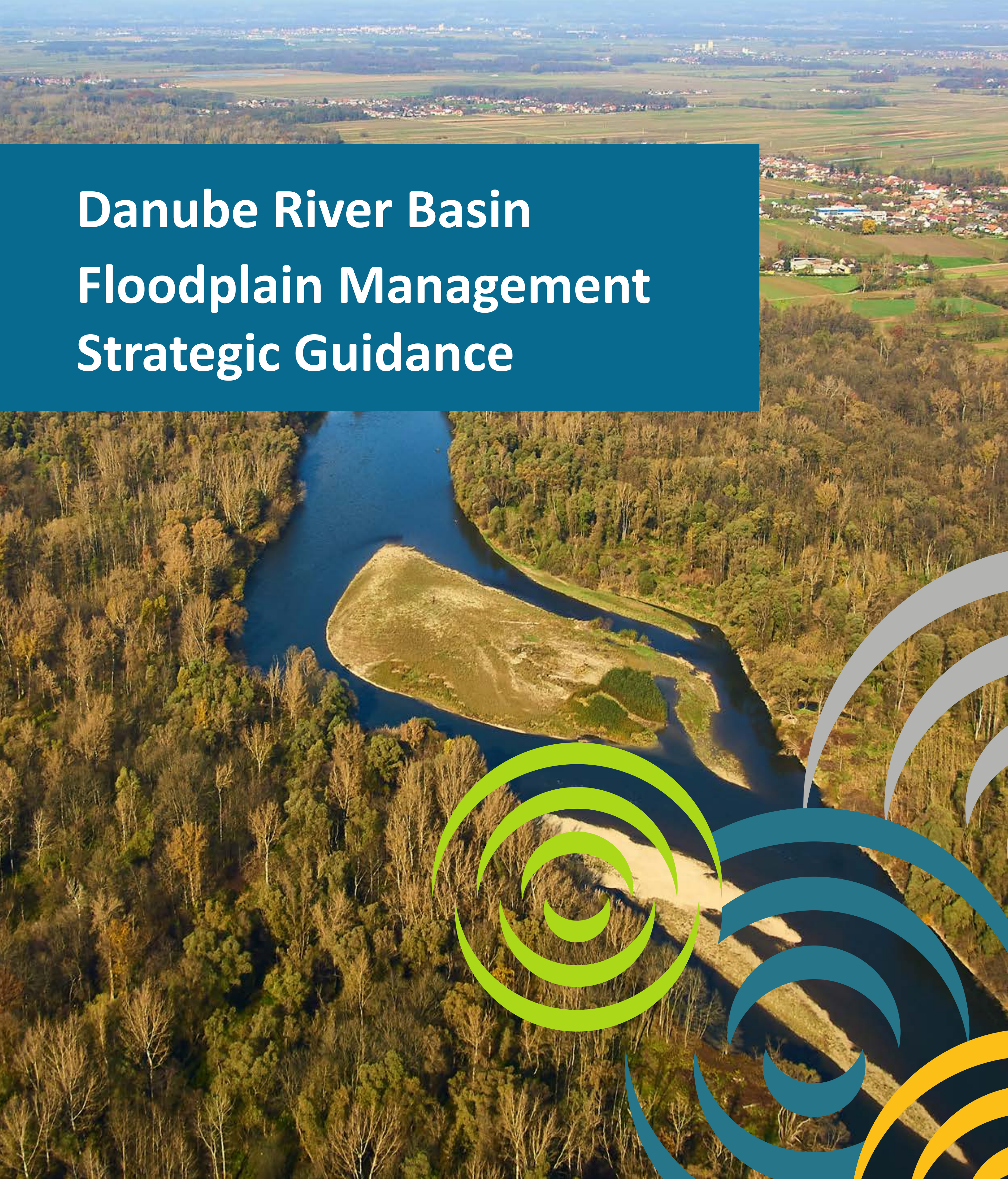
Danube River Basin Floodplain Management Strategic Guidance



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Danube Floodplain

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Why should we care about floodplains?

- Floods are natural and regular reality for many rivers. They can turn into disasters causing economic and environmental damage, health problems and even loss of human life. The areas next to rivers, covered by water during floods, are part of the river system. Known as floodplains, in their natural condition they are an important part of the river system: they store water, filtered nutrients, helps the aquifers to be recharged, ensure a proper functioning of river ecosystems, and sustain the biodiversity.
- Danube River Basin's floodplains covered in the past wide stretches and had a high ecological importance. Flood protection infrastructure, especially dykes, land use changes into arable lands, urban development have considerably fragmented floodplains.
- To improve navigation, river channels are often straightened and dredged. Hydropower and water supply projects caused significant changes in hydrological regime and geomorphological processes influencing floodplains preservation.
- Consequently, the floodplain and wetland areas disconnection in the Danube River Basin has significantly decreased, therefore restoration and preservation actions are needed.

How to act?

- Integration of the environmental objectives with flood risk management objectives requires moving away from the classical flood protection solutions to nature-based ones.
- Nature based solutions refers to actions in which led to reducing the flood risk is provided, while at the same time the natural properties of the floodplain and its connection to the river are restored.
- Because of the multiple benefits provided by natural floodplains, EU policies encourage floodplain restoration based on integrative plans and win-win solutions.
- Agreement on the wide range of benefits provided by floodplain and river restoration could be ensured by using an approach rooted in ecosystem-based management when developing river basin and flood risk management plans.

Introduction
Floods vs loss of floodplains in Danube River Basin

The Danube has a very complex hydrological system. Its flow characteristics change over large reaches, influenced by the main tributaries (e.g., Drava, Sava, Morava, Tisza).

During the last decades, Europe suffered major catastrophic floods along the Danube. Major flood events in the Danube River Basin of the recent past occurred in 2002, 2005, 2006, 2009, 2010, 2013 and 2014.
Heavy rainfall accompanied by temperature rise led to intensive and rapidly snowmelt at the end of March 2006, causing high discharges on Danube and important tributaries: Tisza, Sava and Morava.

This led to a significant 100-year flood event along more than 1000 kilometers of the Danube River. According to the Flood Risk Management Plan for the Danube River Basin District , the flooding stretched from the Morava mouth to the southern tip of the Csepel Island in Hungary, downstream of the Tisza mouth in Serbia and along the whole Romanian section of the Danube where highest historical flows and water levels were recorded. The extent of flooding in Romania was the largest in the last hundred years mouth to the southern tip of the Csepel Island in Hungary.

Photo source: Romania, General Inspectorate for Emergency Situations, Spantov village, Danube flooding 2006

Photo source: Romania, General Inspectorate for Emergency Situations, Ilganii de Sus village, Danube flooding 2006

[1] Flood Risk Management Plan for the Danube River Basin District, 2015

Contrary to the massive single flood events on the Danube, occurred in 2006, due to high precipitation volume in a short time, in 2010 the scattered character of the rainfall throughout the whole year and throughout the most of the Danube River Basin led to a high number of significant flood events.
In 2013, significant 100 years floods events have been registered almost simultaneously in Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania and Bulgaria. Several gauging stations registered 200 even 500 years .

Disconnection over the years of the floodplains, not particularly on Danube River but also on main tributaries causes the loss of large water retention areas that originally mitigated flood risks.

Former Danube floodplains covered an area of approximately 41,605 km², which is equal to about 3.3% of the total Danube catchment area. The total floodplain area for the Danube River basin was reduced by 68% (80% for all assessed rivers) with differences for upper (75%), middle (79%) and lower (73%) Danube River stretches.

Flood protection works, agriculture, urban development, dredging for navigation, land use changes are the main drivers which led to loss of floodplains.

Considering its mission, to promote and coordinate sustainable and equitable water management, including conservation, improvement and rational use of waters for the benefit of the Danube River Basin countries and their people at ICPDR level, a project concept regarding the management of floodplains was promoted in 2015 under the acronym Danube *Floodplain.*

The specific objective of the planned project was to contribute to the more effective implementation of the EU Floods Directive and the Water Framework Directive (WFD) inter alia by developing a common approach on restoring the water storage capacity of floodplains, to develop best practice on using 'green infrastructure' for sustainable flood risk management, to stimulate stakeholder involvement and cooperation in floodplain restoration / flood management planning and implementation.

[2] Floods in June 2013 in the Danube River Basin, accessed on: https://www.icpdr.org/main/sites/default/files/nodes/documents/icpdr_floods-report-web_0.pdf
[3] International Danube-Carpathian Programme: Assessment of the restoration potential along the Danube and main tributaries, accessed on: http://awsassets.panda.org/downloads/wwf_restoration_potential_danube.pdf
[4] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, accessed on: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=EN
[5] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy, accessed on: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0060&from=EN

Danube floodplain guidance. General objective and scope

The *Danube Floodplain Guidance* synthesize the key results of the *Danube Floodplain* project in order to contribute to the knowledge improvement among the countries located within Danube River Basin, to an integrative water management through restoration and preservation of the floodplains. These results were obtained through a broad participative process, with involvement of all relevant stakeholders such as representatives from local administrations, water and flood risk management, NGOs and scientific community. The Danube Floodplain Guidance consider the key findings of the project, targeting wider audience of interested stakeholders, authorities and decision makers. Key restoration approaches starting from identification and evaluation of active and potential floodplains, restoration scenarios, tool for assessing floodplain restoration projects, potential win-win measures to mitigate flood risk through floodplain restoration and preservation actions are included. Steps on how to plan and implement future restoration projects and recommendations comes to complete the proposed guidance.

Legal background information

Floods Directive

As a consequence of continuously increasing of the flood events, the Directive 2007/60/EC on the assessment and management of flood risks (FD) was adopted in 2007 at the EU level. Through Flood Risk Management Plans (FRMPs), FD establish a framework for flood prevention, protection and preparedness (including forecasting). Areas with the potential to retain flood water, like natural floodplains, wetland and river meandering should be considered in the implementation process.
Each 6 years pf FD planning cycle includes three preliminary steps: flood risk assessment, flood hazard and flood risk maps and Flood Risk Management Plans. Each of these steps could be related with the floodplain issue.
Hence, the preliminary flood risk assessment identifies the significant historical floods considering the recorded damage and hazard. This will offer a better understanding of areas that could potentially be at risk of flooding and that consequently deserve more detailed attention and analysis. Overlapping the floodplain reconnection potential in these areas can provide feasible solutions to reduce the flood risk.
Flood hazard maps provide information about water depth, extent of flooded areas, water velocity, for floods that can occur over a certain period of time. The mapping process relies on different modeling techniques and it is based on a detailed mapping of the river and the floodplain. Flood risk maps should contain information on the number of inhabitants potentially affected, the type of economic activity of the area potentially affected, the potentially affected protected areas and water

stretches. Information provided in the flood risk maps, i.e., data on land use, protected areas could offer useful inputs in identification a suitable floodplain restoration scenario.
Flood Risk Management Plans are prepared for all areas identified with potentially significant flood risk and for which hazard and flood risk maps have been developed. Restoration of former floodplain or part of a former floodplain, preservation the existing floodplains should be consider as a matter of priority on the floodplain risk reduction program of measures.

Water Framework Directive

The floodplains have multiple purposes in the context of ecological functioning of the rivers and groundwaters systems : they are an important ecological part of the river system performing water filtering, aquifers recharching, securing the healthy functioning of river ecosystems and helping to sustain the biological diversity.

At European level the ecological functioning of the river systems is regulated by Water Framework Directive which came into force in 2000, as a result of need for healthy rivers, clean waters and public involvement in water policies all around Europe.
WFD introduced a general requirement for ecological protection of surface waters, the central objectives being represented by the achieving of ”good status” and the ”no deterioration ” principle.
In the context of ecological status floodplain plays an important role, even not explicity required by Annex V of WFD ; this includes the notion of river continuity which incorporates the lateral connectivity of rivers and which refers to the connection of river with its floodplain.

Depending of the human interventions generated by man-made structures built for various water uses (e.g., flood
protection, navigation, hydropower generation), the hydromorphological pressures could have consequences not only to the floodplain good functioning but also to the objectives of the WFD. These are cases when human life or economic activity is endangered by flood effects and the measures to preserve and keep it safe and to mitigate the risk could affect the achievement of environmental objectives under the Directive.

Nature Protection Directives

The Birds[6] and Habitats[7] Directives are the most ambitious initiatives to conserve Europe’s natural heritage and represent the most important legislation on nature conservation.
The two directives focuses to ensure that the protected species and habitat types are maintained or restored to a favourable conservation status over the long-term. Conservation means a series of measures required to maintain or restore the natural habitats and the populations of species of wild fauna and flora at a favorable status. Conservation status of a natural habitat means the sum of the influences acting on a natural habitat and its typical species that may affect its long-term natural distribution, structure and functions as well as the long-term survival of its typical species. There might be cases, where for the conservation status of water-dependent habitats and species protected under the Birds and Habitats Directives, the requirements in natural water bodies are different or go beyond the one required for the achievement of Good Ecological Status.and therefore should be considered as additional objectives.

Under this context the coordination between the objectives of the Flood Directive, Water Framework Directive and Birds and Habitats Directives should be clearly taken into account in RBPM Plans and in FRMPs in order to identify the best solutions for the environment and for people. One of these solutions aiming to the reduction of risk of floods is represented by natural water retention measures (NWRM) using natural means and processes, addressing the floodplain restoration, which support multiple ecosystem functions and services needed to achieve the objectives of several EU water policie.

[6] DIRECTIVE 2009/147/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 November 2009 on the conservation of wild birds
[7] COUNCIL DIRECTIVE 92 /43 /EEC of 21 May 1992; https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:31992L0043&from=EN on the conservation of natural habitats and of wild fauna and flora

Setting the scene

Identification and evaluation of active and potential floodplains

Concept

Note: Chapter adapted from the following sources: Danube Floodplain. Deliverable D.3.2.1. Priority list with potential preservation and restoration areas (based on FEM-tool), 2021

First, a methodology was developed for the identification of active and potential floodplains along the Danube River. In the next step, both floodplain types were evaluated with the Floodplain Evaluation Matrix (FEM), a holistic, integrative method for assessing hydrological, hydraulic, ecological, and socio-economic effects of a floodplain.

The methodological steps for active and potential floodplains identification and evaluation processes are presented in the *Figure 1.*

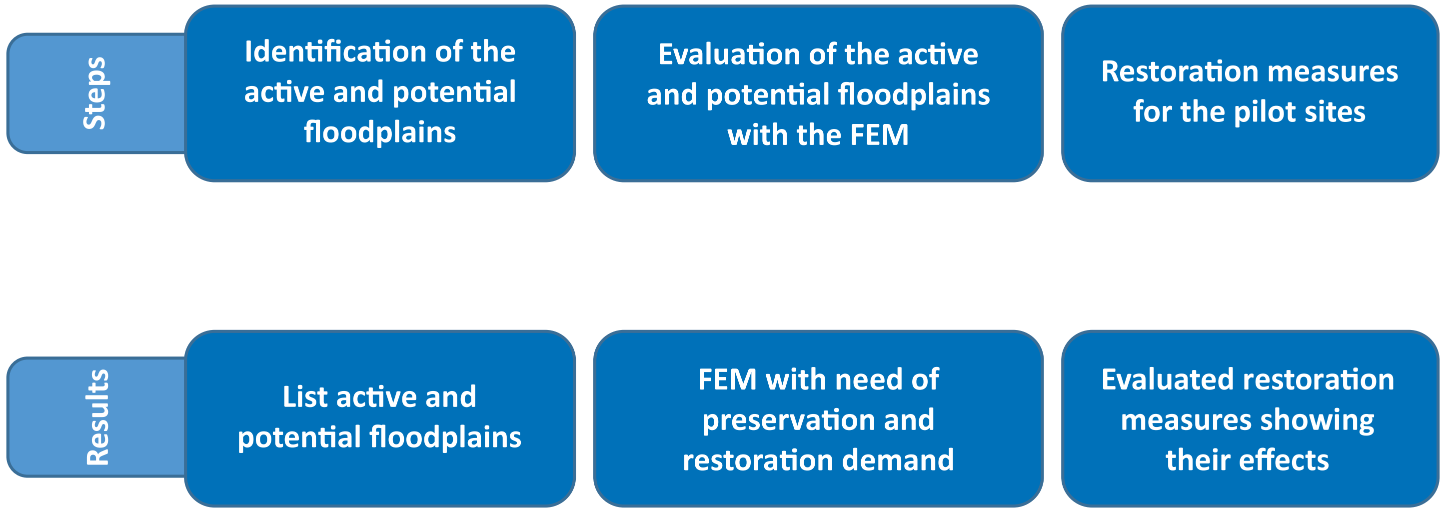

Figure 1 - Methodological steps for active and potential floodplains identification and evaluation processes

STEP 1: Identification of active and potential floodplains

Active floodplains are defined as all areas that are still flooded during an HQ_{100} flood event.

Within the project, a method was developed to identify and delineate active floodplains resulting in a *Danube Floodplain Inventory (DFInv)* of hydraulically predefined floodplain sections.

Flood event with a return period of 100 years was widely accepted as the design discharge for flood protection measures along the Danube River. These inundation outlines (based on the results of the Danube FLOODRISK project[8]) were chosen as the data basis for the identification of the *active floodplains* in the Danube Floodplain project.

The HQ_{100} inundation outlines was completed with three delineation criteria

- *Ratio factor of width floodplain/width river* (to identify the beginning and end of a floodplain);
- *Minimum size of an active floodplain* (to avoid too small floodplains for the evaluation);
- *Current hydraulic characteristics* of the floodplain, like flow paths (identified floodplains should represent the natural flow characteristics).

These criteria cannot be used only at the Danube River, but are applicable at every river. In the Danube floodplain project, the criteria were also applied at the selected tributaries.

Only the values for the first two criteria have to be adjusted for the selected river. In general, the thresholds can be selected for each river individually under consideration of specific characteristics of the river and its floodplains.

For the Danube River the following values were selected:

- A ratio factor of width floodplain/width river > 1:1;
- A minimum floodplain size of 500 ha;
- Floodplain must be hydraulically connected, and characteristic flow behavior is given.

[8] Danube FloodRisk Project, ICPDR, 2012, accessed on http://www.icpdr.org/main/activities-projects/danube-floodrisk-project

After the identification of all active floodplains along the Danube, a methodology was developed for the identification of potential floodplains. The potential floodplains have the potential for reconnection to the river system during a HQ_{100} flood event. Historical maps and/or inundation outlines of a $HQ_{extreme}$ e.g., HQ_{300} or HQ_{1000} are used to identify former/historical floodplain first. Each country decides on its own if an area could be identified as a potential floodplain in case that settlements, critical infrastructures and streets are located in the historical/former floodplain. Settlements, streets and critical infrastructures had to be protected by complementary local flood protection measures – e.g., protective walls, earth deposits/dikes.

Potential floodplains are currently not inundated in the case of HQ_{100}, but with restoration measures, these areas can be reconnected to the river system leading to inundation during various HQ events (at least HQ_{100}), depending on the sites' character and the reconnection design.

In the context of the project, it was decided to differentiate between two types of potential floodplains, namely potential and "operational" potential floodplains. The difference between these two types is that the "operational" potential floodplains was identified and discussed with stakeholders, technical experts and decision makers.

In the following it is described how the identification of potential floodplains is working:

Step 1: Identify historical/former floodplains by using the $HQ_{extreme}$ inundation outline from the Danube Atlas or historical maps.

Step 2: Exclude settlements, infrastructure and streets in the former floodplain.

Step 3: Exclude agricultural land where no compensation is possible or too expensive.

Step 4: Define the Danube Floodplain scenario for this potential floodplain. The scenario for the reconnection (e.g., cut of dikes, removal of dikes, land use change) will then be used for the modelling of the potential floodplains.

Step 5: Discuss with stakeholders to define the "operational" potential floodplain and the technical aspects of the reconnection. Even some agricultural areas excluded in Step 3 can be considered as potential floodplains again, leading to additional potential floodplain areas with higher potential for conflicts. These areas should be also discussed with the relevant stakeholders from different sectors. This is not done in the Danube Floodplain project.

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Figure 2 presents on overview of active, potential and former floodplains along the Danube River assessed in frame of Danube Floodplain project

Figure 2 - Overview of active, potential and former floodplains along the Danube River[9]

STEP 2: Evaluation of active and potential floodplains - Floodplain Evaluation Matrix (FEM)

The evaluation of active and potential floodplains was based on the Floodplain Evaluation Matrix (FEM), developed by the Institute of Hydraulic Engineering and River Research at the University of Natural Resources and Life Sciences, Vienna (BOKU)[10].

[9] Eder, M., Scheuer, S., Tritthart, M., Perosa, F., Gelhaus, M., Cyffka, B., van Leeuwen, B., Tobak, Z., Sipos, G., Smetanova, A., Bokal, S., Samu, A. Gruber, T., Galie, A., Moldovenau, M., Petrisor, M., Habersack, H. (in preparation). Identifying active, potential and former floodplains - Methods and lessons learned from the Danube River. Water.
[10] Habersack, Schober & Hauer 2015

For the Danube Floodplain project, the original FEM method was further developed to serve the project needs. All possible parameters from the previous applications of the FEM were collected and explained to the partners. Additional parameters have been discussed together with all project partners. From the list of parameters, the partners then selected which ones they see as important for the evaluation of floodplains.

In general, the method allows the evaluation of various river reaches by setting up a priority ranking, which indicates where efforts of floodplain preservation / restoration should be spent first to obtain maximum benefits. With this methodology, a valuable decision support method is available for stakeholders and decision makers to assess multiple benefits that floodplain restoration and preservation can offer.

A minimum set of parameters, was considered mandatory for all partners to be calculated. All other parameters are additional ones, which can be evaluated and serve as additional information in the Danube Floodplain GIS but will not be considered for the ranking list.

The Figure 2 presents the Floodplain Evaluation Matrix developed in Danube Floodplain project for assessment active and potential floodplains.

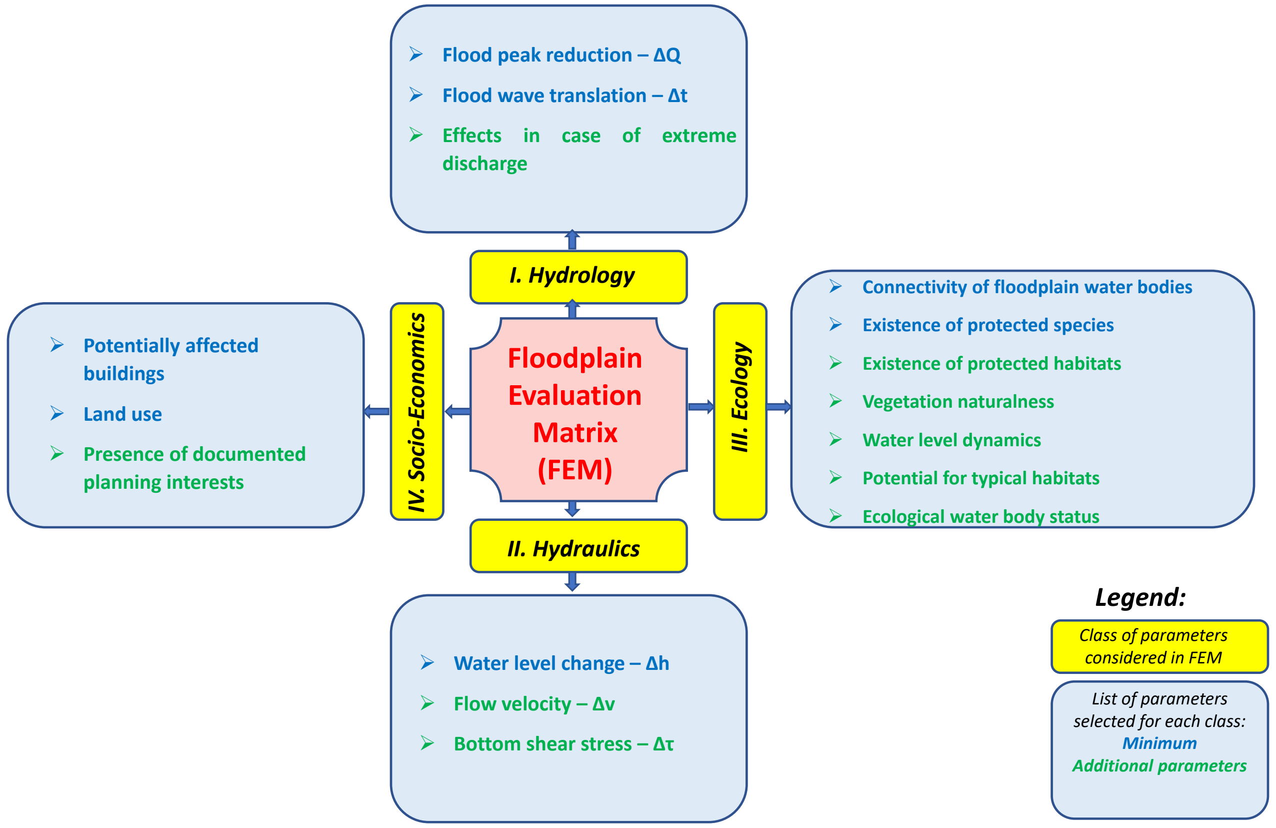

Figure 3 - Floodplain Evaluation Matrix developed in Danube Floodplain project for assessment active and potential floodplains

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A brief description of the FEM parameters is presented below[11]:

Hydrology:

Flood peak reduction – ΔQ. It considers the effect of a floodplain on the peak of a flood wave. The peak of an input hydrograph (e.g. HQ_{100}) at the beginning of the floodplain and the peak of the output hydrograph[12] at the end of the floodplain is determined. The difference between the peaks is the peak reduction *ΔQ [m³/s]* for the investigated floodplain.

Flood Wave Translation - Δt. It is determined in a similar way as the peak reduction, namely by calculating the time difference *Δt [h]* between the occurrence of the output/input hydrograph peak.

Effects in case of extreme discharge: It allows accounting for remaining risk (higher discharges due to climate change) and refers to the effects of floodplain areas on hydrological parameters (ΔQ, Δt) for scenarios with discharges larger (HQ_{1000}) than the design discharge (HQ_{100}).

Hydraulics:

Water level change – Δh: It refers to the influence of changes in floodplain geometry (e.g., by dyke-shifting) considering a hydrodynamic-numerical model. The water levels corresponding to the two scenarios (with and without floodplain) in the river channel at the middle of the floodplain are compared.

Flow velocity – Δv: It refers to the influence of changes in floodplain geometry (e.g., by dyke-shifting) considering a hydrodynamic-numerical model. It shoes the effects of a total loss of a floodplain on the flow velocity. The velocities corresponding to the two scenarios (with and without floodplain) in the river channel at the middle of the floodplain are compared.

Bottom shear stress – Δτ: It refers to the influence of changes in floodplain geometry considering a hydrodynamic-numerical model. Reducing or extending floodplain widths by modelling of fictive dykes exhibits how big changes in the bottom shear stress of the scenarios (Δτ) can be.

[11] Danube Floodplain Project: Priority list with potential preservation and restoration areas (based on FEM-tool) (Deliverable D 3.2.1 from WP3: Floodplain evaluation) accessed on http://www.interreg-danube.eu/approved-projects/danube-floodplain/outputs

[12] Hydrograph is a graph or plot that shows the rate of water flow in relation to time, given a specific point or cross section.

Ecology:

Connectivity of floodplain water bodies: Lateral connectivity is crucial for the functionality of riverine ecosystems. It describes the connectivity in the up- and downstream direction and is especially relevant for the exchange of populations of water organisms and their migration during their life cycle.

Existence of protected species: A floodplain is especially valuable and should be preserved if red list species or species and habitats (recognized by Natura2000) are found in the area. This parameter evaluates how many protected species can be found at the floodplain according to Natura2000 or the Emerald Network.

Vegetation naturalness: The landscape patterns of a floodplain can be a good indicator for the naturalness of vegetation.

Water level dynamics: In order to restore floodplain habitats, rivers and floodplains must have a water level dynamic, almost like the one that exists in the natural floodplains. The parameters water level duration, frequency of the flood and amplitude of the water levels are summarized to describe the possible water level dynamics.

Potential for typical habitats: The typical river and floodplain habitats should have the possibility to re-establish habitats if they are not already existing. The parameter evaluates how many of the typical habitats are available at the floodplain or could be restored.

Ecological water body status: As part of the Water Framework Directive, the countries should evaluate the ecological status of the water bodies. The potential effect of restoration measures at the floodplain on the ecological water body status will be assessed by experts to the best of their knowledge.

Socio-Economics:

Potentially affected buildings: This parameter determines the number of buildings on each active floodplain.

Land use: Land use that is adapted to future inundation will minimize the socio-economical vulnerability of the floodplain. The different types of land uses are aggregated proportional to their areas to one evaluation value for the whole floodplain.

Presence of documented planning interests: This parameter evaluates the presence of infrastructure or spatial development plans/ projects in the floodplain area or close to it.

After the calculation of the minimum parameters for the active floodplain, the performance of each parameter is determined with the minimum parameters. Three levels of performance are possible for each parameter:

- High performance (5 points, colour code: blue)
- Additional performance (3 points, colour code: green)

Based on selected thresholds, the performance of the floodplain for each parameter can be determined. The thresholds can be selected for each river individually under consideration of specific characteristics of the river and its floodplains.

It is recommended to start with the thresholds used at the Danube River and if necessary, adaptation can be made.

The selected thresholds can be found in Deliverable 3.2.1[13]

In the following set of maps[14], the restoration demand of all active floodplains and all identified potential floodplains are presented.

[13] Danube Floodplain Project: section 2.2.2 from Priority list with potential preservation and restoration areas (based on FEM-tool) report (Deliverable D 3.2.1 from WP3: Floodplain evaluation) accessed on http://www.interreg-danube.eu/approved-projects/danube-floodplain/outputs
[14] Based on GIS shapefiles collected and processed within Danube Floodplain Project (under WP3 coordination - USZ)

Danube Active and Potential Floodplains - Germany

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Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
DE_DU_AFP01	Donaueschingen	973.3	
DE_DU_AFP02	Riedlingen	634.1	
DE_DU_AFP03	Oberelchingen - Lech	15554.4	medium
DE_DU_AFP04	Lech - Neuburg	3229.3	medium
DE_DU_AFP05	Bergheim – Ingolstadt	2192	high
DE_DU_AFP06	Neustadt – Weltenburg	1644.6	high
DE_DU_AFP07	Regensburg	745.3	high
DE_DU_AFP08	Geisling/Gmünd	1061.5	high
DE_DU_AFP09	Straubing - Isar	6716.4	medium
DE_DU_AFP10	Isar - Vilshofen	4531.1	medium

Restoration demand

- *high*
- *medium*
- *low*
- *no information*
- *Potential floodplain*

N W E S

0 30 km

Potential Floodplains

DFGIS_ID	Location	Area [ha]
DE_DU_PFP01	Oberelchingen - Lech	16697.8
DE_DU_PFP02	Lech - Neuburg	3735.8
DE_DU_PFP03	Großmehring	493.5
DE_DU_PFP04	Katzau	308.6
DE_DU_PFP05	Geisling/Gmünd	2502.1

Legend *Danube River* *Danube River Basin District* *National borders* *100000 - 250000 inhabitants* *250000 - 2000000 inhabitants* *Urban areas*

Danube Active and Potential Floodplains - Austria

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Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
AT_DU_AFP01	Aschach - Ottensheim	5641.9	medium
AT_DU_AFP02	Linz - Mauthausen	3480	high
AT_DU_AFP03	Mauthausen - Ardagger Markt	7220.3	low
AT_DU_AFP04	Krems - Wien	15192	low
AT_DU_AFP05	Wien - Devin	8533.8	low
AT_SK_DU_AFP01	Devin - Wolfsthal	1984.9	medium

Restoration demand

high
medium
low
no information

Potential floodplain

N W E S

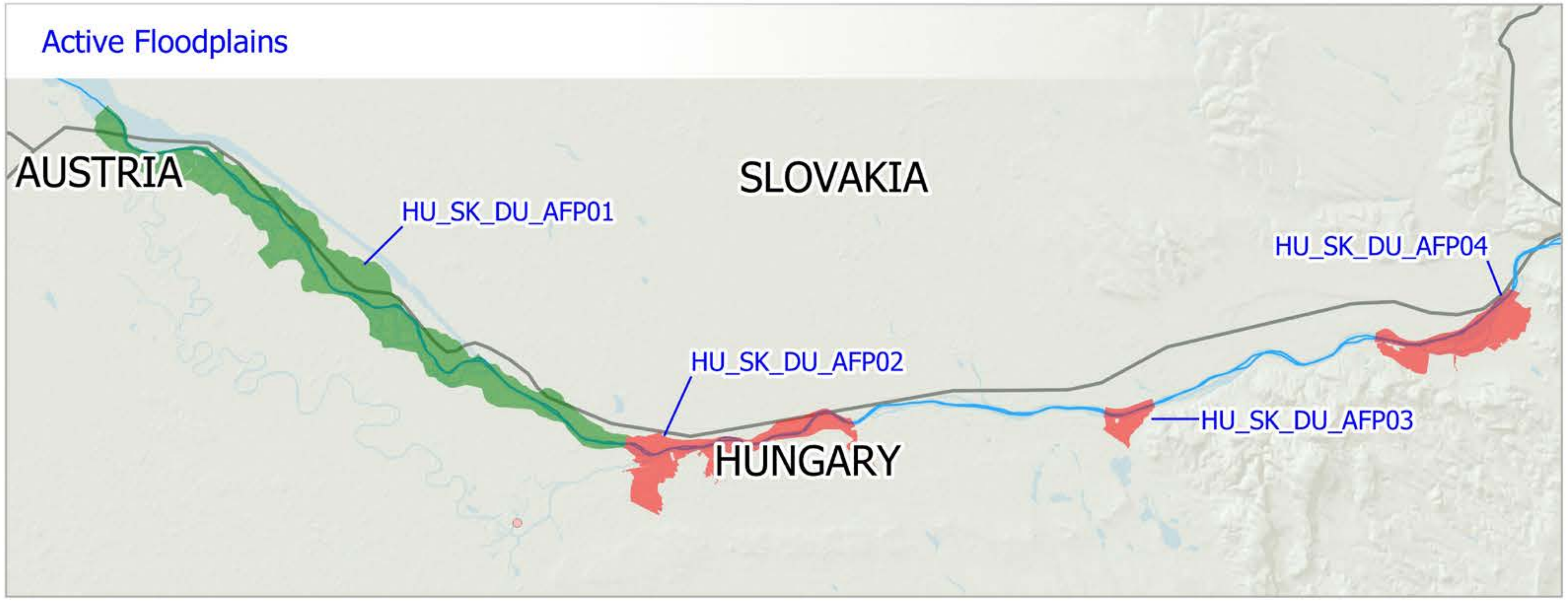
0 30 km

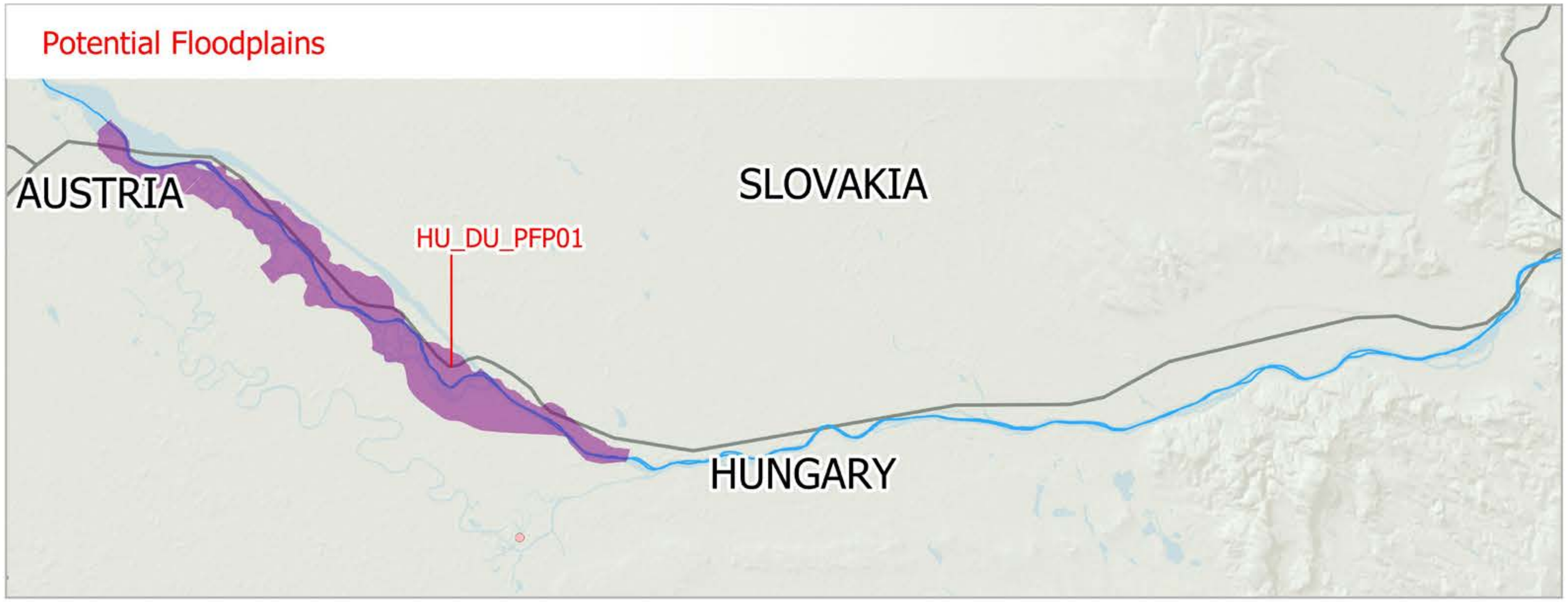
Potential Floodplains

DFGIS_ID	Location	Area [ha]
AT_DU_PFP01	Krems - Wien	16065.5
AT_DU_PFP02	Wien - Devin	12139.1

Legend
Danube River *Danube River Basin District* *National borders* *100000 - 250000 inhabitants* *250000 - 2000000 inhabitants* *Urban areas*

Danube Active and Potential Floodplains - Slovakia / Hungary





Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
HU_SK_DU_AFP01	Szigetköz	14024.6	low
HU_SK_DU_AFP02	Gönyű	4059.2	high
HU_SK_DU_AFP03	Almásfüzitő	827.1	high
HU_SK_DU_AFP04	Esztergom	3118.2	high

Restoration demand

- *high*
- *medium*
- *low*
- *no information*

- *Potential floodplain*

N W E S

0 30 km

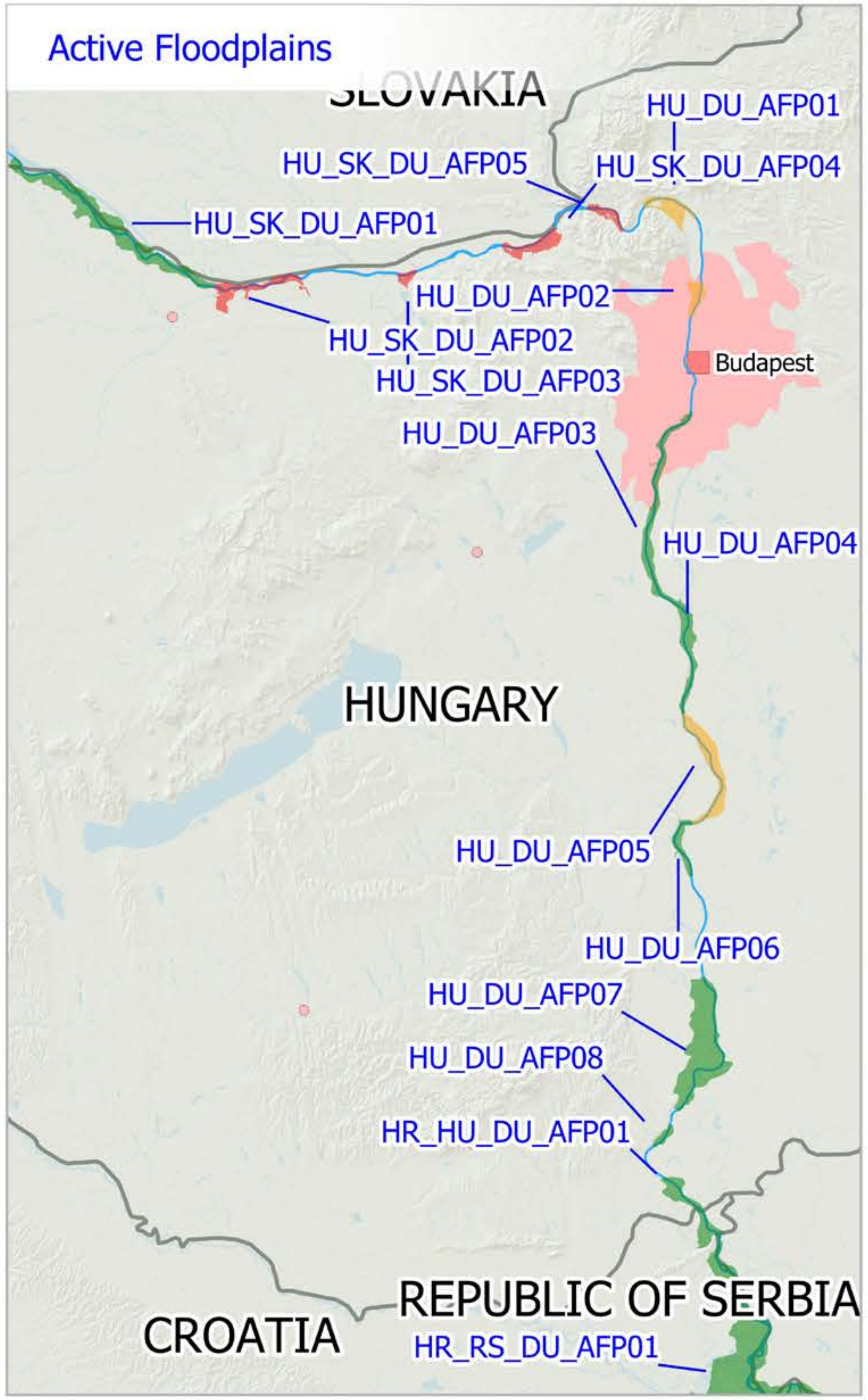
Potential Floodplains

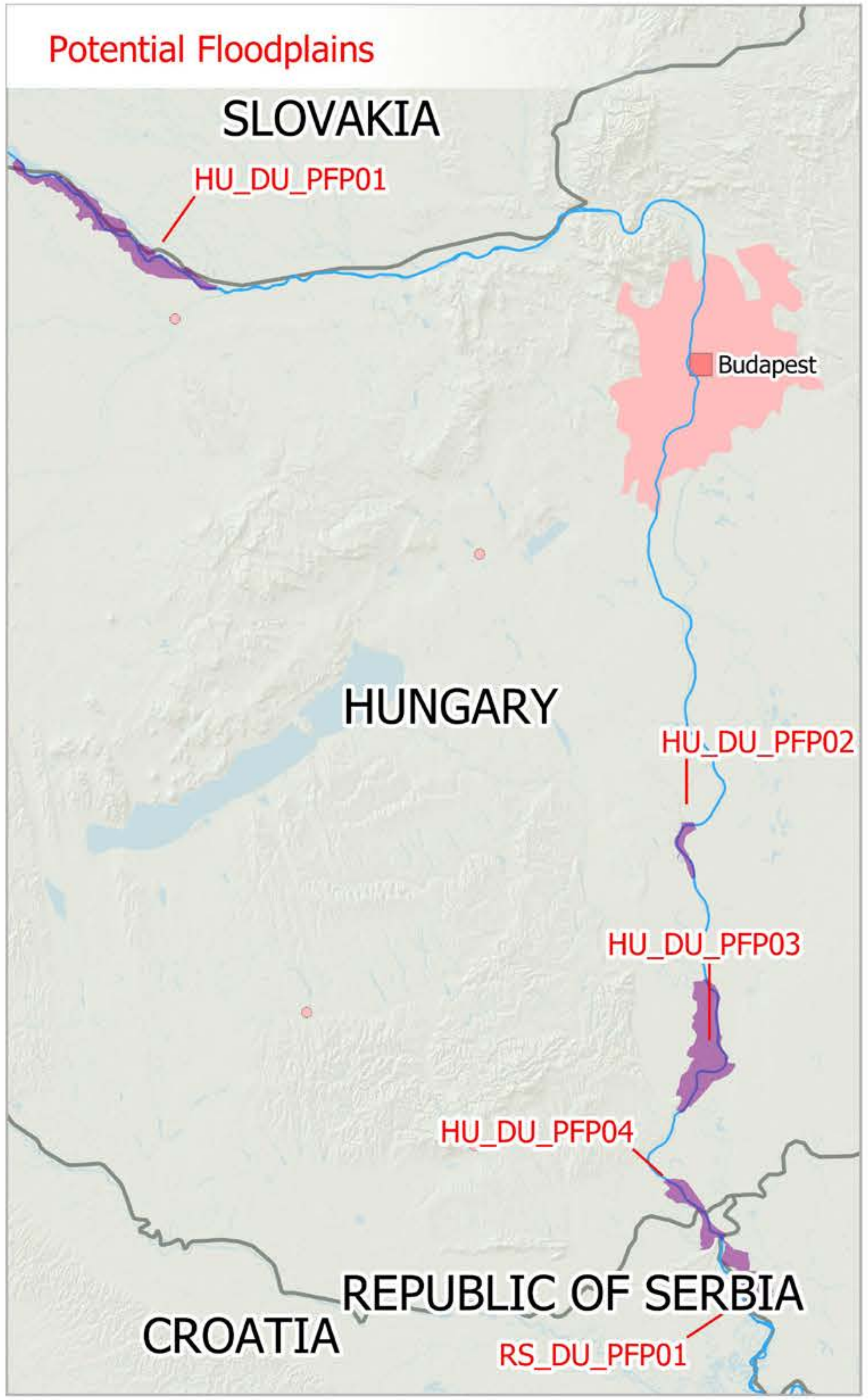
DFGIS_ID	Location	Area [ha]
HU_DU_PFP01	Szigetköz	15711.3

Legend: *Danube River* | *Danube River Basin District* | *National borders* | *100000 - 250000 inhabitants* | *250000 - 2000000 inhabitants* | *Urban areas*

Danube Active and Potential Floodplains - Hungary

Interreg
Danube Transnational Programme
Danube Floodplain





Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
HR_HU_DU_AFP01	Béda-Karapnacsa	4822.1	low
HR_RS_DU_AFP01	Kopački rit / Gornje Podunavlje	27994.1	low
HU_DU_AFP01	Szentendrei-sz. North	3230.8	medium
HU_DU_AFP02	Szentendrei-sz. South	1817	medium
HU_DU_AFP03	Csepel-sziget	7077.8	low
HU_DU_AFP04	Dunaújváros	4472.1	low
HU_DU_AFP05	Dunaföldvár	6377.7	medium
HU_DU_AFP06	Paks	2034.8	low
HU_DU_AFP07	Veránka-sziget	15904	low
HU_DU_AFP08	Bezerédy-sziget	901.1	low
HU_SK_DU_AFP01	Szigetköz	14024.6	low
HU_SK_DU_AFP02	Gönyű	4059.2	high
HU_SK_DU_AFP03	Almásfüzitő	827.1	high
HU_SK_DU_AFP04	Esztergom	3118.2	high
HU_SK_DU_AFP05	Pilismarót	1492.6	high

Restoration demand

- *high*
- *medium*
- *low*
- *no information*

N W E S

0 30 km

Potential Floodplains

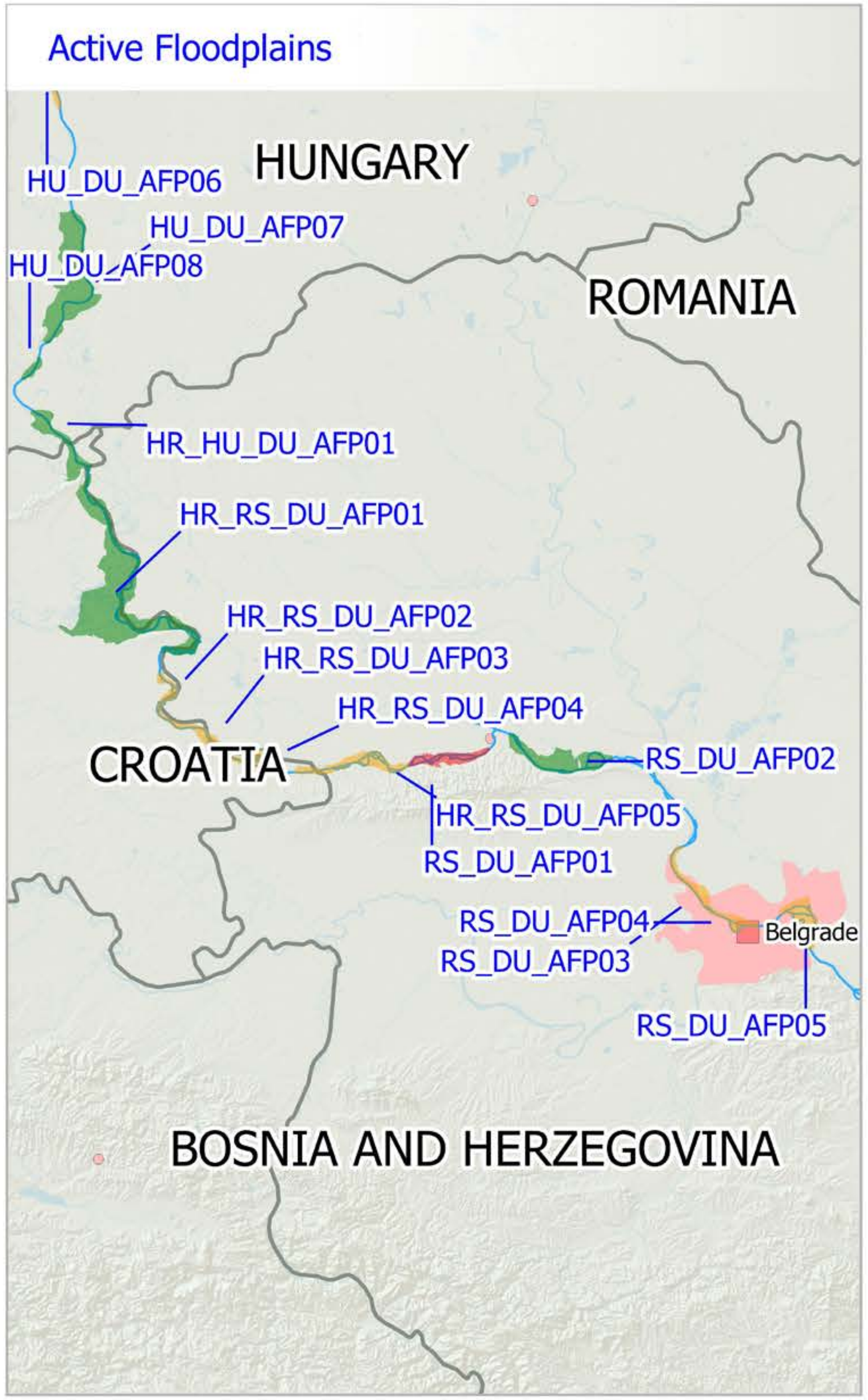
DFGIS_ID	Location	Area [ha]
HU_DU_PFP01	Szigetköz	15711.3
HU_DU_PFP02	Paks	2214.2
HU_DU_PFP03	Veránka-sziget	16171.6
HU_DU_PFP04	Béda-Karapnacsa	5470.6
RS_DU_PFP01	Siga - Kazuk	6057.5

Legend

- *Danube River*
- *Danube River Basin District*
- *National borders*
- *Urban areas*
- *100000 - 250000 inhabitants*
- *250000 - 2000000 inhabitants*
- *Potential floodplain*

Danube Active and Potential Floodplains - Hungary / Croatia / Serbia

Interreg
Danube Transnational Programme
Danube Floodplain



Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
HR_HU_DU_AFP01	Béda-Karapnacsa	4822.1	low
HR_RS_DU_AFP01	Kopački rit / Gornje Podunavlje	27994.1	low
HR_RS_DU_AFP02	Borovo / Vajska	1958.5	medium
HR_RS_DU_AFP03	Vukovar / Bačko Novo Selo	2462.3	medium
HR_RS_DU_AFP04	Mohovo / Karađorđevo	3001.2	medium
HR_RS_DU_AFP05	Ilok / Bačka Palanka	4922.2	medium
HU_DU_AFP05	Dunaföldvár	6377.7	high
HU_DU_AFP06	Paks	2034.8	medium
HU_DU_AFP07	Veránka-sziget	15904	low
HU_DU_AFP08	Bezerédy-sziget	901.1	low
RS_DU_AFP01	Futog-Beočin	3481.3	high
RS_DU_AFP02	Koviljsko-petrovaradi rit	7480.7	low
RS_DU_AFP03	Novi Banovci	2765.8	medium
RS_DU_AFP04	Beograd	1838.4	medium
RS_DU_AFP05	Pančevo	4323.5	medium

N W E S

0 30 km

Restoration demand

- *high*
- *medium*
- *low*
- *no information*

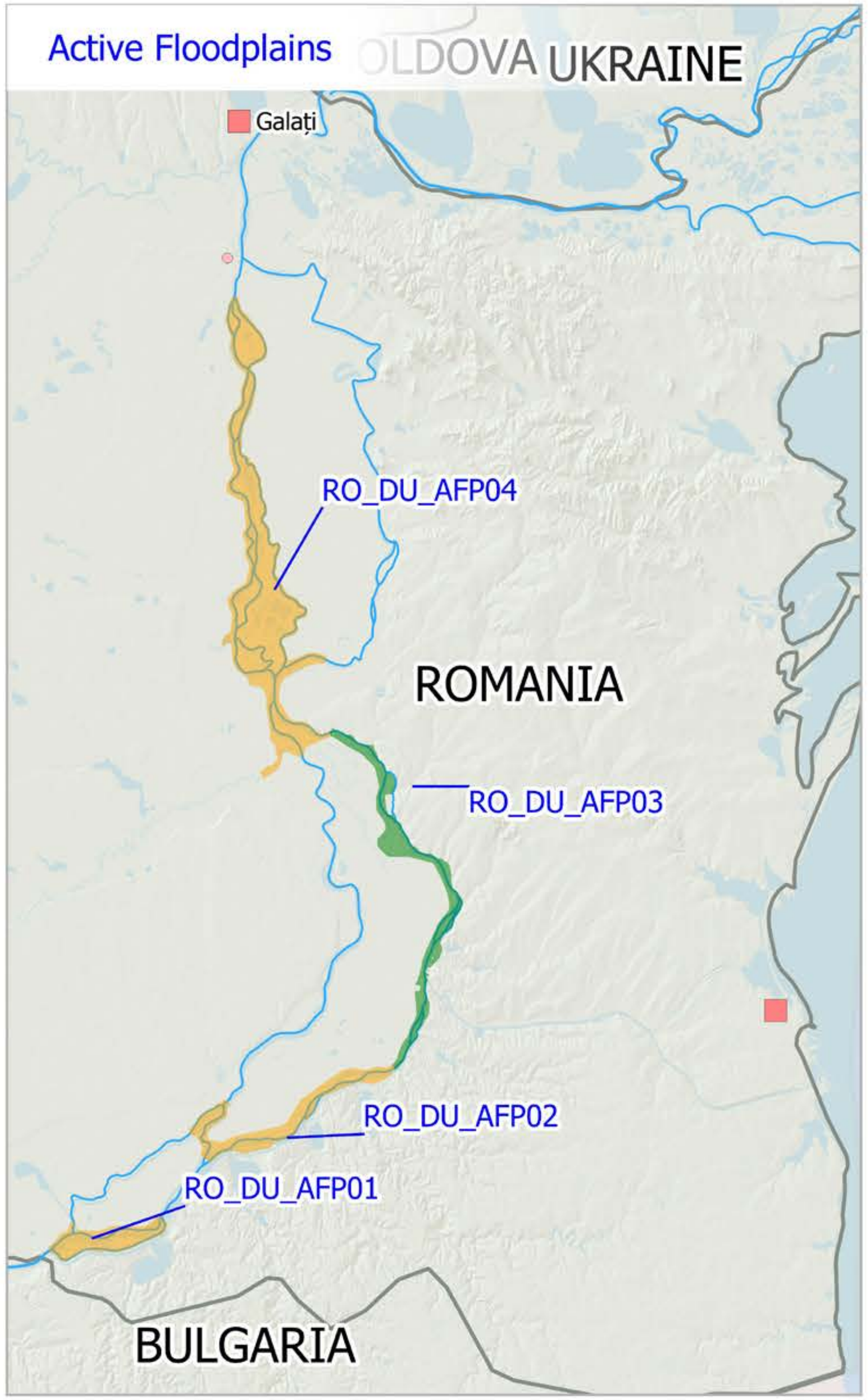
Potential Floodplains

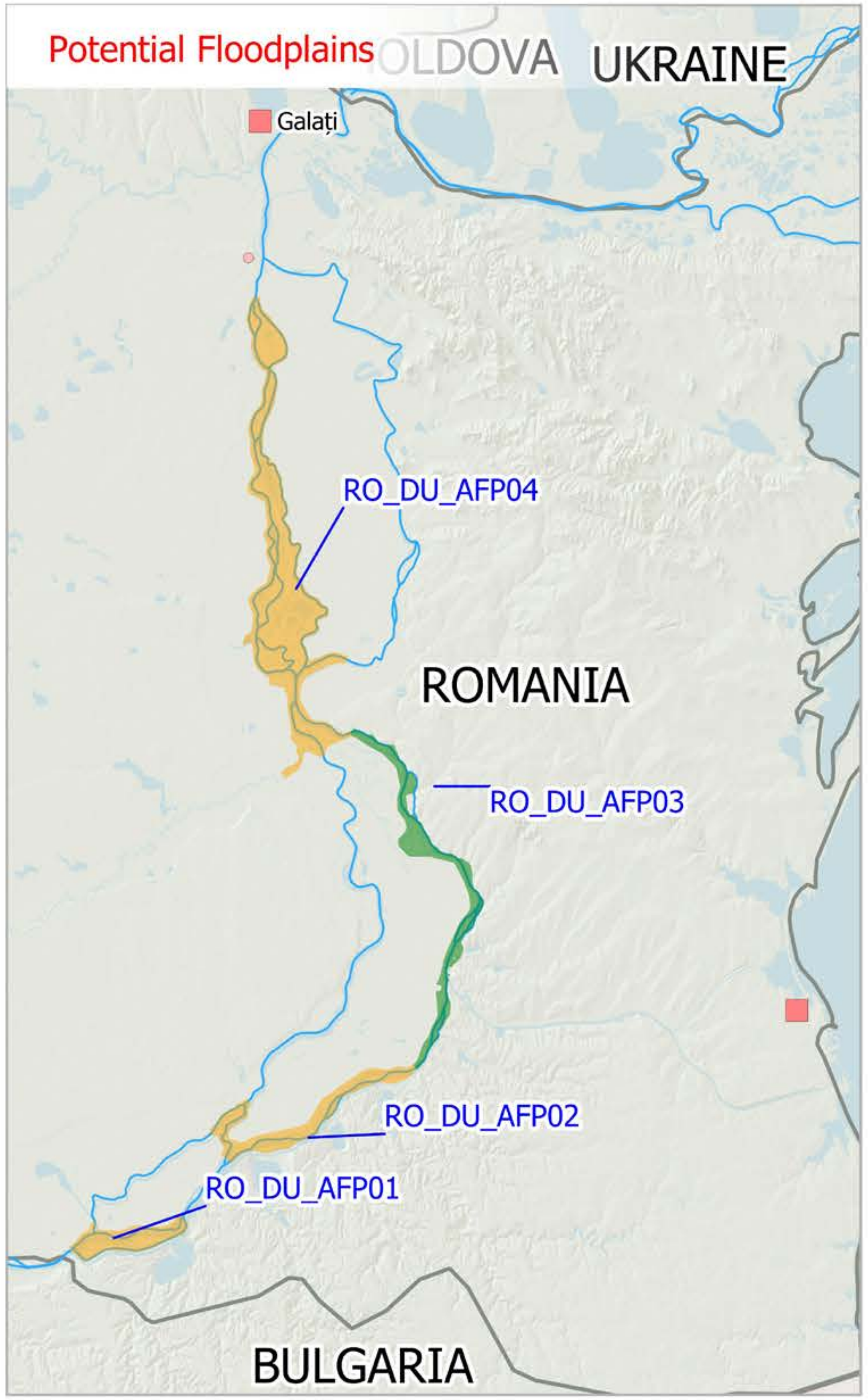
DFGIS_ID	Location	Area [ha]
HU_DU_PFP02	Paks	2214.2
HU_DU_PFP03	Veránka-sziget	16171.6
HU_DU_PFP04	Béda-Karapnacsa	5470.6
RS_DU_PFP01	Siga - Kazuk	6057.5
RS_DU_PFP02	Vajska	5986.2
RS_DU_PFP03	Kamari[illegible]te	10069.1

Legend

Danube River
Danube River Basin District
National borders
Urban areas
100000 - 250000 inhabitants
250000 - 2000000 inhabitants
Potential floodplain

Danube Active and Potential Floodplains - Romania





Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
RO_DU_AFP01	Calarasi	5027.5	medium
RO_DU_AFP02	Oltina - Rasova	7944.7	medium
RO_DU_AFP03	Rasova - Cernavoda - Harsova	9358.1	low
RO_DU_AFP04	Harsova - Braila	29876	medium

N W E S

0 30 km

Restoration demand

- *high*
- *medium*
- *low*
- *no information*

Potential Floodplains

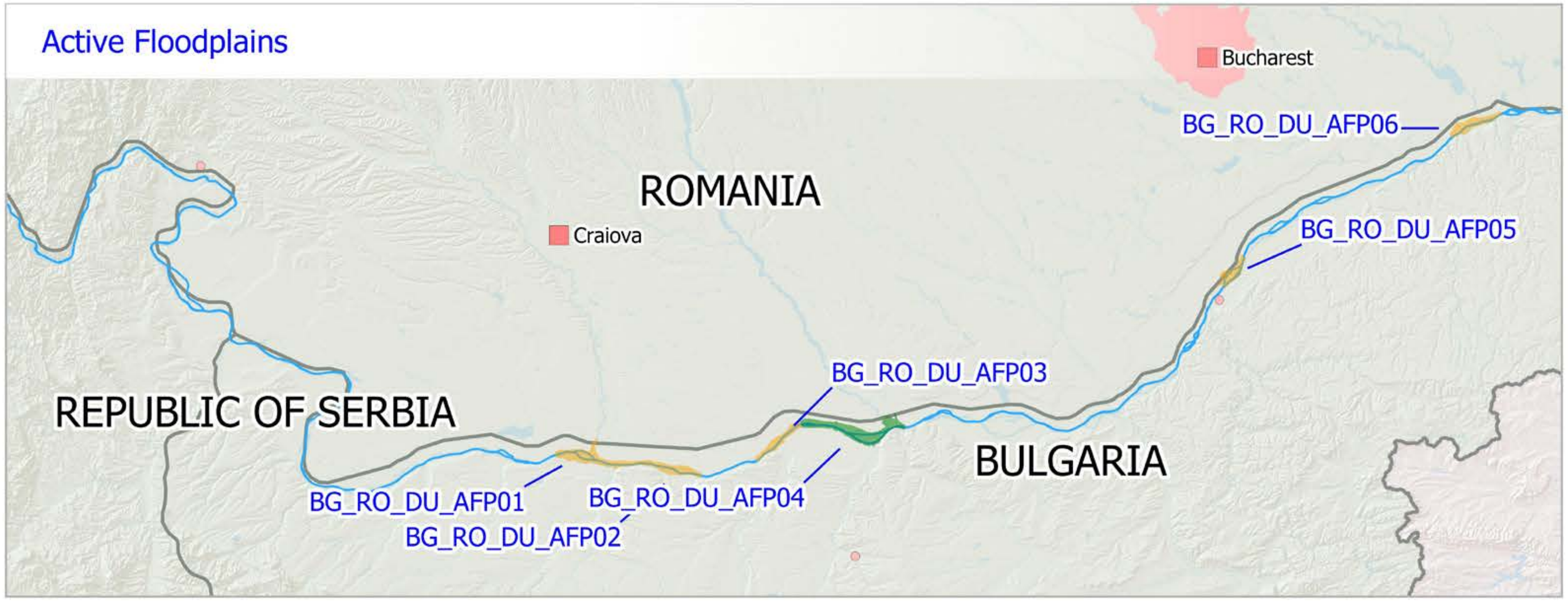
DFGIS_ID	Location	Area
RO_DU_PFP01	Borcea Buliga	857.9
RO_DU_PFP02	Bentu	68.6
RO_DU_PFP03	Garliciu	1083.8
RO_DU_PFP04	Tichilesti	31808.3
RO_DU_PFP05	Cotu Pisicii	1163.5

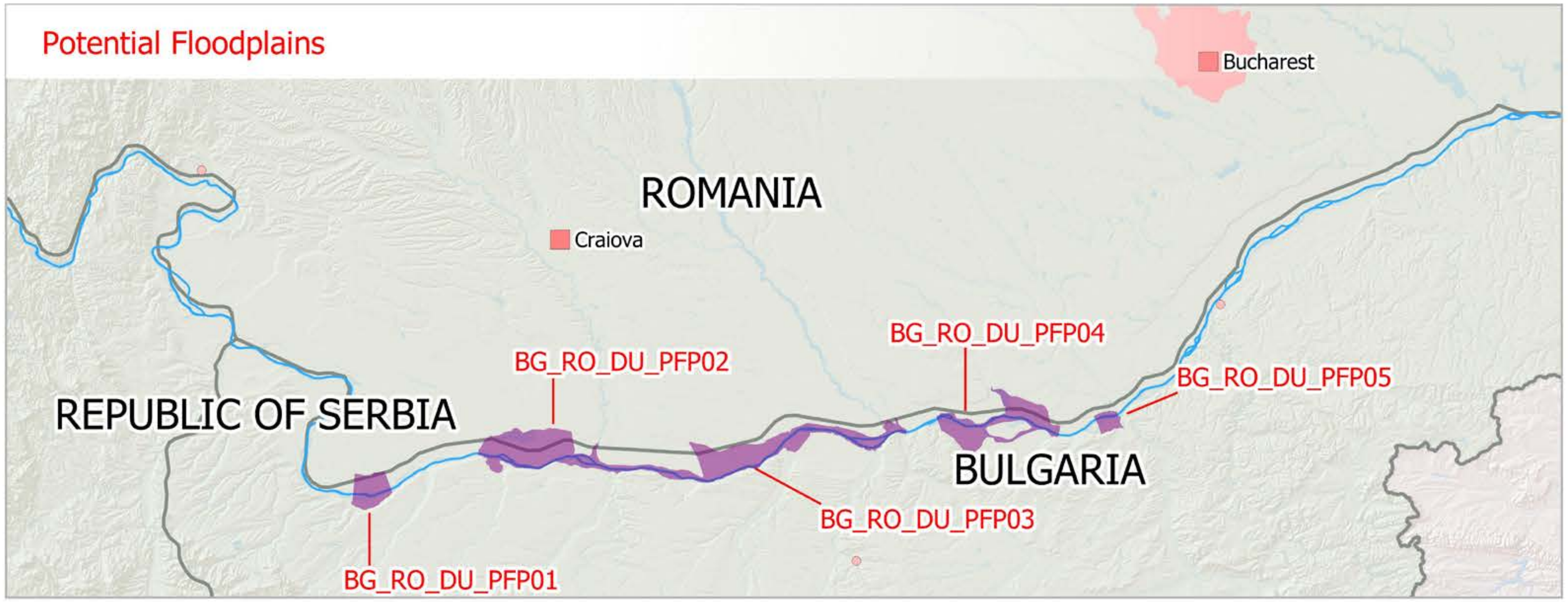
Legend

- *Danube River*
- *Danube River Basin District*
- *National borders*
- *Urban areas*
- *100000 - 250000 inhabitants*
- *250000 - 2000000 inhabitants*
- *Potential floodplain*

Danube Active and Potential Floodplains - Romania / Bulgaria

Interreg
Danube Transnational Programme
Danube Floodplain





Active Floodplains

DFGIS_ID	Location	Area [ha]	Rest.dem.
BG_RO_DU_AFP01	RO: Ostroveni - Bistret; BG: Kozlodui - Oreahovo	6009.3	medium
BG_RO_DU_AFP02	RO: Dabuleni; BG:Leskovet - Ostrov	3227.4	medium
BG_RO_DU_AFP03	RO: upstream from Corabia; BG: Baikal - Ghighen	2932.6	medium
BG_RO_DU_AFP04	RO: downstream from Corabia - Islaz; BG: Zagrajden - Somovit	8162.3	low
BG_RO_DU_AFP05	RO: Giurgiu; BG: Marten	2534.8	medium
BG_RO_DU_AFP06	RO: Chiselet-Dorobantu; BG: Popina	3357.8	medium

N W E S
0 30 km

Restoration demand

- *high*
- *medium*
- *low*
- *no information*

Potential Floodplains

DFGIS_ID	Location	Area [ha]
BG_RO_DU_PFP01	RO: Desa; BG: Slivata - Orsoia	8276.8
BG_RO_DU_PFP02	RO: Bistret - Bechet; BG: Dolni Tibar - Oreahovo	27972.8
BG_RO_DU_PFP03	RO: Bechet - Turnu Magurele; BG: Oreahovo - Cerkovita	30972
BG_RO_DU_PFP04	RO: Traian - Zimnicea; BG: Deagas Voivoda - Svistov	20450
BG_RO_DU_PFP05	RO: Nasturelu; BG: Novgrad	3169.1

Legend

- *Danube River*
- *Danube River Basin District*
- *National borders*
- *Urban areas*
- *100000 - 250000 inhabitants*
- *250000 - 2000000 inhabitants*
- *Potential floodplain*

STEP 3: Scenarios for restoration and preservation in pilot areas

Note: Section adapted from the following sources: Deliverable D 4.1.2: Technical document concerning the homogenization of different models, as well as the basin wide assessment of the strategy measures' impact and efficiency.

To assess the changes of the effects of floodplain restoration to flood events, it was decided to investigate *three restoration scenarios: current state scenario (CS)* and *two restoration scenarios (RS1* – realistic and *RS2* – optimistic).

Therefore, the three restoration scenarios have been applied in five pilot areas: Bececka Jama in Serbia; Bistret in Romania, Krka in Slovenia, Middle Tissa in Hungary, and Morava in Slovakia and Czech Republic *(Figure 4).*

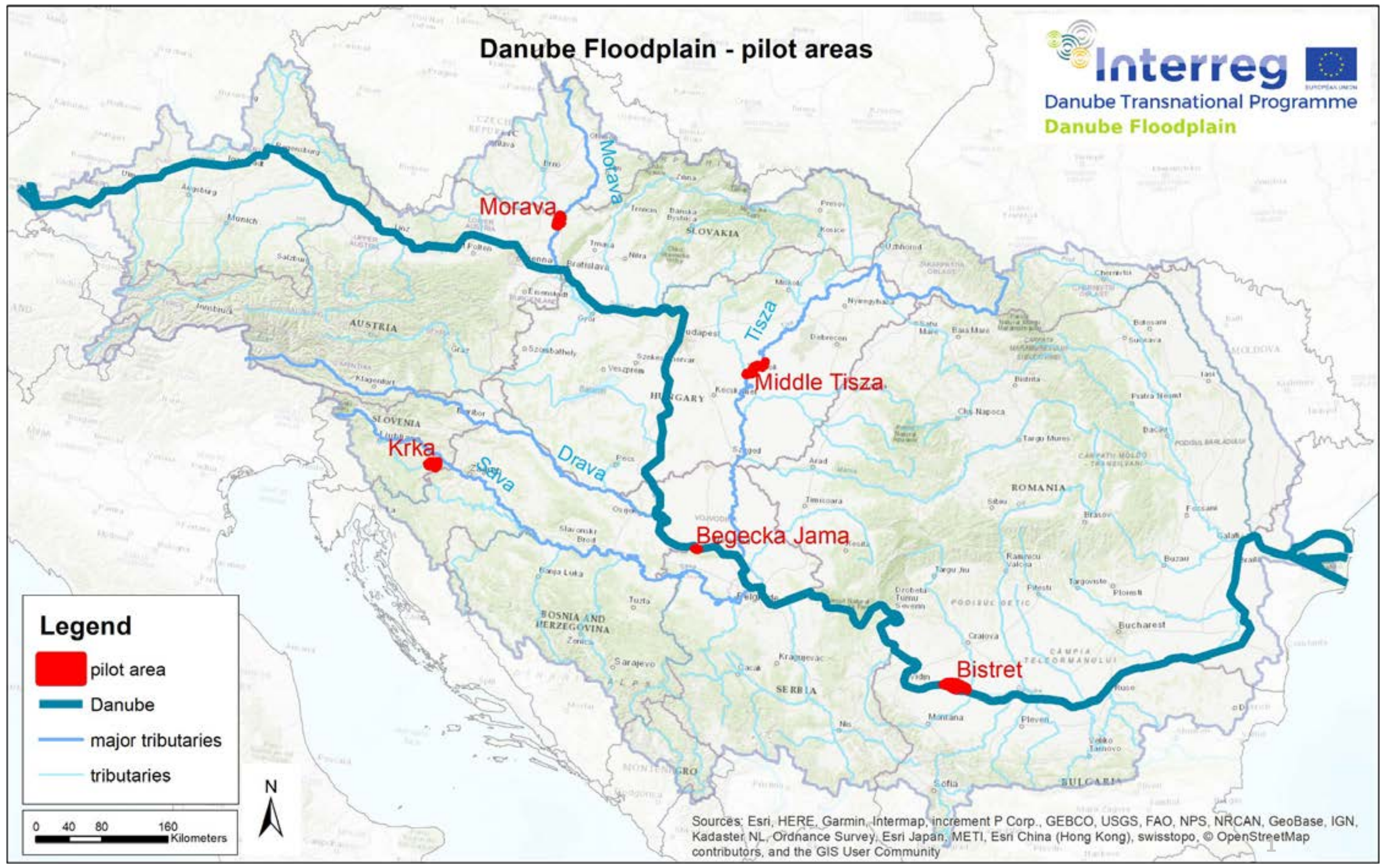


Figure 4 - The pilot areas in the frame of the Danube Floodplain project

In cooperation with national authorities, as well as the identified stakeholders, two restoration scenarios were developed, specific for each pilot area. The planned restoration measures were discussed with relevant stakeholders on a stakeholder workshop in each of the pilot areas, including discussions on various domains like fishery, agriculture, shipping, municipal authorities, nature protection, residents, etc.

1. Current State (CS)
The first model represents the current state of the area (CS). It was set up based on a recent high-resolution Digital Elevation Model (DEM) and up-to-date ground survey data. It is the base model for the restoration scenarios models.

2. Realistic restoration scenario 1 (RS1)
In the second scenario **(realistic restoration scenario 1; RS1)**, all planned measures are implemented, e.g., dike relocation, modification of land cover, and river geometry.

3. Optimistic restoration scenario 2 (RS2)
Furthermore, an optimistic scenario model **(optimistic restoration scenario 2; RS2)** is developed which includes more extensive measures. With this approach, the maximum capacity of flood protection obtained by restoration measures in the pilot areas without consideration of real limitations is shown.

Hydrodynamic Modeling in the Pilot Areas

Note: Section adapted from the following sources: Deliverable D 4.1.1: Report on the technical realization scenarios taken into consideration for modelling, the implementation in a 2D model and assessment of the impact; Deliverable D 4.3.4: Summary of used complex methodology and process description on hydraulic 1D and 2D, CBA, ESS, ecological assessment and stakeholder analysis; Deliverable D 4.4.3: Summary of general recommendations for a successful realization process, communicated to local, national, and international stakeholders in workshop activities and publications as input for D 5.2.1 and D 5.2.2.

After an agreement on the explicit restoration measures in each scenario with the stakeholders, the project partners set up the three 2D models for the pilot areas.[15] First, the current state model was set up, calibrated, and validated with input data requested from local authorities. After calibrating and validating the current state model, the measures of both restoration scenarios were implemented. This was done e.g., by adjusting the digital elevation model (DEM), the channel geometries, and the roughness coefficients of the models according to the planned measures. For each model, three hydrological scenarios were tested. A frequent flood event (HQ_{2-5}), a medium flood event (HQ_{10-30}) and a 100-year flood event (HQ_{100}) were simulated by the project partners in their pilot area models. The input data for these events were mainly taken from observed past events in the pilot areas at nearby gauging stations or up- or downscaled hydrographs of these events to fit to the selected HQ values.

The results obtained from the model runs were then evaluated regarding several hydraulic components (water depth, flow velocity, flooded area, peak discharge, stored volume, temporal displacement of the flood wave). These parameters were used to assess the impact of the restoration scenarios of the flood hazard. The complete methodology and results description can be found in the deliverable's report "D 4.1.1: Report on the technical realization scenarios taken into consideration for modelling, the implementation in a 2D model and assessment of the impact" of the Danube Floodplain project.

[15] Danube Floodplain Project: section 4.2 from Summary of used complex methodology and process description on hydraulic 1D and 2D, CBA, ESS, ecological assessment and stakeholder analysis (Deliverable D 4.3.4 from WP4: Flood prevention pilots) accessed on http://www.interreg-danube.eu/uploads/media/approved_project_output/0001/46/74485a6e25d48c946a4f7af3a313d1a946c3184d.pdf

Extended Cost Benefit Analysis

Section adapted from the following sources: Output 4.1: Flood Prevention Measures tested in pilot areas; D 4.3.1. Report on assessment results of the CBA applied to the pre-selected pilot areas including ESS, stakeholders and biodiversity as input for 4.4.1 and therefore part of the feasibility studies in output 4.1; 2021a; Deliverable D 4.3.2. Method documentation describing the implementation of ESS and biodiversity to traditional CBA; Deliverable D 4.3.4: Summary of used complex methodology and process description on hydraulic 1D and 2D, CBA, ESS, ecological assessment and stakeholder analysis; Deliverable D 4.4.3: Summary of general recommendations for a successful realization process, communicated to local, national, and international stakeholders in workshop activities and publications.

Cost-benefit-analysis (CBA) methods are useful instruments in the decision-making process and estimate the economic efficiency of alternative options, by comparing the benefits derived from an option with the associated costs[16].

A common methodology for conducting a cost-benefit-analysis (CBA), improved with ecosystem services (ESS) assessment and evaluation was developed. In other words, the avoided flood risk benefit as a result of the floodplain restoration measure was completed with ESS benefits as result of the same measure. This resulted in an extended CBA.

For a better understanding of the CBA related process, the Figure 4 synthesize the workflow of the extended CBA for floodplain restoration measures in the Danube Floodplain Project.

Three kinds of input data, which came from previous project tasks, were required for conducting the extended CBA (ESS analysis and mapping, hydrodynamic modeling, and stakeholder analysis). As in a standard CBA, the costs and the flood risk were estimated. The extension of the standard CBA consisted then in the quantitative assessment and evaluation of other four ESS groups, besides flood mitigation (greenhouse gases sequestration, nutrients retention, cultivated goods, and nature-based recreation).

[16] ICPDR, 2015

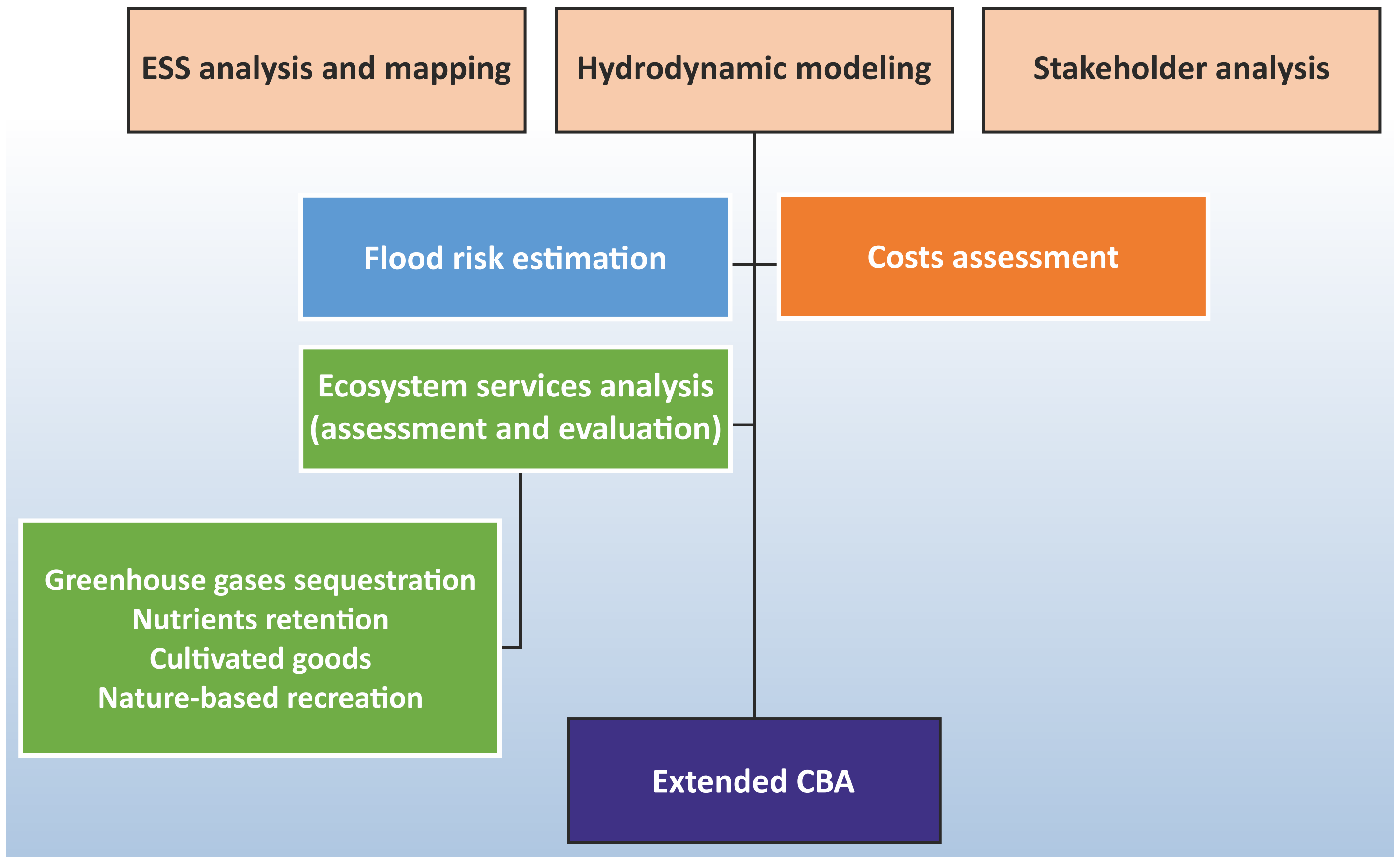


Figure 5 - Workflow of the extended CBA for floodplain restoration measures in the Danube Floodplain Project

Ecosystem services – analyzing and mapping

Note: Section adapted from the following sources: Output 4.1: Flood Prevention Measures tested in pilot areas; Deliverable D 4.2.2. Report, database and maps of ESS analysis of the pilot areas including a list, description, assessment, and ranking concerning the demands and supplies; 2020b; Deliverable D 4.2.3. Report on the assessment of biodiversity in the pilot areas including a database and maps of pilot areas' biodiversity and habitat modeling as input for 4.4.1 and part of output 4.1; 2020c.

Ecosystems are defined as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on Biological Diversity) and are multi-functional. The aim of using the ESS approach in the Danube Floodplain Project was to show the benefits and value of ecosystems to society and to improve the conditions for sustainable management of nature and ecosystems at the Danube River Basin. Three classes of ecosystem services: provisioning, regulating and cultural were considered.

Ecosystem services were firstly analyzed based on stakeholders' feedbacks in pilot areas enriched with analyses on land cover/land use data from Copernicus[17] and additional CORINE land cover data[18] with the help of responsible project partners of the pilot areas (and some external experts not related to the project). Further the data were georeferenced. This process played a significant role in understanding ecosystem services processes and identifying the potential ecosystem services hotspots and low spots for restoration projects. The results are presented in Deliverable D 4.2.2.

In the ESS assessment process, The Toolkit for Ecosystem Service Site-based Assessment (TESSA)[19] was used as theoretical background for the ESS estimation and evaluation. A detailed description of the methodology is presented in Deliverable D 4.3.2.

The ESS assessment workflow is presented below:

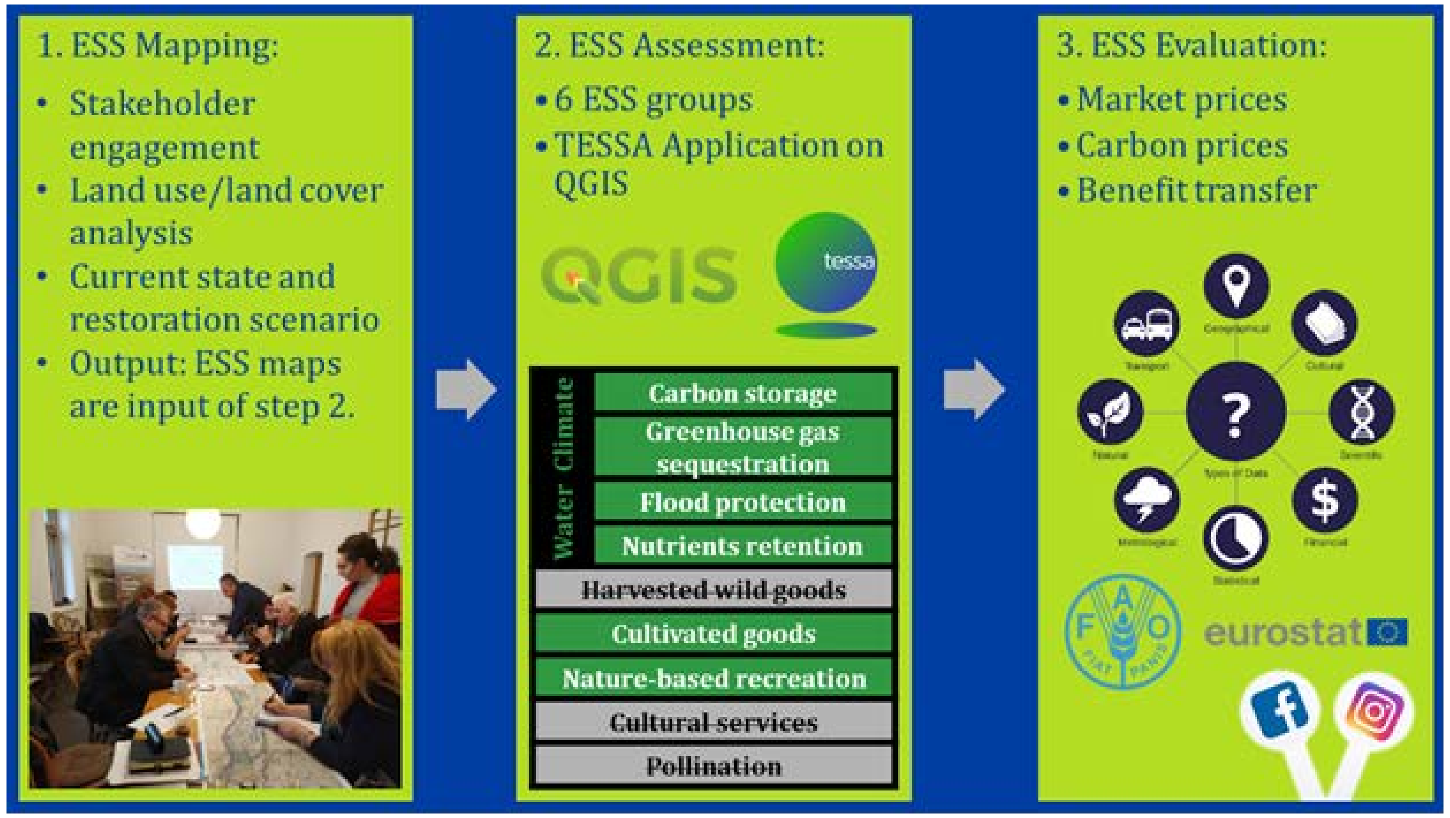


Figure 6 - Workflow for ESS mapping and assessment

[17] EEA, 2012
[18] EEA, 2018
[19] Peh et al., 2013

For a consistent approach, the project team developed and used a scale of intensity for provisioning and regulating ecosystem services. With this, maps of the intensity of each provided ESS were created for the three scenarios for each pilot area. Five classes of intensity of provisioning and regulating the ESS were considered *(Figure 7)*.

ESS Class	**1**	**2**	**3**	**4**	**5**
Intensity	Missing to very low	Low	Medium	High	Very high

Figure 7 - Scale for the intensity of provisioning and regulating ESS together

This classification was also carried out, applied for all provisioning ESS and all regulating ESS. For the classification of the intensity of the provisioning ESS only the real occurring provisioning ESS of the pilot area were considered. This means that only the sum of the intensity of the occurring ESS was used for the classification.
An example *(Begecka Jama pilot area)* from Danube Floodplain project related to assessment of ecosystem services is provided below:

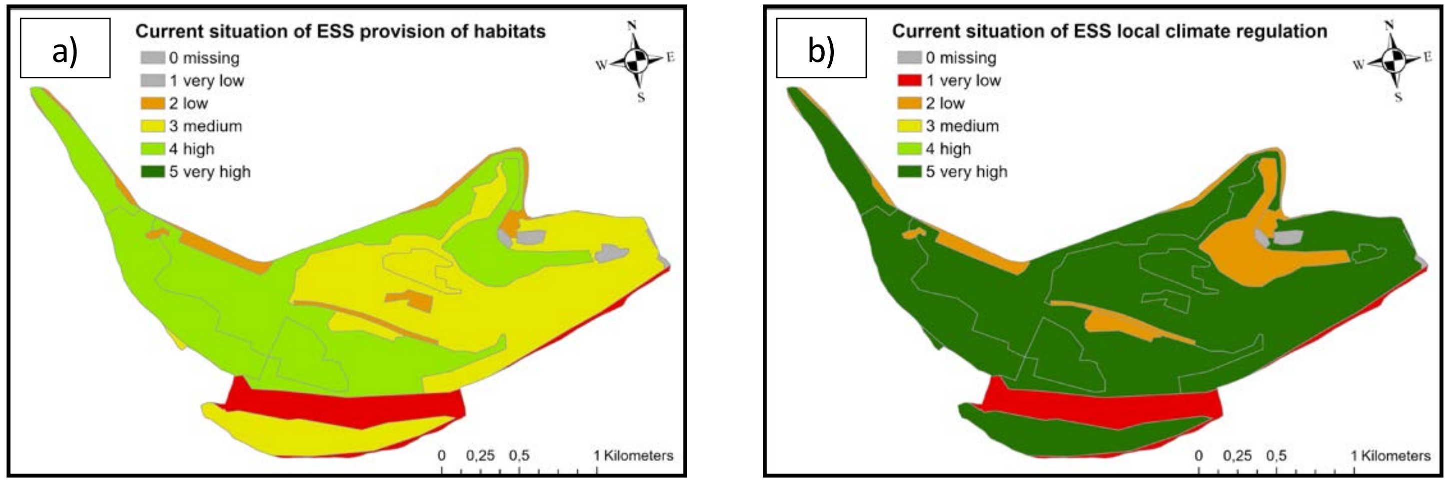


Figure 8 - Intensity of the ecosystem services provision of habitats and local climate regulation in the pilot area Begecka Jama

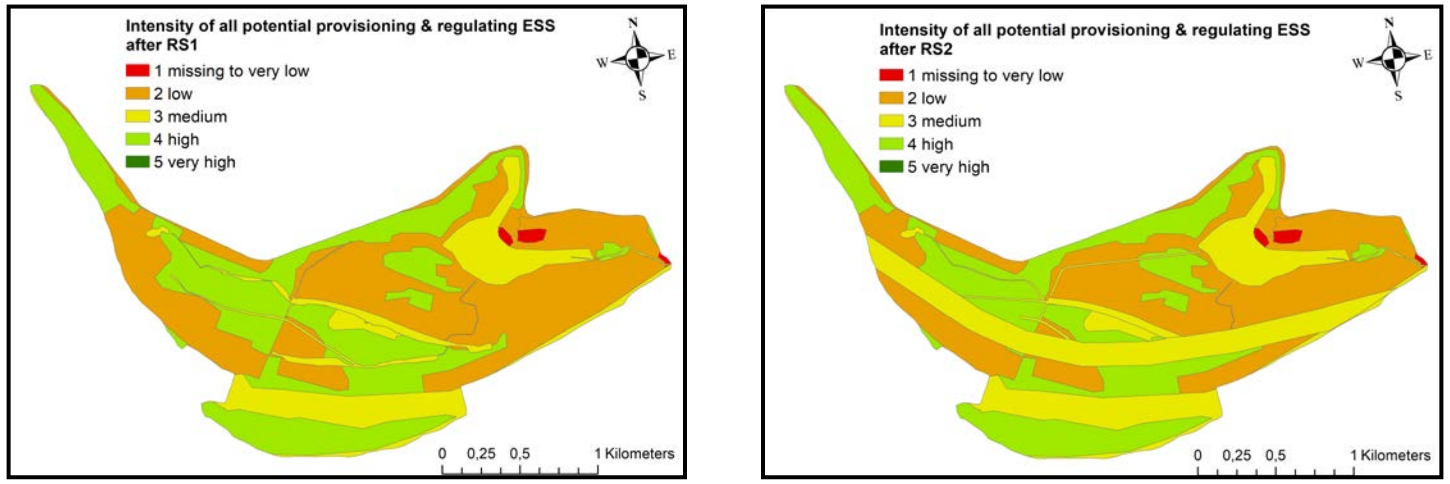


Figure 9 - Intensity of potential provisioning and regulating ESS after implementation of RS1 and RS2

Habitat modeling

Note: Section adapted from the following sources: Output 4.1: Flood Prevention Measures tested in pilot areas; D 4.2.3. Report on the assessment of biodiversity in the pilot areas including a database and maps of pilot areas' biodiversity and habitat modeling; Deliverable D 4.3.4: Summary of used complex methodology and process description on hydraulic 1D and 2D, CBA, ESS, ecological assessment and stakeholder analysis; Deliverable D 4.4.3: Summary of general recommendations for a successful realization process, communicated to local, national, and international stakeholders in workshop activities and publications.

The general aim of the habitat modeling work within the Danube Floodplain Project was to evaluate whether a certain floodplain restoration measure is capable of improving typical floodplain habitats. Such prediction was made based on environmental co-variables, like water depth, flood duration, flow velocity, etc.[20,21]. At the basis of the method, there is a conceptual understanding of how these environmental factors influence habitats and the species living in them. Therefore, quantitative formulations were made to link habitats and environmental variables.

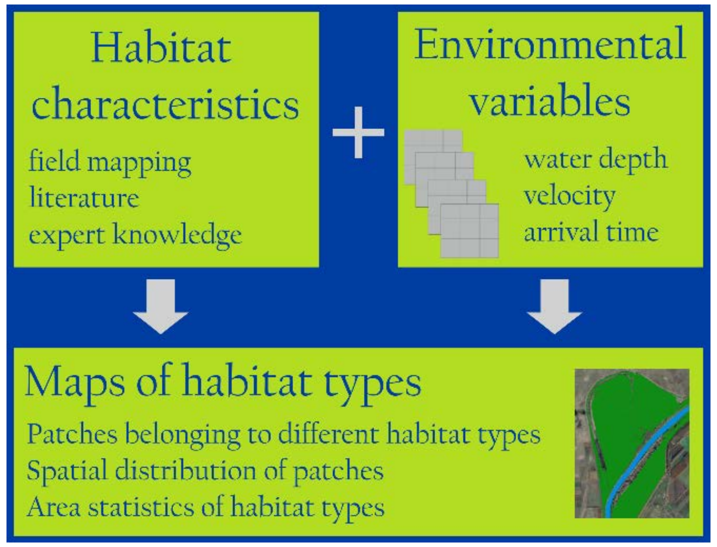


Figure 10 - Habitat modelling at the meso scale

[20] Guisan and Zimmermann, 2000

[21] Maddock et al., 2013

The results of meso-scale biodiversity assessment in the pilot areas show that floodplain habitats, and thus biodiversity, can benefit from increasing the lateral connectivity, as intended by the majority of restoration scenarios. While the assessment on the meso-scale shows the general tendency for the development of habitats, a microscale analysis gives insights on the level of species or specific communities. However, this requires in-depth knowledge of the setting and cannot be obtained without extensive fieldwork.

Tools for assessing restoration projects

Note: this chapter was adapted from the following sources: Danube Floodplain. Deliverable D4.4.3. General evaluation tool based on table calculation or GIS software for possible later assessment of other restoration projects ensuring a simplified and standardized assessment of such projects, which is described in the manual (output 5.1), 2021.

A general evaluation tool for assessing floodplain restoration projects was developed in the Danube Floodplain project. The tool based on table calculation or GIS software is addressed to possible later assessment of other restoration projects ensuring a simplified and standardized assessment of floodplain restoration projects. The FEM-Tool offers the possibility to enter all relevant input data and proceed the FEM results leading to a recommendation if a restoration project should implement or not. Basic form of the FEM-Tool was created in Microsoft Excel. Macros are used to proceed the entered input data automatically. The FEM-Tool has been be further developed in the additional Work Package 6 of the Danube Floodplain project and integrated in a QGIS software as plug in. It is recommended to use the upgraded FEM-Tool, which is described in Deliverable D.6.1.1. and can be downloaded using this link: https://github.com/boku-iwa/Floodplain-Evaluation-Matrix-Tool.

Figure 11 shows an overview about all possible input data that can be included in the FEM-Tool.

The evaluation of a restoration project with the FEM-Tool is based on two main steps. First, the evaluation of the current state of an active floodplain with the FEM method (See section Evaluation of active and potential floodplains - Floodplain Evaluation Matrix – FEM), followed by assessment of the restoration state, including stakeholder analysis, FEM analysis, ecosystem services, habitat modelling etc. *(Figure 12).*

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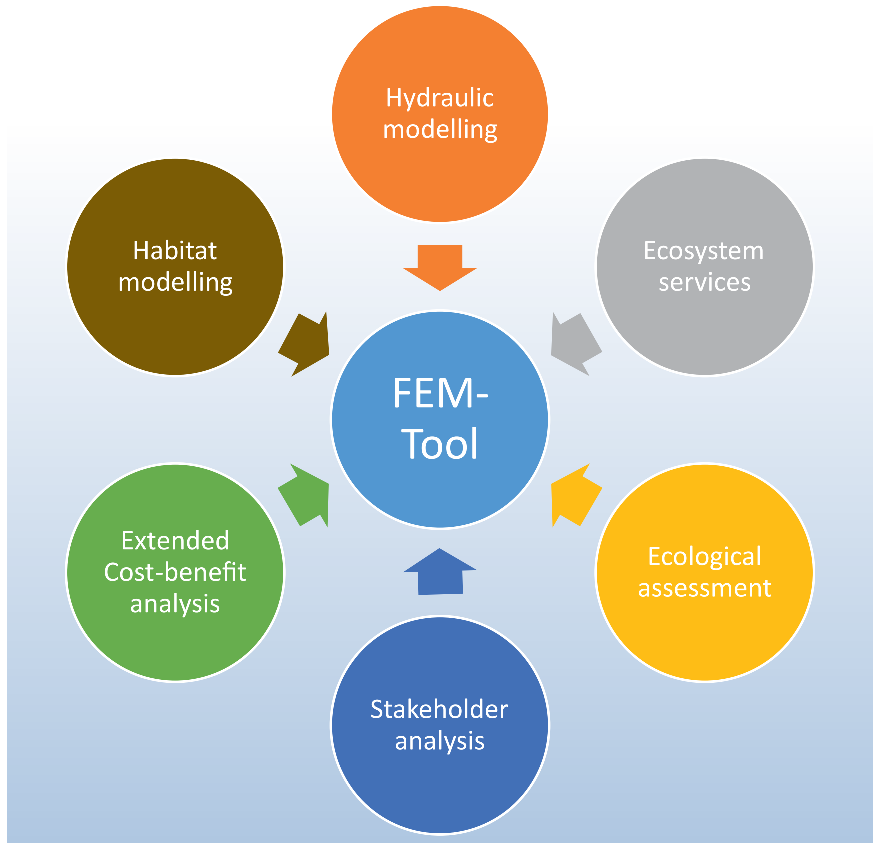

Figure 11 - Overview about possible input data in the FEM-Tool

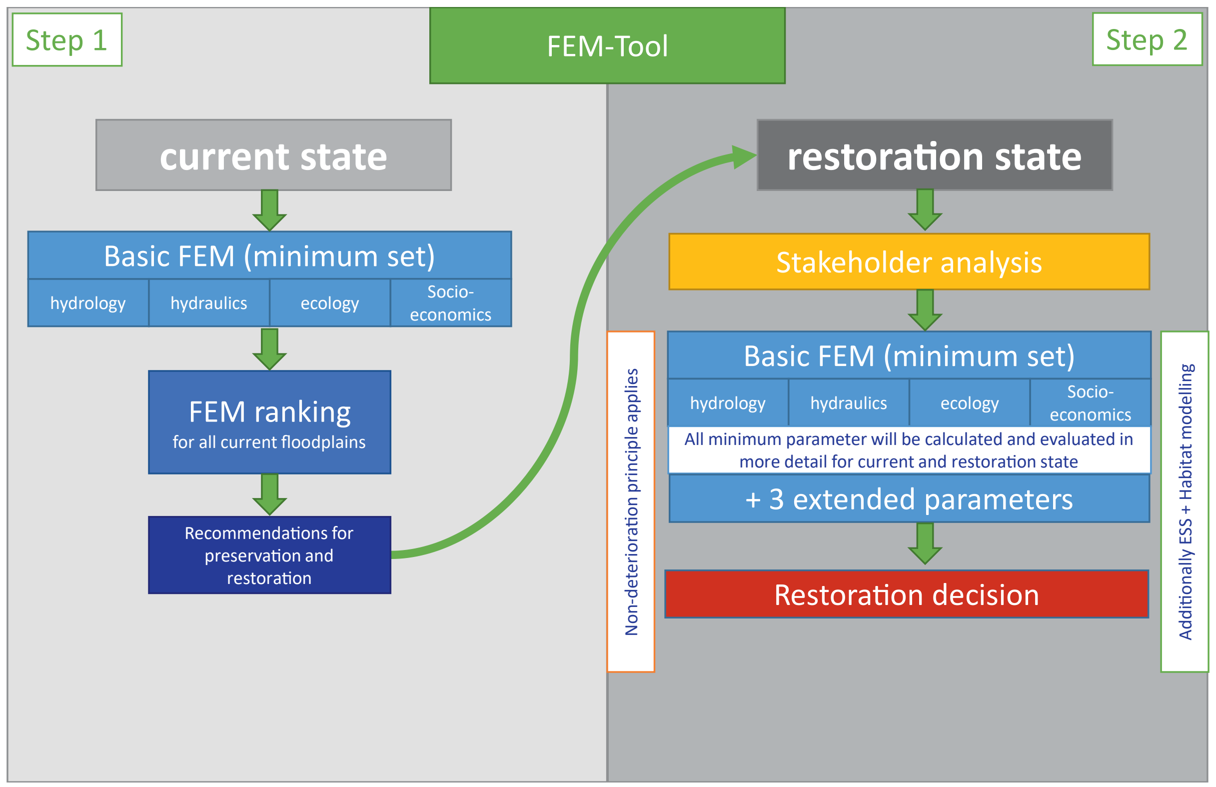

Figure 12 - Steps for evaluation of a restoration project with the FEM-Tool

Catalogue of "win-win" restoration and preservation measures for reaching flood protection, environmental and biodiversity objectives

In the last centuries, the traditional engineering solutions (like dams, river channeling, banks protection, dykes) related to flood risk management have delivered better and better results in terms of flood protection with an increasing negative impact on the environment, especially on aquatic and riparian ecosystems. The sustainable development concept, crystallized in recent decades, brings a balanced approach in flood risk management, granting aquatic ecosystems an important role in present and future generations well-being. Thus, floodplain restoration and preservation might modify the relation of local communities to floodplains, and how the community can benefit from the floodplain related ecosystem services.

Natural Water Retention Measures (NWRM) are measures that aim to safeguard and enhance the water storage potential of landscape, soil, and aquifers, by restoring ecosystems, natural features and characteristics of water courses and using natural processes[22]. Implementing these measures will support green infrastructure[23], improve the status of water bodies, and reduce the vulnerability to floods and droughts.

The Danube Floodplain project propose a *Catalogue of "win-win" floodplain restoration and preservation measures* mainly derived from the pilot areas approaches. It is structured on types of measures, effects in terms of key Water Directives and ecosystem services. Effects on FEM parameters are also considered in a qualitative way *(Figure 13)*. The Catalogue is a non-exhaustive case book which proposes a variety of key structural measures addressed to restoration and preservation of the natural functions of the river that will reduce flooding, improve water status and biodiversity, and revitalize social and economic conditions of the communities.

[22] https://ec.europa.eu/environment/water/adaptation/ecosystemstorage.htm

[23] https://ec.europa.eu/environment/nature/ecosystems/strategy/index_en.htm

Danube Transnational Programme
Danube Floodplain
www.interreg-danube.eu/danube-floodplain

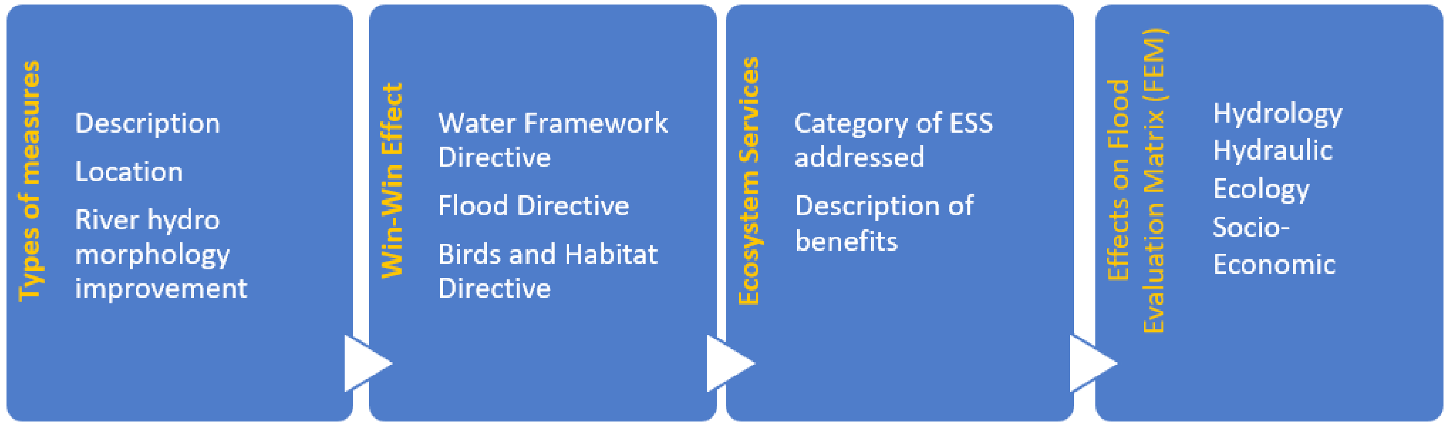

Figure 13 - Structure of the catalogue

Types of measures

In the last years, a variety of such restoration and preservation measures have been planned and implemented across the world, with the aim of recovering ecological value of the rivers and keeping, or even raising flood protection level. That is why these restoration and preservation measures have shown the potential to achieve a win-win situation for both, the environment and flood protection.

It is necessary to underline the importance of stakeholders' consultation regarding the planned restoration & preservation measures. Thus, in each of the pilot areas, specialists and representatives from various domains (like fishery, agriculture, river navigation, municipal authorities, nature protection agencies/ organisations), as well as local population were consulted aiming to have a well-tailored set of measures and suitable instruments. The synthesis of the restoration and preservation measures resulting from the previously presented activity gave the possibility to classify them in four main categories, mostly by the river system's parts addresing area: technical works, floodplain morphology restoration, river morphology restoration and support measures.

First category of measures, technical works, includes structural and non-structural measures which can be applied to the existing flood protection defence works (e.g. dams, dykes, weirs) in order to become more friendly with river ecosystems, without diminishing their flood protection function.

The measures for restoring the floodplain morphology have as main purpose the increase of the water retention capacity in periods of high waters and the delay of the flood wave by diversifying the habitats of this area. These benefits can be achieved through optimal land-use management and restoring former floodplain's elements, like meanders, oxbows or river arms.

Another category of restoration and preservation measures are addressed to the river channel, more precisely to river's morphology, these measures are used to achieve a balance state between natural dynamics and river's bed & banks stability, so as to restore the river's ability to develop and maintain an optimal diversity of aquatic and riparian habitats.

The success of the implementation of a set of restoration and preservation measures depends, in most cases, on the synchronization with the establishment of a complementary legislative and administrative set of measures. All these support measures, considered rather instruments, cannot bypass fields such as spatial planning, water resources management, nature conservation and even public awareness, in order to improve people's manner to relate flood risk management.

Win-Win Effect

Within this category of characteristics, the beneficial effects of each measure were evaluated from three important perspectives: on reducing the risk of floods, on supporting reaching water bodies' environmental objectives, also on the birds & habitats' conservation status. These perspectives superpose the European's strategies and adjacent legislation objectives': Flood Directive, Water Framework Directive and Birds & Habitats Directives - Natura 2000.

Ecosystem Services

It is well-known that nature brings a widespread range of economic, material, health or psychological benefits to people, either directly or indirectly. All these benefits leading to the Ecosystem services concept (EES). The use of the EES approach gives a better way to quantify the benefits (or losses) resulting from implementing floodplains restoration / preservation measures, allowing measures' comparison of different types.

Effect on Flood Evaluation Matrix Parameters

This decision support tool allows the evaluation of various river reaches by setting up a priority ranking which indicates where efforts of floodplain preservation / restoration should be spent first in order to obtain maximum benefits. A synthesis of floodplain restoration and preservation measures is presented in the *Figure 14.*

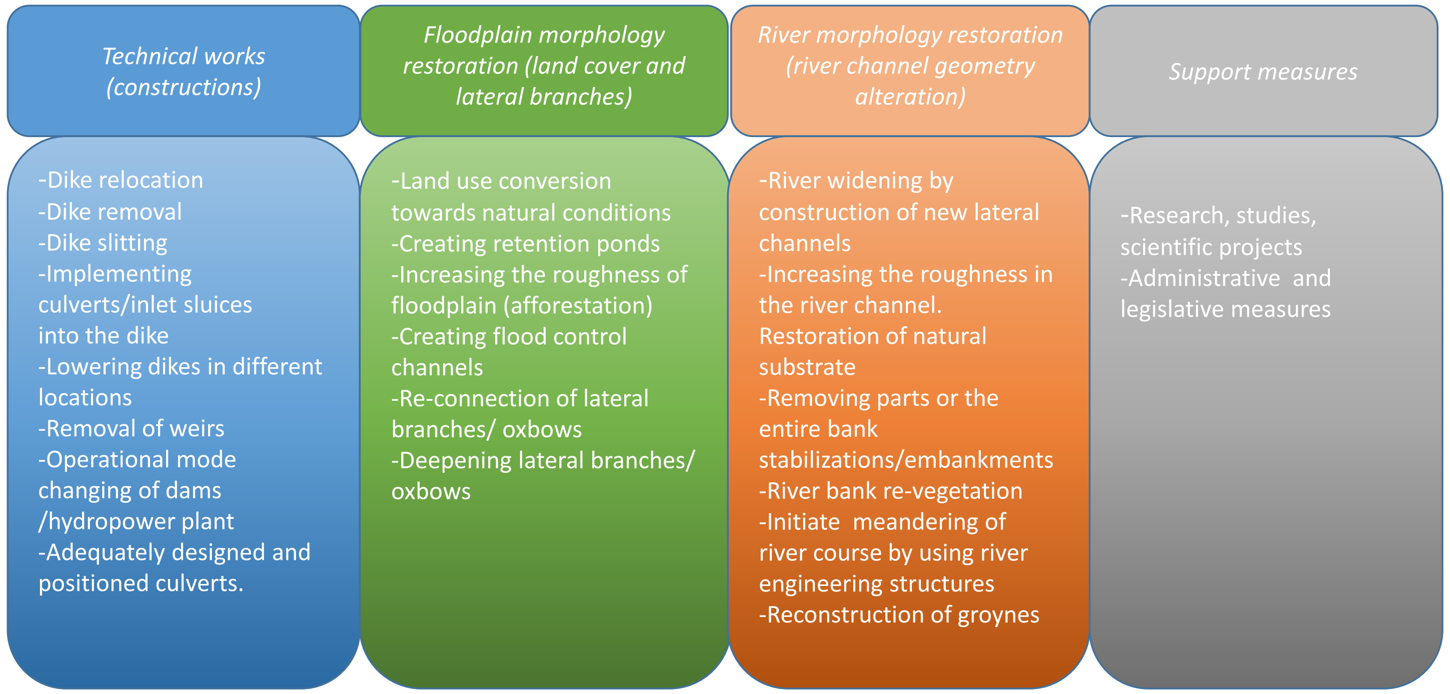

Figure 14 - Synthesis of floodplain restoration and preservation measures

Decision support for floodplain restoration

The river restoration projects has been a rapid expansion since the late 1980s in industrialized countries as an effort to improve degraded habitats and improve their ecological functions. The experience gained in these projects showed that the conceptual planning and design is the key to a successful implementation of the restoration projects. Also, the design of an efficient restoration project should include clear goals and objectives, sufficient baseline data and historical information, integrated planning and comprehensive design, and long-term monitoring.

In case of floodplain restoration and preservation projects the goal (or desired future condition) is to restore floodplain dynamics by reconnecting to the river. So, the desired future condition is that the ecosystem looks and functions as it did before it was damaged or degraded. In practice the total recovery of the ecosystem to its former state and the exact replication of past conditions are rarely possible.

Five general steps are proposed in the process of floodplain restauration and preservation: (1) conceptual planning; (2) planning; (3) implementation; (4) post-implementation action (monitoring and maintenance); and (5) evaluation of the project objective. Figure 15illustrates the main action that should be done within each step.

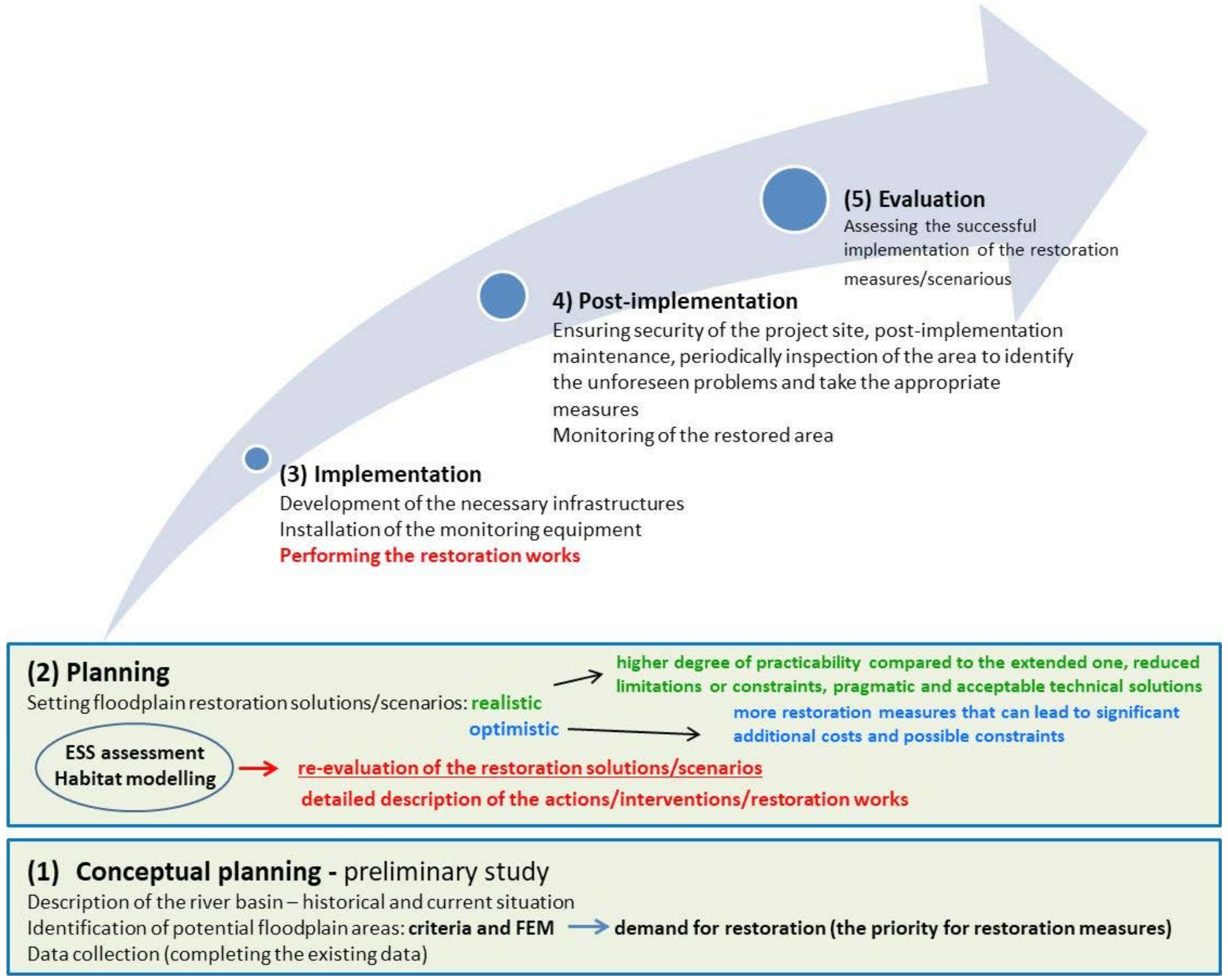

Figure 15 - General steps for planning and implementing the floodplain restoration projects

As can be seen from the general steps described above the floodplain restoration is a process that should be addressed either to the recovery of the floodplain areas that have been lost, but also to preservation of the active ones. It is a complex activity that initiates or accelerates floodplain ecosystems recovery. The health (functional processes), integrity (species composition and community structure), and sustainability (resistance to disturbance and resilience) will be improved by applying appropriate restoration measures. In order to restore floodplain dynamics by reconnecting to the river the measures are usually addressed directly to abiotic parameters (e.g. water depth, flow velocity) that create suitable habitats for biological ones (e.g. fish, aquatic plants).

Restoring river's natural floodplains create "more room for the river" so that the floodplains can act as "natural water sponges" within the flood events. Therefore, measures so called "win-win" like dike relocation, dike removal, river widening and so on, are increasing the water retention capacity of rivers mitigating the flood events and improving the river water quality.

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