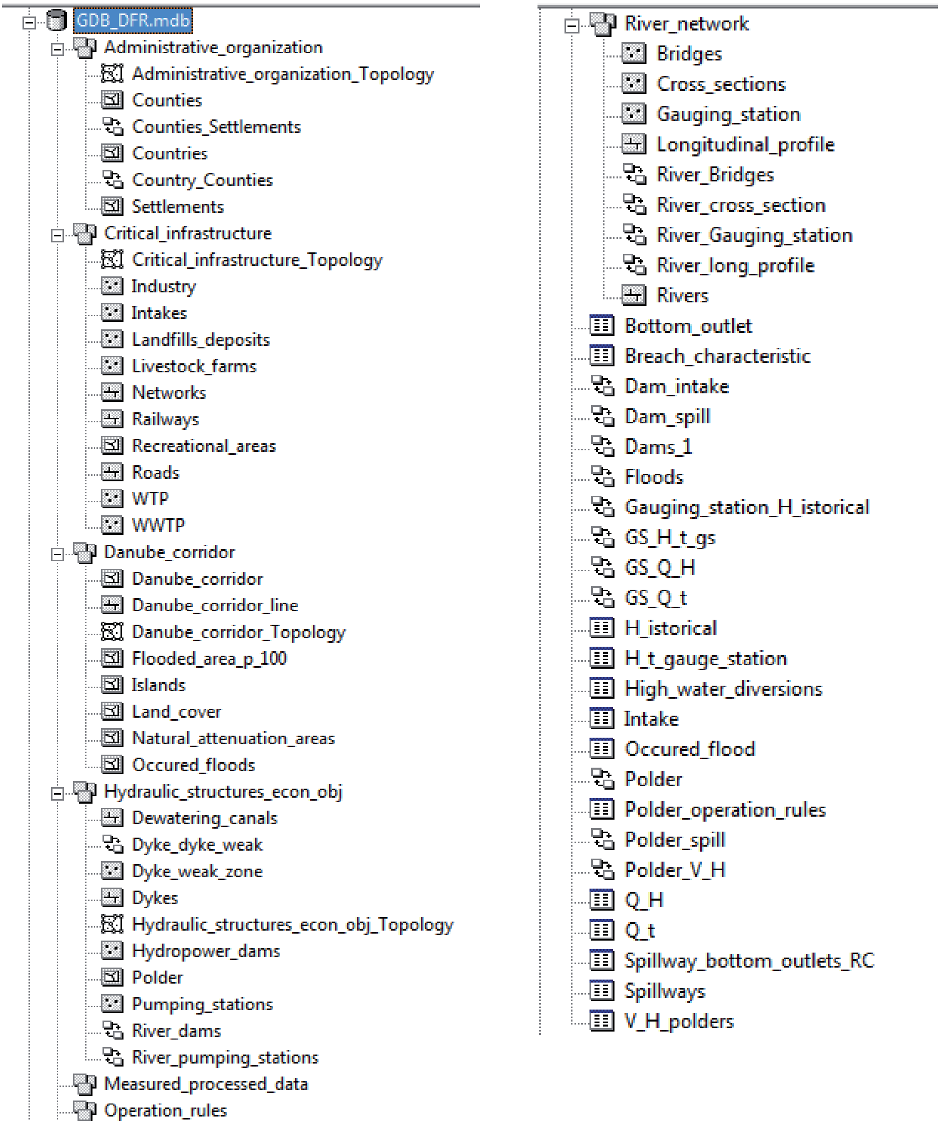


Figure 2. Geodatabase structure

According to the INSPIRE Directive regulations metadata are mandatory for any geodatabase. Thus they have been created specifying additional information regarding the designers of the geodatabase (email addresses, phone numbers), the moment it was created, and a short description of each Feature Class or Table.

ANNEX 4

Glossary of common understanding concerning vulnerability and damage assessment

0.2 percent annual chance flood – the flood that has a 0.2-percent chance of being equalled or exceeded in any given year.

100 year flood – see 1 percent annual chance flood or base flood.

10 percent annual chance flood – the flood that has a 10-percent chance of being equalled or exceeded in any given year.

10 year flood – see 10 percent annual chance flood

1 percent annual chance flood – the flood that has a 1-percent chance of being equalled or exceeded in any given year.

2 to 4 family residence – a residential building (excluding hotels and motels with normal room rentals for less than 6 months' duration) containing no more than four dwelling units. Incidental occupancies such as office, professional, private school, or studio space are permitted if the total area of such occupancies is limited to less than 25 percent of the total floor area within the building.

2 percent annual chance flood – the flood that has a 2 percent chance of being equalled or exceeded in any given year.

500 year flood – see 0.2 percent annual chance flood

50 year flood – see 2 percent annual chance flood

Acceptable risk – The level of loss a society or community considers acceptable given existing social, economic, political, cultural and technical conditions.

Accuracy – the degree of correctness attained in a measurement.

Annual average damages – are the damages expected from all episodes of a particular hazard (e.g. in the case of floods, from floods of every size) averaged (in theory) over an infinite period. Annual average damages estimates enable easy comparison with the costs of mitigation proposals, and allow priorities to be set between different locations. This is because the cost of mitigation can also be expressed on an average annual basis in the same way as a mortgage. An inherent problem with this approach is that low-probability high consequence events will appear insignificant

when converted to annual average damages because of their very low probability of occurrence. Nevertheless, it may be considered socially desirable to consider them in the analysis. It is not possible to conduct cost-benefit analysis without annual average damages data.

Annual exceedance probability – the chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an annual exceedance probability of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m^3/s (or larger) occurring in any one year.

Average recurrence interval – the long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20 year ARI design flood will occur on average once every 20 years. Average recurrence interval is another way of expressing the likelihood of occurrence of a flood event.

Avoidable loss – loss that can be avoided through mitigation.

Base flood – the flood having a 1% chance of being equalled or exceeded in any given year.

Base flood elevation – the water surface elevation resulting from a flood that has a 1% chance of equalling or exceeding that level in any given year.

Base map – map of the community that depicts cultural features (roads, railroad, bridges, dams, culverts, etc.), drainage features, and the corporate limits.

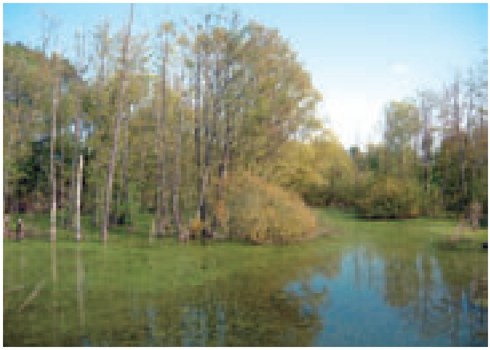
Basement – any area of the building, having its floor below ground level (sub grade) on all sides.

Cadastral data – property boundary data

Catchment – The catchment at a particular point is the area of land that drains to that point.

Commerce – in a loss assessment context, "commerce" refers to the retail, wholesale, service industries and the manufacturing sectors.

Community – a political entity that has the authority to adopt and enforce floodplain ordinances for the area under its jurisdiction. In most cases, a community is an incorporated city, town, township, borough, village, or an unincorporated area of



a county or parish. However, some states have statutory authorities that vary from this description.

Costs – in a loss assessment context, the resources or alternative consumption which must be sacrificed to achieve the desired end result, such as implementing mitigation.

Cultural features – railroads, airfields, streets, roads, highways, levees, dykes, seawalls, dams and other flood-control structures, and other prominent man-made features and landmarks shown on a map.

Database – a collection of information related by a common fact or purpose.

Defences flood awareness – an appreciation of the likely threats and consequences of flooding and an understanding of any flood warning and evacuation procedures. Communities with a high degree of

flood awareness respond to flood warnings promptly and efficiently, greatly reducing the potential for damage and loss of life and limb. Communities with a low degree of flood awareness may not fully appreciate the importance of flood warnings and flood preparedness and consequently suffer greater personal and economic losses.

Flood damage – The losses by flooding including tangible and intangible assets.

Flood behaviour – The characteristics of a flood as there are peak discharge and number of peaks, season of the year and reason for flooding as well as duration of the flood.

Design flood – a hypothetical flood representing a specific likelihood of occurrence (for example the 100 year or 1% probability flood). The design flood may comprise two or more single source dominated floods.

Design floor level – the minimum (lowest) floor level specified for a building.

Development – any human-caused change to improved or unimproved real estate including, but not limited to, buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations.

Digital Elevation Model (DEM) – a file with terrain elevations recorded for the intersection of a fine-grained grid and organized by quadrangle as the digital equivalent of the elevation data on a topographic base map.

Disaster preparedness – the state of readiness on the part of the government and society to both respond effectively to a disaster and recover quickly from its effects. Disaster Preparedness includes preparing and testing emergency response plans, training, acquiring and maintaining equipment needed for response, stockpiling relief materials, etc. The purpose of preparedness is to anticipate likely impacts of disasters so that ways can be devised to effectively mitigate major adverse effects.

Disaster risk management – comprehensive approach and activities to reduce the adverse impacts of disasters. It encompasses all actions taken before, during, immediately after, and sometime after a disaster. It is holistic and includes activities on mitigation, preparedness, emergency response, recovery, rehabilitation, and reconstruction.

Disaster risk reduction – the systematic development and application of policies, strategies, and practices to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) adverse impact of hazards, within the broad context of economic development.

Disaster – a crisis event that surpasses the ability of the affected individual, community, or society to control or recover from its consequences.

Discharge – the rate of flow of water measured in terms of volume over time (i.e. the amount of water moving past a point). Discharge and flow are interchangeable.

Economic loss – see Loss/damage.

Emergency Response – actions taken during and immediately after a disaster to ensure that its adverse effects are minimized and that people affected are given immediate relief and support. It includes search and rescue, relief services, as well as restoration of power, water, and telephone services.

Exposure – assets, activities, people, and things people value, such as the environment, which are exposed to the impacts of some hazard.

Financial Loss – see Loss/damage.

Flood – a general and temporary condition of partial or complete inundation of normally dry land areas from (1) the overflow of inland or tidal waters or (2) the unusual and rapid accumulation or runoff of surface waters from any source.

Flood frequency analysis – an analysis of historical flood records to determine estimates of design flood flows.

Flood fringe – land that may be affected

by flooding but is not designated as floodway or flood storage.

Flood hazard – the potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods.

Flood hazard area – the greater of the following: (1) the area of special flood hazard, or (2) the area designated as a flood hazard area on a community's legally adopted flood hazard map, or otherwise legally designated.

Flood prone land – land susceptible to inundation by the probable maximum flood event.

Flood Profile – a graph showing the relationship of water-surface elevation to location, with the latter generally expressed as distance above the mouth for a stream of water flowing in an open channel.

Flood protection system – those physical works for which funds have been authorized, appropriated, and expended and which have been constructed specifically to modify flooding in order to reduce the extent of the area subject to a "special flood hazard" and the extent of the depths of the associated flooding. Flood protection systems typically include hurricane tidal barriers, dams, reservoirs, levees, or dykes.

Flood storages – floodplain areas that are important for the temporary storage of floodwaters during a flood.

Flood zone – a geographical area shown on a flood hazard boundary map that reflects the severity or type of flooding in the area.

Floodplain – land adjacent to a river that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation.

Floodplain management – operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to emergency preparedness plans, flood control works, and floodplain management regulations.

Floodplain management measures – a range of techniques that are aimed at reducing the impact of flooding. This can involve reduction of flood damages, disruption and psychological trauma.

Floodplain management plan – a document outlining a range of actions aimed at improving floodplain management. The plan is the principal means of managing the risks associated with the use of the floodplain. A floodplain risk management plan should be developed in accordance with the principles and guidelines contained country laws and regulations. The plan will usually contain both written and diagrammatic information describing how particular areas of the floodplain are to be used and man-

aged to achieve defined objectives.

Floodplain management scheme – a floodplain management scheme comprises a combination of floodplain management measures. In general, one scheme is selected by the floodplain management committee and is incorporated into the plan.

Flood-prone community – any community that is subject to inundation by the base (100-year) flood.

Flood-proofing – Protective measures added to or incorporated in a building that is not elevated above the base flood elevation to prevent or minimize flood damage. "Dry floodproofing" measures are designed to keep water from entering a building. "Wet floodproofing" measures minimize damage to a structure and its contents from water that is allowed into a building.

within a stream or other waterway, such as bridge and culvert construction, fill, and excavation.

Hazard – an event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss.

Future conditions floodplain or flood hazard area – the land area that would be inundated by the 1 percent annual chance (100-year) flood based on future-conditions hydrology.

Future conditions hydrology – the flood discharges associated with projected land-use conditions based on a community's zoning maps and/or comprehensive land-use plans and without consideration of projected future construction of flood detention structures or projected future hydraulic modifications

Historical flood – a flood that has actually occurred.

Intangible – items which are not normally bought or sold (such as memorabilia, lives, health and the environment) and for which therefore no agreement on their monetary value exists.

Levee – A man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding.

Loss/Damage – a loss is counted if it is an economic loss – unless otherwise specified. An economic loss is a measure of the impact of the disaster on the specified economy. It is taken as being equal to the resources (expressed in time, money or intangible loss) lost by the specified area as a result of the disaster (see Net loss). This is distinct from the financial losses due to the disaster which are the losses borne by individual enterprises as well as the other sectors. Many individual business losses do not amount to economic losses as their losses are offset by other businesses gaining the trade, or are made up over time.

Lot – a parcel of land for which a metes and bounds description or a plat has been recorded and on which one or more structures may be built.

Maximum probable flood – the largest flood expected from a specified catchment at the current state of knowledge. The probability of such an event occurring is very low, such as 1:10 000 or less in any year. A maximum probable flood may also be estimated deterministically from knowledge of flood producing processes. Although these floods – or their equivalent for other hazards – are extremely rare, their impacts may be devastating.

Minimally floodprone community – a community that has been determined to be subject to inundation by the 1-percent-annual-chance (100-year) flood, but for which existing conditions indicate that the area is unlikely to be developed in the foreseeable future. The criteria used to evaluate a community's development potential are as follows: (1) Floodplains are publicly owned and designed for open space or preservation; (2) Zoning laws, sanitary codes, subdivision regulations, shore land regulations, or community regulations effectively prohibit floodplain development; (3) Surrounding land use or topography effectively limits the

development potential; (4) Population is decreasing or stable, and there is no foreseeable pressure for floodplain development; and (5) Floodplains are remote and uninhabited, and future development is unlikely.

Mitigation – a sustained action taken to reduce or eliminate long-term risk to people and property from flood hazards and their effects. Mitigation distinguishes actions that have a long-term impact from those are more closely associated with preparedness for, immediate response to, and short-term recovery from specific events.

Net loss – the disaster loss experienced by an economy minus any benefits to that economy which resulted directly from the same disaster.

Non-residential – includes, but is not limited to: small business concerns, churches, schools, farm buildings (including grain bins and silos), pool houses, clubhouses, recreational buildings, mercantile structures, agricultural and industrial structures, warehouses, hotels and motels with normal room rentals for less than 6 months' duration, and nursing homes.

Occurrence probability – the chance of a hazard event of a specific magnitude

at a specific place occurring in a given time period. It is usually expressed as a chance per year, for example a 10 % flood is the flood with a 10% probability of occurring (or being exceeded) in any year. Also expressed as a probability of 0.1 per year, or a recurrence interval of 10 years being the theoretical average time between a flood

of that magnitude.

Other residential – hotels and motels where the normal occupancy of a guest is 6 months or more; a tourist home or rooming house which has more than four roomers. A residential building (excluding hotels and motels with normal room rentals for less than 6 months' duration) containing more than four dwelling units. Incidental occupancies such as office, professional private school, or studio occupancy, are permitted if the total area of such incidental occupancies is limited to less than 25 percent of the total floor area within the building.

Prevention – encompasses activities designed to provide permanent protection from disasters, including engineering and other physical protective measures, but also legislation on land use and urban planning.

Reconstruction – actions taken to re-establish a community after a period of rehabilitation following a disaster. Actions include construction of permanent housing, full restoration of all services, and complete resumption of the pre-disaster state.

Rehabilitation – the operations and decisions taken after a disaster with a view to restoring a stricken community to its former living conditions, whilst encouraging and facilitating the necessary adjustments to the changes caused by the disaster.

Replacement cost value – the cost to replace property with the same kind of material and construction without deduction for depreciation.

Retrofit – any change made to an existing structure to reduce or eliminate damage to that structure from flooding, erosion, high winds, earthquakes, or other hazards.

Retrofitting – retrofitting techniques include flood-proofing, elevation, construction of small levees, and other modifications made to an existing building or its yard to protect it from flood damage.

Riparian ecosystem – a distinct association of flora, fauna, and soil occurring along a river, stream, or other body of water and dependent upon high water tables and occasional flooding to maintain its viability. These areas often exhibit high biological productivity and species diversity.

Risk aversion – term used to describe the tendency of an individual person to avoid risk.

Risk dialogue – interpretation and communication of risk assessments in terms that are comprehensible to the general public or to others without specialist knowledge.

Risk perception – subjective perception of the gravity or importance of the risk based on a person's knowledge of different risks and the moral, economic, and political judgment of their implications.

Risk – the potential for losses associated with a hazard, defined in terms of expected severity and/or frequency, and locations or areas affected.

Riverine flooding – the overbank flooding of rivers and streams.

Riverine – of or produced by a river. Riverine floodplains have readily identifiable channels. Floodway maps can only be prepared for riverine floodplains.

Single family residence – a residential single family dwelling. Incidental office, professional, private school, or studio occupancies, including a small service operation, are permitted if such incidental occupancies are limited to less than 50 percent of the building's total floor area.

Special flood hazard area – any area inundated by the base (1% annual chance) flood.

Stage – the height of a water surface above an established datum plane.

Stage (or depth) damage curves – are graphical representations of the losses expected to result at a specified depth of flood water. Such curves are typically used for housing and other structures where the stage or depth refers to depth of water inside a building and the damage refers to the damage expected from that depth of water. They may be thought of more generally as representing the relationship between hazard magnitude and loss – and can be adapted to cover other hazards.

Stakeholders – Business leaders, civic groups, academia, non-profit organizations, major employers, managers of critical facilities, farmers, landowners, developers, and others whose actions affect hazard mitigation.

Substantial damage – damage of any origin sustained by a building whereby the cost of restoring the building to its before-damage condition would equal or exceed 50% of the market value of the building before the damage occurred.

Substantial improvement – any reconstruction, rehabilitation, addition, or other improvement to a building, the cost of which equals or exceeds 50% of the market value of the building before the start of construction of the improvement.

Tangible – items which are normally bought or sold and which are therefore easy to assess in monetary terms.

Total loss – the sum of avoidable losses and unavoidable losses. Unavoidable losses are those which mitigation cannot or does not reduce.

Unavoidable loss – unavoidable losses occur when mitigation action cannot be taken to counter the effects of a potential hazard, or cannot reduce the resulting loss. Changes in knowledge and approaches will alter what is considered unavoidable through time.

Vulnerability – the level of exposure of human life, property, and resources to impact from hazards.

Water surface elevation – the height of floods of various magnitudes and frequencies in the floodplains of coastal or riverine areas.

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MAFWM – Ministry of Agriculture, Forestry and Water Management (RS)
RHMSS – Republic Hydrometeorological Service of Serbia (RS)

Observers:

ICPDR – International Commission for the Protection of the Danube River (AT)
JRC – European Commission - DG Joint Research Center (IT)
BfG – Bundesanstalt für Gewässerkunde (DE)
LfU – Bavarian Environmental Agency (DE)
RPT BWL – Regional Council Tübingen (DE)

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