Danube Floodplain

A 3.3 Floodplain assessment on selected tributaries

D 3.3.1 Map of floodplains on selected tributaries
D 3.3.2 List of floodplains, their characteristics, restoration/preservation potential and associated measures
D 3.3.3 Recommendations for floodplain assessment on tributaries including the description of implemented methods and classification criteria

May 14, 2021

Activity Leader:

DRSV – Slovenian Water Agency, Ljubljana, Slovenia

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WP	WP3: Floodplain evaluation
Activity	Activity 3.3
Deliverable	D 3.3.1 *Map of floodplains on selected tributaries* D 3.3.2 *List of floodplains, their characteristics, restoration/preservation potential and associated* *D 3.3.3* *Recommendations for floodplain assessment on tributaries including the description of implemented methods and classification criteria*
Activity-leader	DRSV
Deliverable prepared by	Jurij Krajčič, Marjan Jarnjak, DRSV
Involved partners	All partners from the countries with pre-selected tributaries – VUVH, MRBA, KOTIVIZIG, JCI, CW, MWF, NARW, NIHWM, DRBD, USZ and BOKU
Connection with other deliverables/outputs	WP5

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1. Introduction

The Activity 3.3 of the DFP aims to identify and evaluate the active and potential floodplains and their reconnection on six Danube tributaries. Namely, tributary watersheds have an important role in floodplain analysis, assessment and management, especially in the context of ensuring the holistic approach to water and flood risk planning. Besides restoration, a significant floodplain management aspect is the preservation of floodplains through spatial plans considering environmental, economical, societal and land development issues.

The methodology for delineation and evaluation of active and potential floodplains was developed and applied on the Danube River, as well as on six tributaries: Krka (Slovenia), Morava (Czech Republic, Slovakia), Tisza (Hungary, Serbia), Sava (Croatia, Serbia), Desnăţui (Romania) and Yantra (Bulgaria) (Figure 1). In addition, possible restoration measures to activate potential floodplains have been identified.

DRSV coordinated the Activity and the project partners (PPs) for the evaluation of floodplains on selected tributaries. Project partners (DRSV, MRBA, KOTIVIZIG, USZ, JCI, CW, MWF, NARW, NIHWM, DRBD) have:

- identified active and former floodplains and associated measures on their selected tributaries,
- reviewed FEM (Floodplain Evaluation Matrix) ranking method and cooperated in its adaptation for multiple-criteria floodplain evaluation,
- defined criteria and classified floodplains on their selected tributaries considering specific national conditions,
- cooperated in preparation of recommendations for floodplain evaluation on tributary floodplains based on knowledge exchange that will be incorporated in WP5 deliverables.

The following is the report of the Activity 3.3 (Floodplain assessment on selected tributaries), consisting of three deliverables:

- D 3.3.1 Map of floodplains on selected tributaries,
- D 3.3.2 List of floodplains, their characteristics restoration/preservation potential and associated measures,
- D 3.3.3 Recommendations for floodplain assessment on tributaries including the description of implemented methods and classification criteria.

Figure 1: Danube river basin with the six selected tributaries

In this report, the process of floodplain assessment on the tributaries is given, including the implemented methods and classification criteria. The results for any given tributary are based on the data contributed by the project partners.

2. Map of floodplains on selected tributaries

2.1. Methodology

The methodology for identification of active and potential floodplains on tributaries is based on the experience of the PPs from the Danube river and the selected tributaries. At the beginning of the project, the PPs faced some obstacles in the process due to different background of water management, data availability, and legislation in their countries. Several meetings were organised to harmonize the specific backgrounds of the PPs with the demands of the project. Nevertheless, the wide pool of knowledge and experience helped create the methodology that proved useful and efficient, which resulted in common approach and comparability of the results among different countries and rivers. Its flexibility and adaptability overpassed the restrictions which could stem from different size of the watercourses and their floodplains. It will help rise awareness of the importance of the floodplains, their integration in the process of water and flood risk management, and overall better transnational water management in the Danube river basin.

The document summarises the results on the selected tributaries. Extended reports on each tributary are available on the FTP site. The evaluation of the tributaries is based on commonly agreed procedures between the project partners on tributaries and on the Danube.

2.1.1. Krka

The Krka river basin was chosen for the Danube floodplain project mainly due to increased flood risk present in some areas, and because several floodplains had been identified within the catchment. The aim was to delineate and evaluate the floodplains from the point of view of their suitability for the purpose of flood risk management.

OVERVIEW

The Krka Sub-basin has an area of 2,315 km^2 with approximately 120.000 inhabitants. From administrative point of view 23 municipalities are positioned on its territory. It is a tributary of the Sava river to which the Krka river discharges just some 11 km upstream the cross section where Sava discharges from Slovenia to Croatia. Beside the main watercourse of the river in the length of 94 km its tributaries and springs in the upper part of the river basin are mainly karstic, as shown on 2 with absence of surface watercourses.

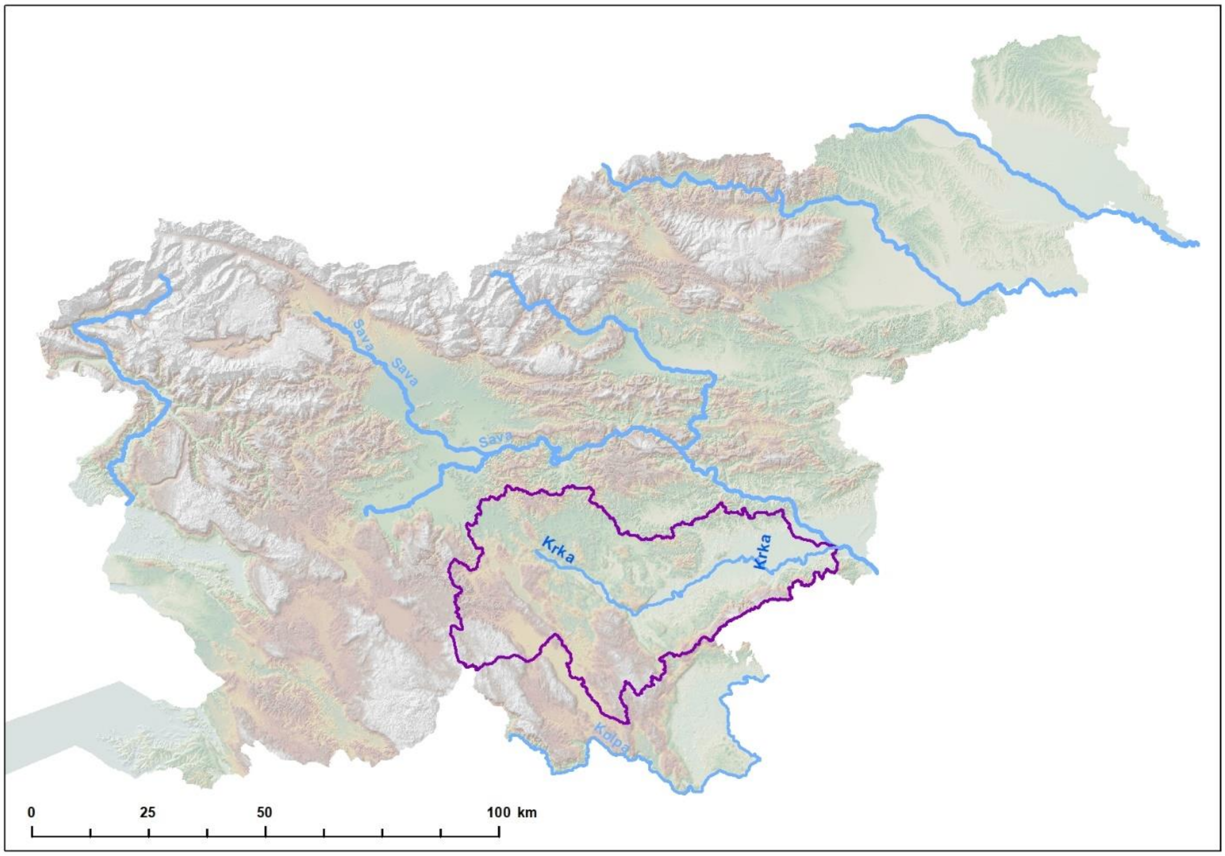


Figure 2: Krka river basin

Comparison between the historical map (1829-1835) – Second military survey of the Habsburg Empire[1] and LIDAR DEM of 2014 shows historical development of the Krka river and the observed floodplains. It can be observed that in almost 200 years the watercourse topology has not changed much, nor were any dykes constructed along the river. Turbidity does occur, but due to the prevailing karstic springs, there is little bedload transport. A special characteristic of Krka is its natural tuft weirs that can be found in the river bed.

Krka river features very long propagation times and hence long flood waves for a catchment of its size. Observed and calculated hydrogrpahs show flood waves of more than 10 days (300 hours) at a 100-year flood event. This specific characteristic is again defined by the mainly karstic character of the river basin. During flood events, the water is retained on karst fields and underground for an extended period of time,

[1] https://mapire.eu/en/

before reaching the Krka springs. The water is then gradually discharging to Krka river over several days, thus extending the flood event.

2-D MODEL

Hydrologycal study of the Krka river basin had been finished in 2019. The results were used as input for the hydraulic model designed within the project. Additionally, eight gauging stations are managed within the catchment by the Slovenian Environment Agency. The data from the stations were used for calibration of the models.

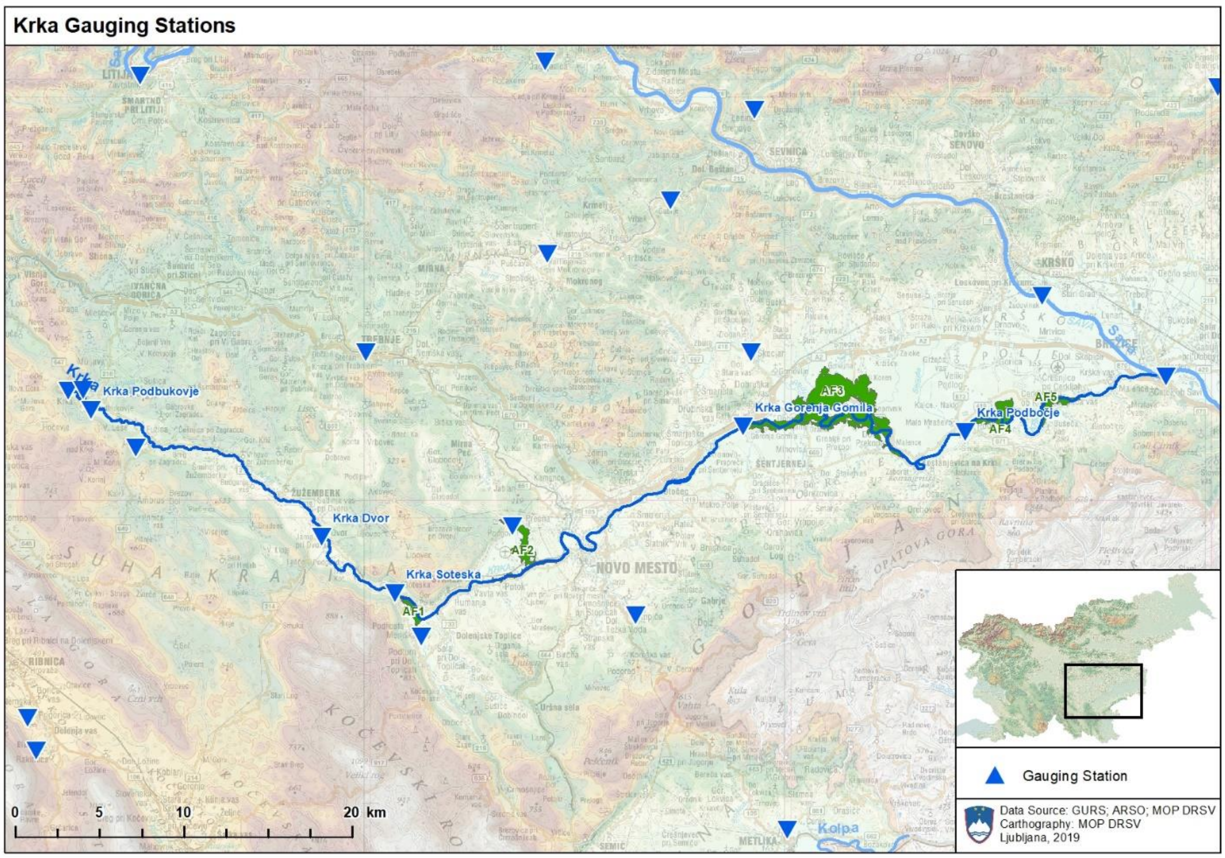


Figure 3: Krka river basin Gauging stations in the Krka river basin

For the purpose of identification of active floodplain, HQ100 (100-year return period) was used. Except for occasional slightly elevated roads, there are no major dykes along the Krka river which could be subject to removal for the purpose of defining potential floodplains. Therefore, we used the HQ500 hydrological scenario to define the extent of potential floodplain.

On Figure 4, main karstic sub-terrain flows are indicated. It could be observed that the upper part of the river basin is characterized by karstic phenomena, while on the lower part of the river basin mainly regular, surface runoff could be observed.

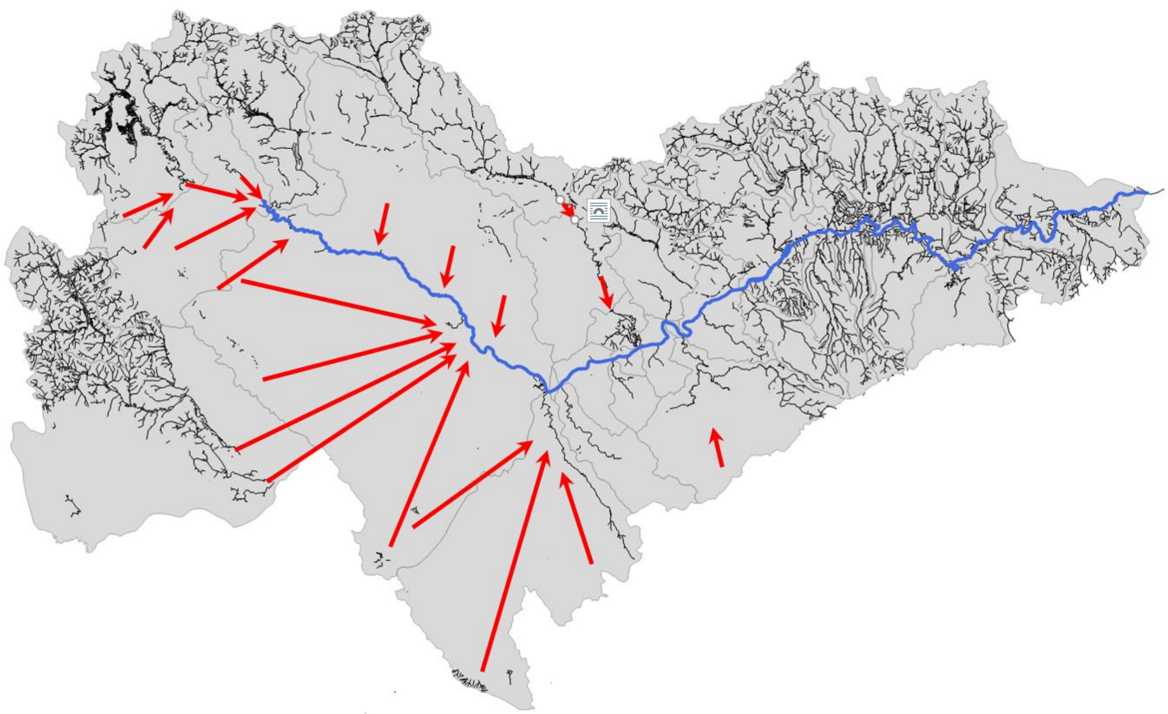


Figure 4: Hydrography of the Krka river basin with indicated main directions of subsurface karstic flow

Floodplains larger than 100 ha were identified in the middle and lower part of the Krka river basin, where the river is already running over quartarian and tertiarian alluvium (see Figure 3). For all five listed floodplains, hydraulic model was developed and hydrological data were analysed in order to properly delineate them. In the upper part of the catchment, the river mainly flows through hilly karstic terrain, featuring gorges and canyons, and thus no floodplains have been identified there.

Two 2-D hydraulic models were developed for the purpose of floodplain delineation, one for the upper part and one for the lower part of the river.

Modelling domain 1: Floodplains: 1-Soteska, 2-Prečna Scenario: Actual Flood Plains:

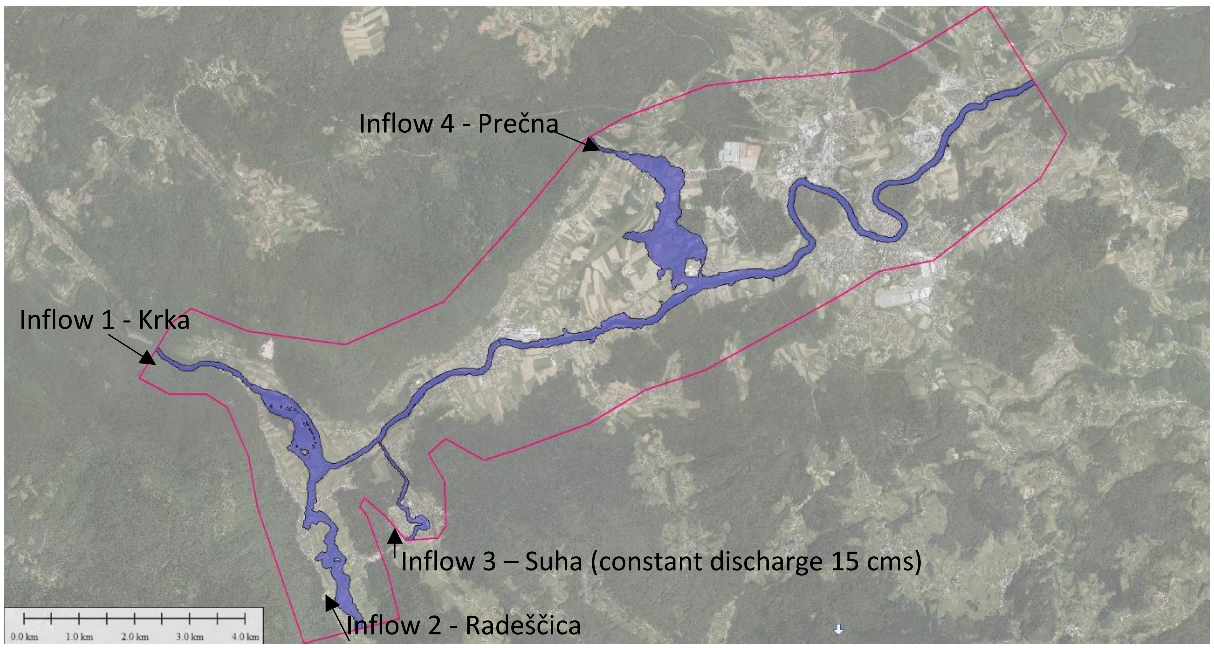


Figure 5: Locations of applied hydrographs for the modeling domain 1 – Floodplain SLO1 (Soteska) and Floodplain SLO2 (Prečna)

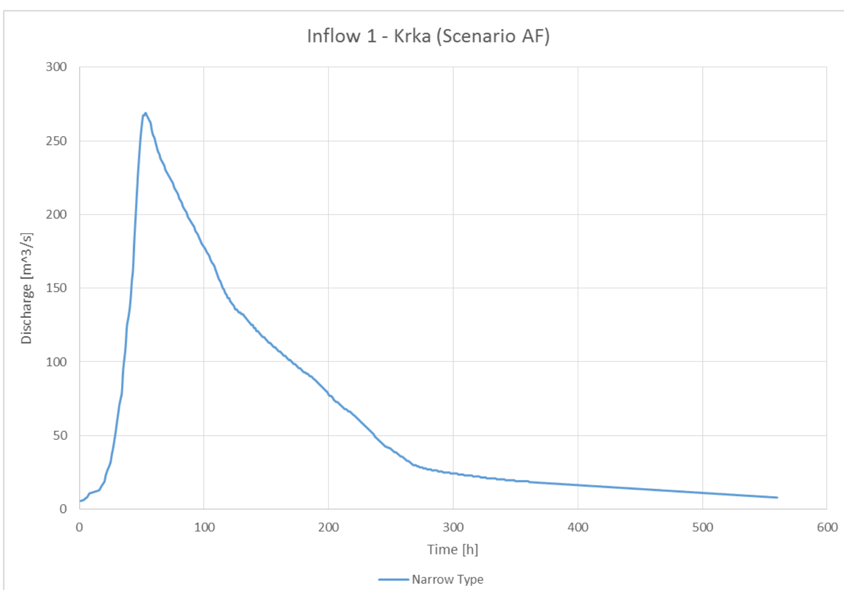


Figure 6: Applied hydrograph for the inflow 1 – Soteska – Krka, actual flood plains (AF) (Qn100) – narrow type (small volume) flood wave was used

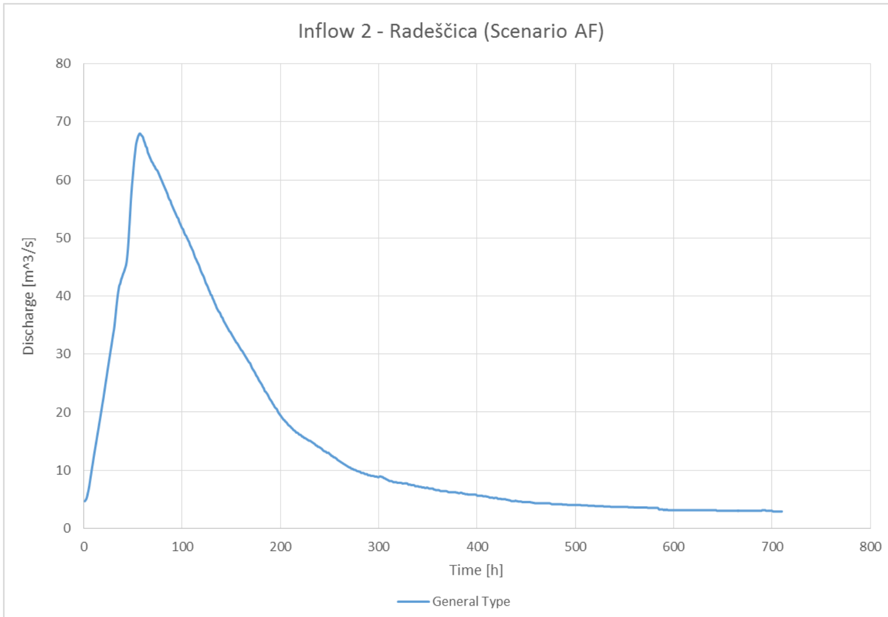


Figure 7: Applied hydrograph for the inflow 2 – Radeščica, actual flood plains (AF) (Qn100) – narrow type (small volume) flood wave was used

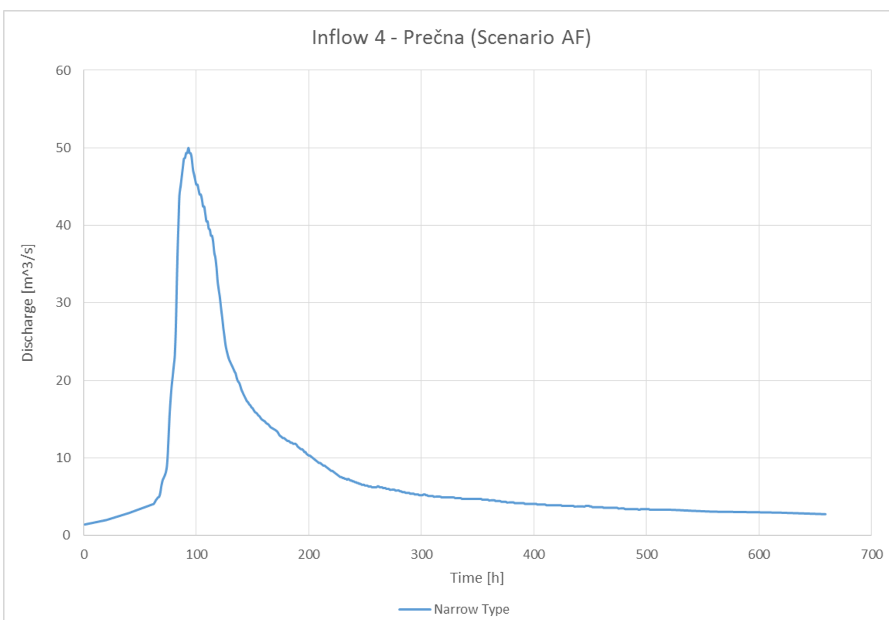


Figure 8: Applied hydrograph for the inflow 3 – Prečna, actual flood plains (AF) (Qn100)– narrow type (small volume) flood wave was used

Scenario potential floodplains (PF) – Krka modelling domain 1, floodplains: 1-Soteska and 2-Prečna:

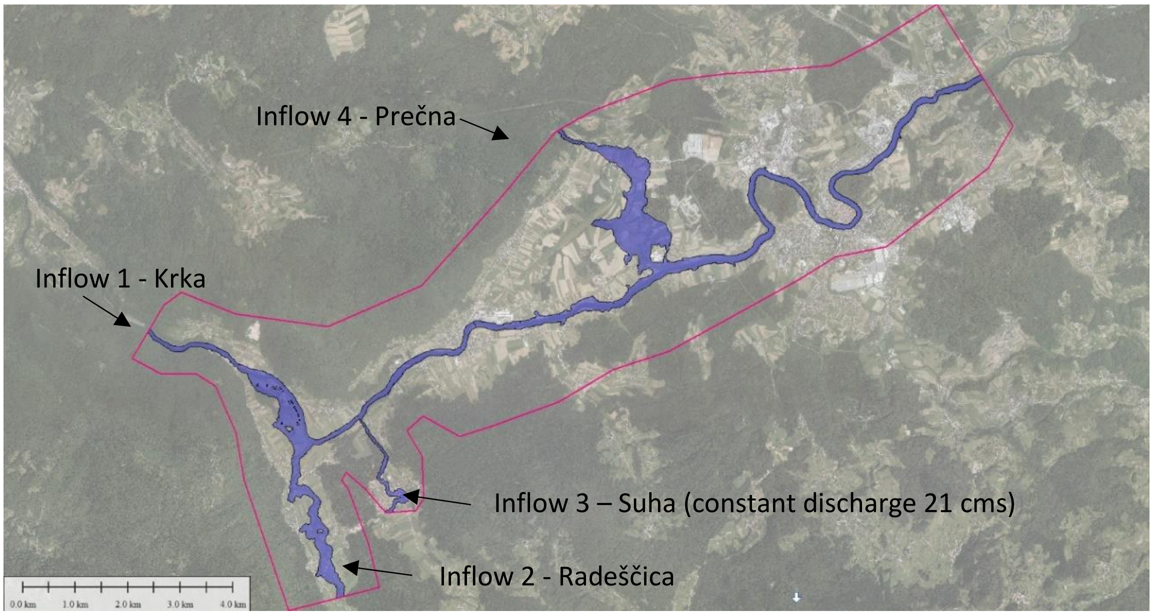


Figure 9: Locations of applied hydrographs for the modeling domain 1 – Floodplain SLO1 (Soteska) and Floodplain SLO2 (Prečna) – FF

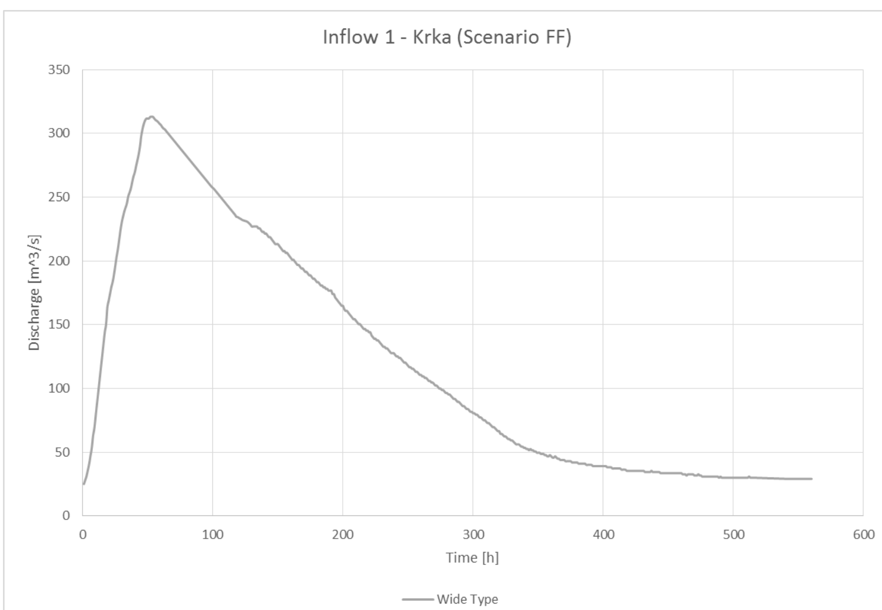


Figure 10: Applied hydrograph for the inflow 1 – Soteska – Krka, future flood plains (AF) (Qn500)– wide type (large volume) flood wave was used

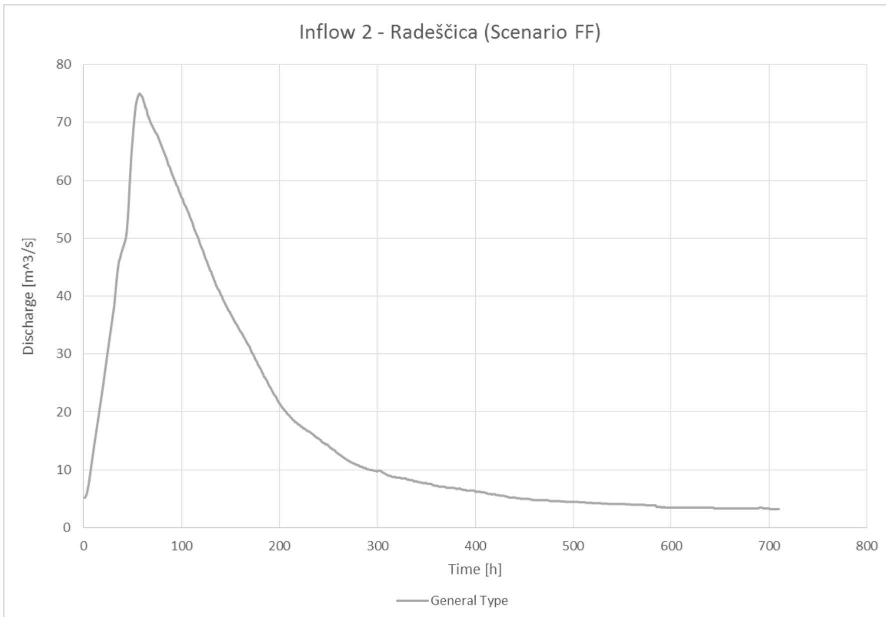


Figure 11: Applied hydrograph for the inflow 2 –Radeščica , future flood plains (FF) (Qn500)– regular type (mid volume) flood wave was used

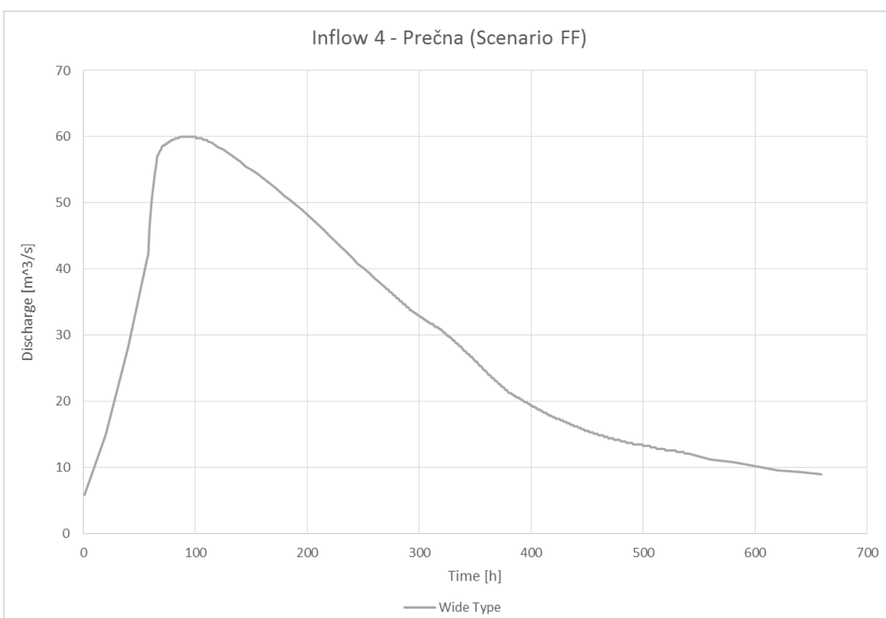


Figure 12: Applied hydrograph for the inflow 3 –Prečna , future flood plains (FF) (Qn500)– wide type (large volume) flood wave was used

Modelling domain 2: Floodplains: 3-Kostanjevica– river Sava, 4-Podbočje, and 5 – Cerklje
Scenario actual flood plains (AF):

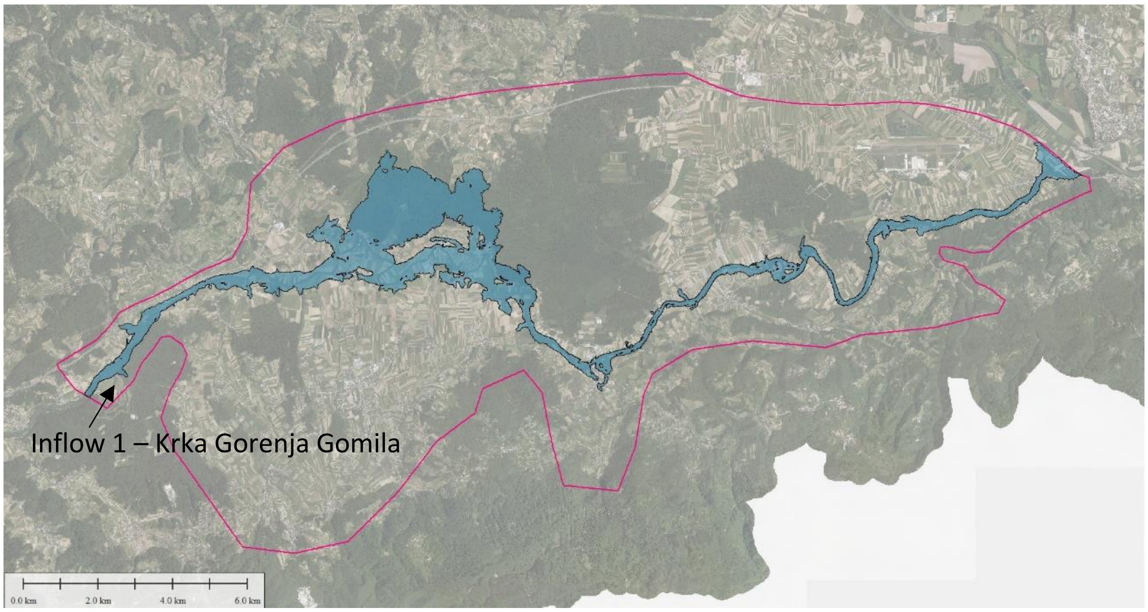


Figure 13: Locations of applied hydrographs for the modelling domain 2 – Inflow 1

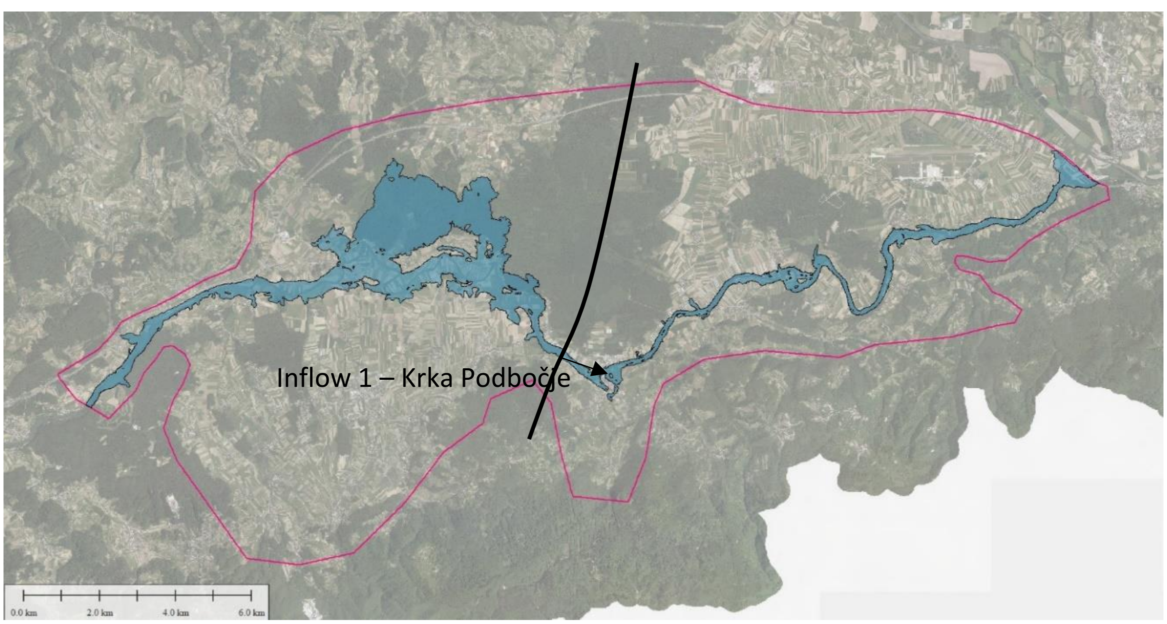


Figure 14: Locations of applied hydrograpsh for the modelling domain 2 – Inflow 2

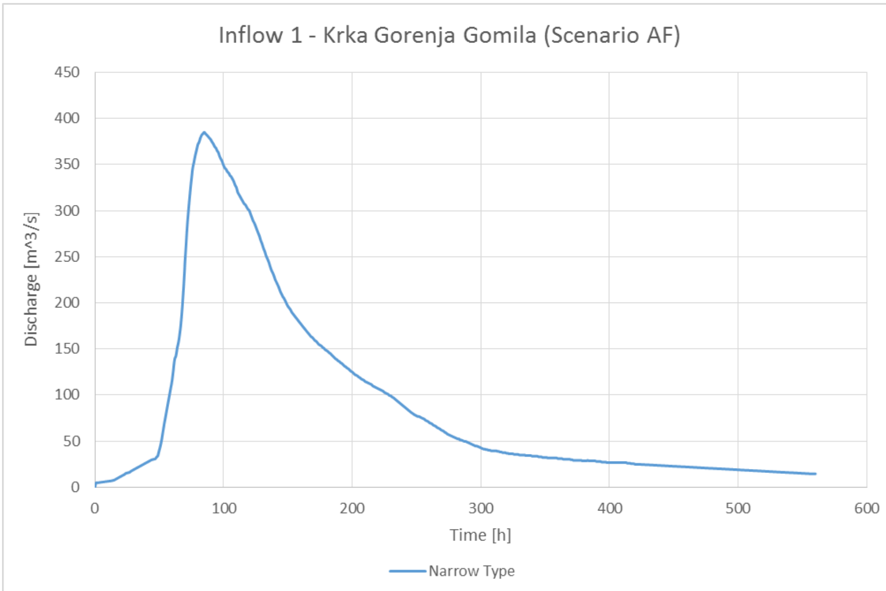


Figure 15: Applied hydrograph for the inflow 1 – Krka G. Gomila, actual flood plains (AF) (Qn100) – narrow type (small volume) flood wave was used

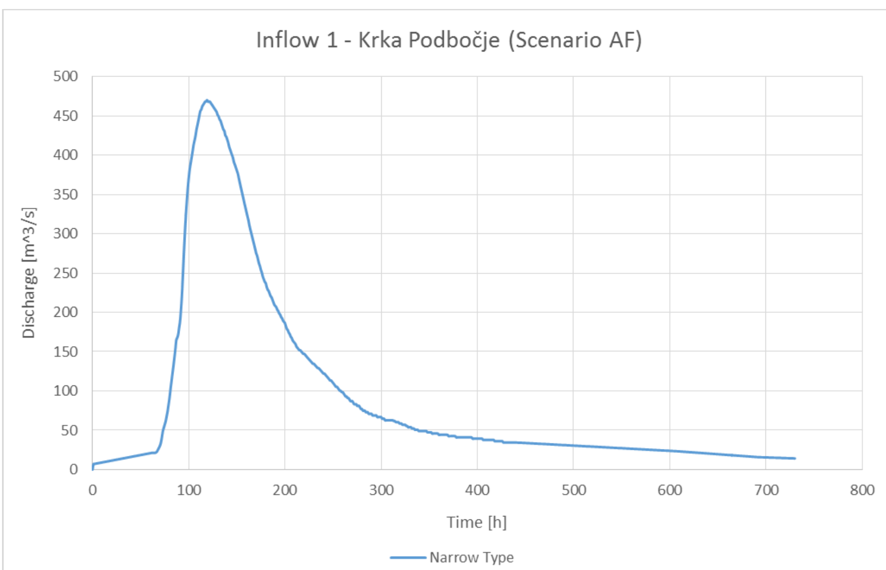


Figure 16: Applied hydrograph for the inflow 2 – Krka Podbočje, actual flood plains (AF) (Qn100)– narrow type (small volume) flood wave was used

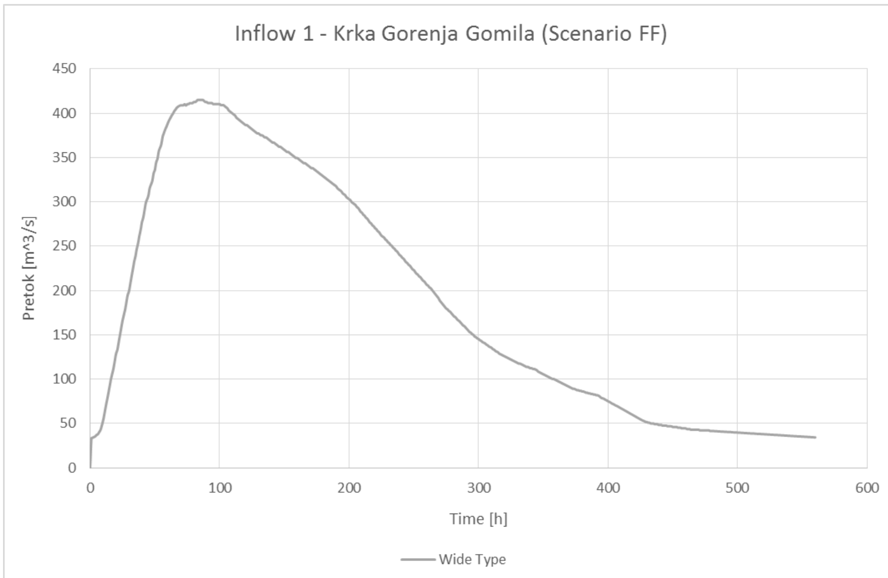


Figure 17: Applied hydrograph for the inflow 1 – Krka G. Gomila, future flood plains (FF) (Qn500)– wide type (large volume) flood wave was used

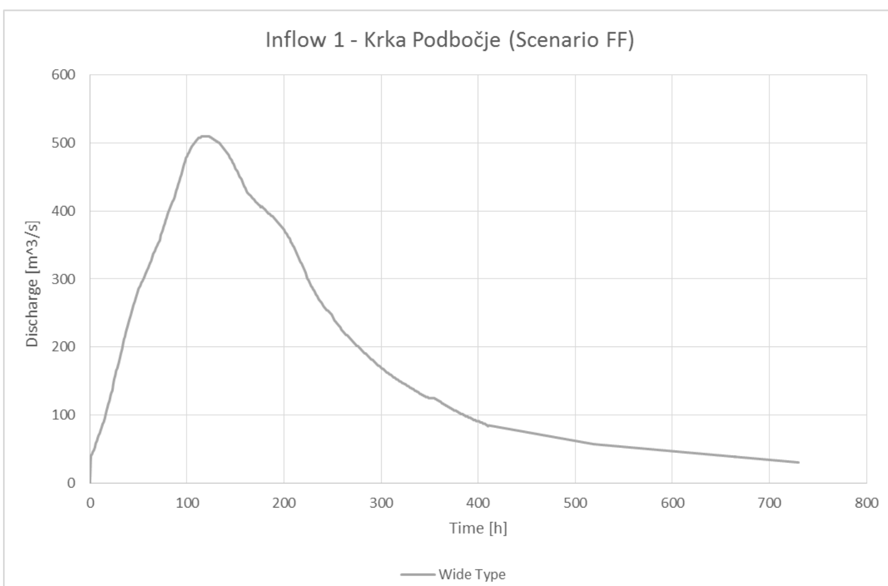


Figure 18: Applied hydrograph for the inflow 2 – Krka Podbočje, future (potential) floodplains (FF) (Qn500)– wide type (large volume) flood wave was used

2.1.2. Yantra

- The methodology for identification of active and potential floodplains was applied to the main course of the Yantra River. This study identifies floodplains along the main Yantra River course. Due to the relatively identical way of determining the active and potential floodplains, they were assessed together.

- The Yantra River is 223.5 km long and has a catchment area of 7 862 km2. The river originates from the Shipka part of the Balkan, east of Hadji Dimitar (Buzludzha) Peak 1439.8 m. It crosses the Predbalkan and the Danube Plains and flows into the Danube River near the village of Krivina (Russe), east of Vardim Island. The catchment area of the Yantra River is fan-shaped - with an extended southern part and a narrowed northern one. The river receives three large tributaries, whose catchment area is equal to nearly 70% of the total catchment area of the Yantra River - Rositsa River (left tributary - 28.6%), Belitsa River (right tributary - 9.4%) and the Lefedzha River (30.9%).

- The identification of the geomorphologic floodplain was made for the entire course of the Yantra River by slope-based analysis. The boundaries of the delineated floodplains were refined using large-scale topographic maps and geological maps. Due to their small scale (1: 100,000), the geological maps were only applicable in the lower course of the Yantra River, where the river forms wide floodplains. Defining the floodplains beginning and end places was made on the basis of the accepted criterion for the ratio between the width of the floodplain and the width of the water mirror to be greater than 1. On this basis, 22 floodplains were determined along the main course of the Yantra River - 12 active and 10 potential.

- The floodplains definition is based on the results of a non-stationary two-dimensional hydraulic model. The hydraulic model SRH-2D was used. Models are defined using an unstructured network of triangular and quadrangular elements, varying in size to minimize defects in the digital terrain model.

- The hydraulic model was built on the basis of a digital elevation model with a cell size of 8 m. Due to its poor quality (in some places it is a digital terrain model), the model was processed with data from large scale topographic maps, in order to print the riverbed in it. Thus, the exact location and altitude of the hydrotechnical facilities has been incorporated into the DEM. Such kind of information is not available in digital format at the responsible institutions and cannot be used.

- Based on the current cadastral data, an adjustment was made of the floodplains defined so far, namely the urban and industrial territories were removed. For territories for which no up-to-date cadastral data are available, a visual inspection of the aerial photo was made.

- All hydrological and hydraulic parameters were assessed, except the parameter "bottom shear stress" (due to the very low quality of the available DTM and the presence of local elevations and reductions in the riverbed, the bottom tangential stresses calculated from the model are incorrect).

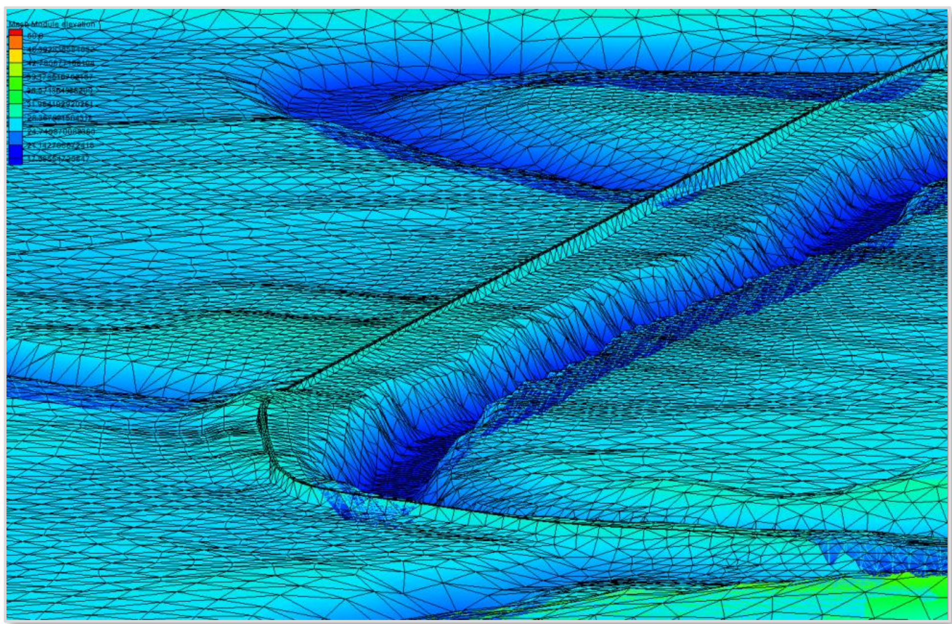
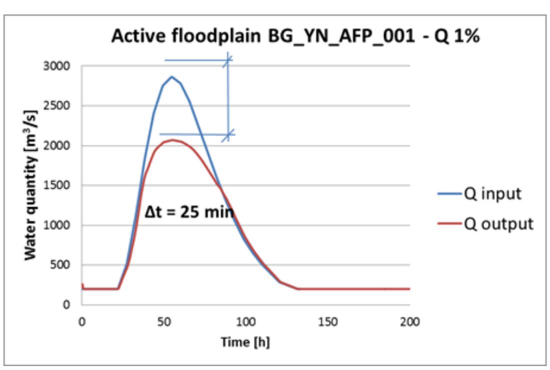
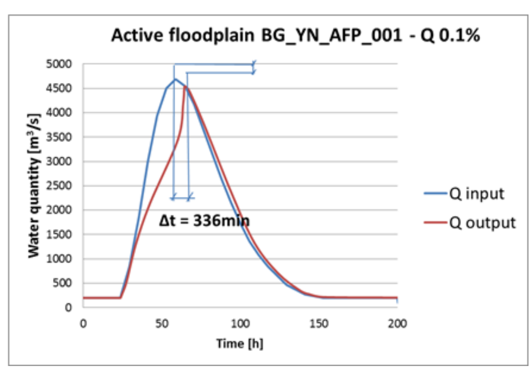
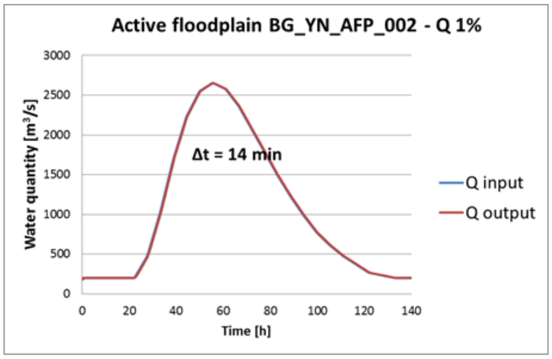


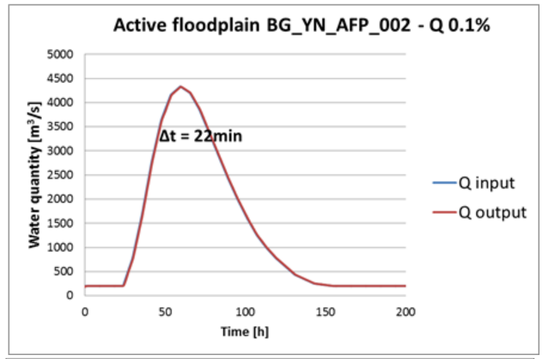
Figure 19: Computing network based on digital elevation model with dykes and riverbed

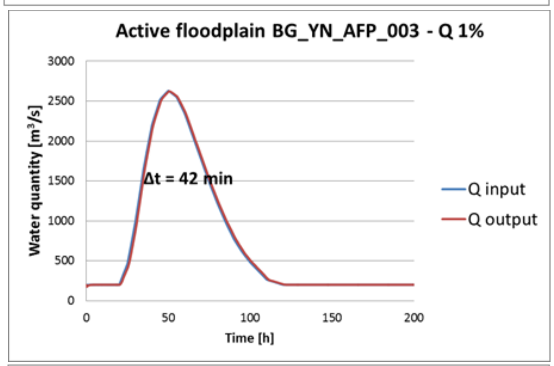
- The poor quality of DEM is the reason for serious numerical instabilities in the computational model, which makes it impossible to determine the flow parameters and by this reason no further assessment has been performed for three of the identified geomorphologic floodplains.

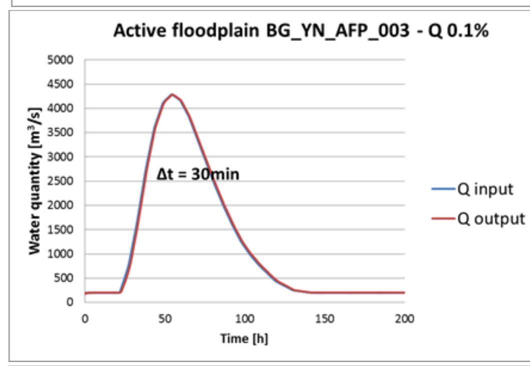


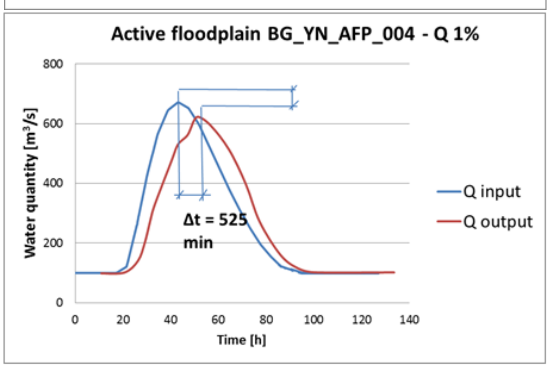


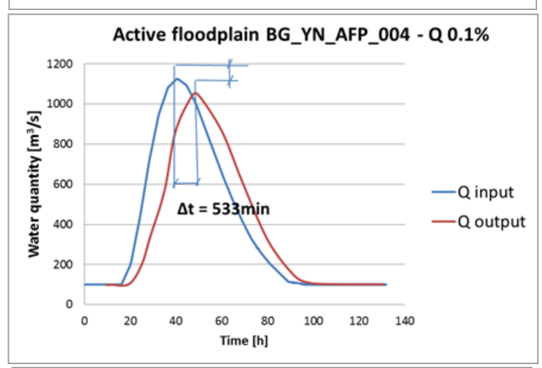

Active floodplain BG_YN_AFP_002 - Q 1%
Δt = 14 min
Water quantity [m³/s]
Time [h]
Q input
Q output

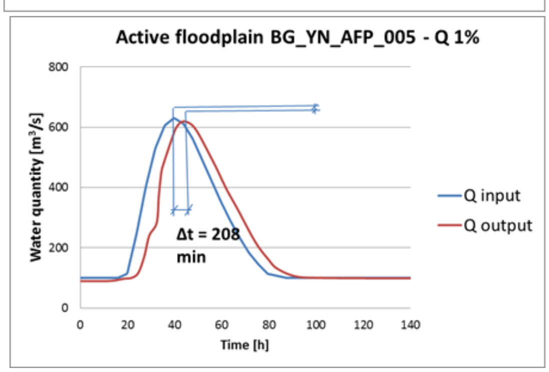

Active floodplain BG_YN_AFP_002 - Q 0.1%
Δt = 22min
Water quantity [m³/s]
Time [h]
Q input
Q output

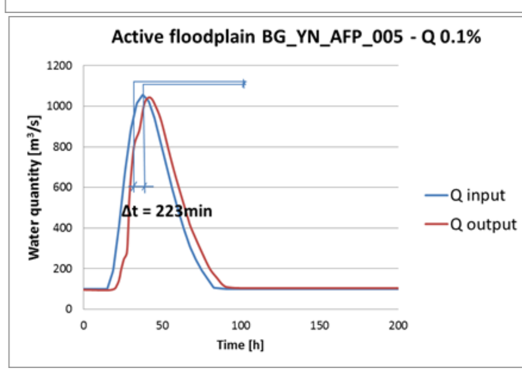

Active floodplain BG_YN_AFP_003 - Q 1%
Δt = 42 min
Water quantity [m³/s]
Time [h]
Q input
Q output

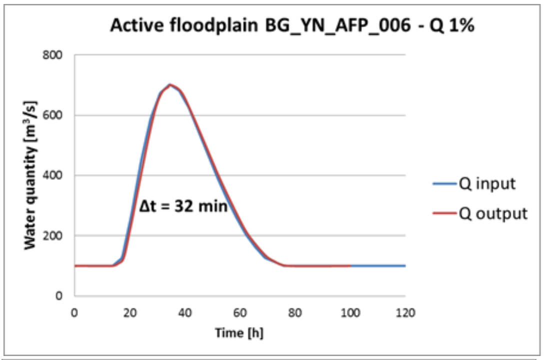

Active floodplain BG_YN_AFP_003 - Q 0.1%
Δt = 30min
Water quantity [m³/s]
Time [h]
Q input
Q output

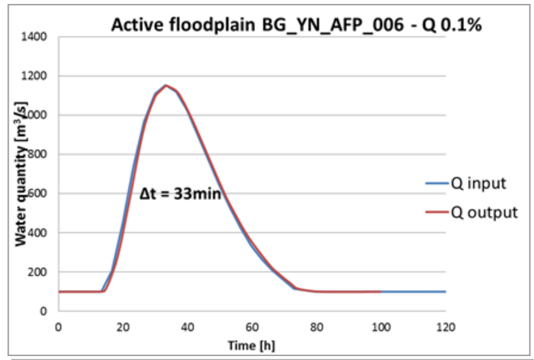

Active floodplain BG_YN_AFP_004 - Q 1%
Δt = 525 min
Water quantity [m³/s]
Time [h]
Q input
Q output

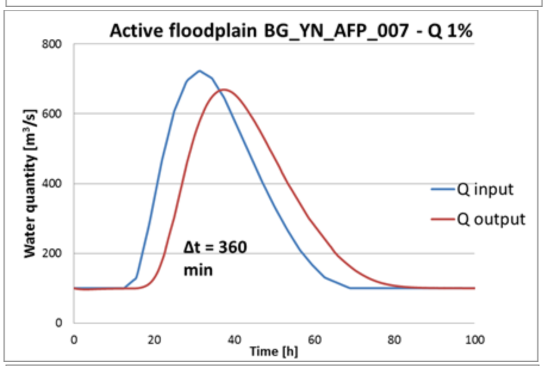

Active floodplain BG_YN_AFP_004 - Q 0.1%
Δt = 533min
Water quantity [m³/s]
Time [h]
Q input
Q output

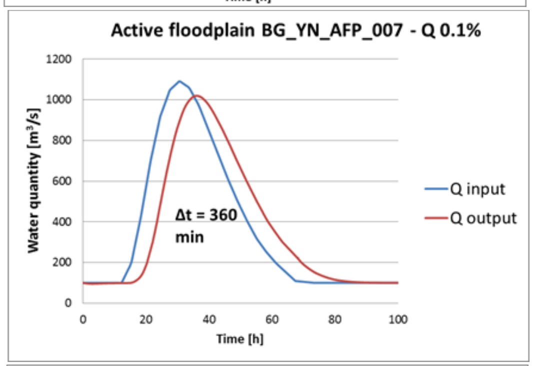

Active floodplain BG_YN_AFP_005 - Q 1%
Δt = 208 min
Water quantity [m³/s]
Time [h]
Q input
Q output

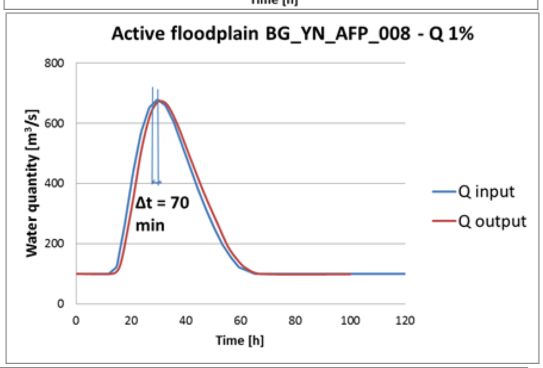

Active floodplain BG_YN_AFP_005 - Q 0.1%
Δt = 223min
Water quantity [m³/s]
Time [h]
Q input
Q output

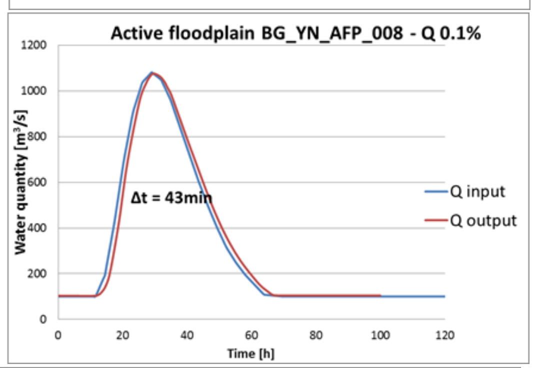

Active floodplain BG_YN_AFP_006 - Q 1%
Water quantity [m³/s]
Time [h]
Δt = 32 min
Q input
Q output

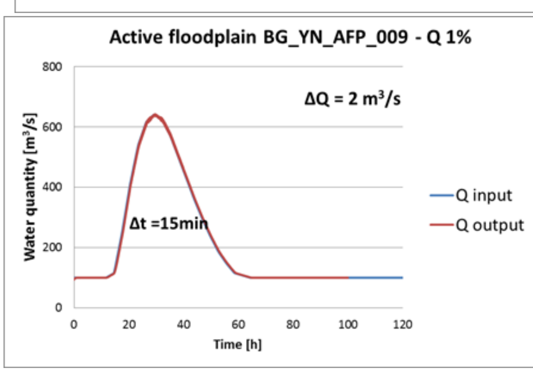

Active floodplain BG_YN_AFP_006 - Q 0.1%
Water quantity [m³/s]
Time [h]
Δt = 33min
Q input
Q output

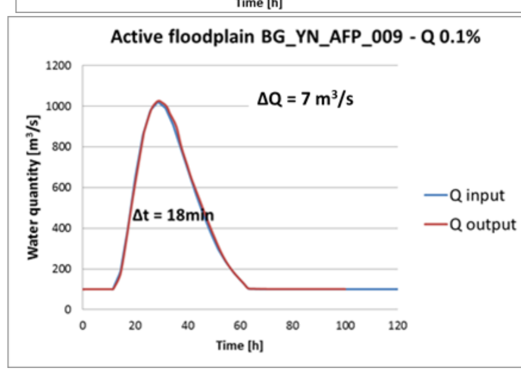

Active floodplain BG_YN_AFP_007 - Q 1%
Water quantity [m³/s]
Time [h]
Δt = 360
min
Q input
Q output

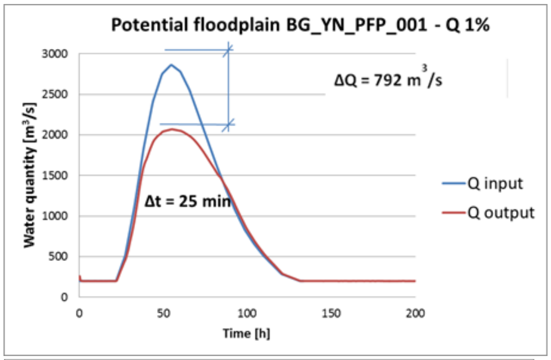

Active floodplain BG_YN_AFP_007 - Q 0.1%
Water quantity [m³/s]
Time [h]
Δt = 360
min
Q input
Q output

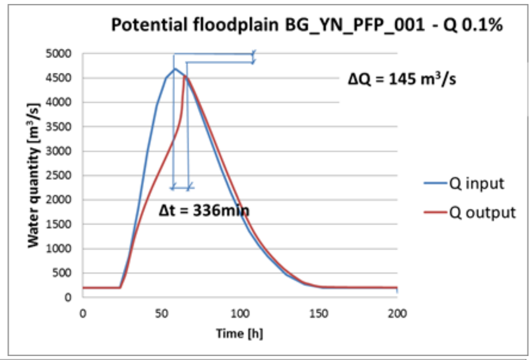

Active floodplain BG_YN_AFP_008 - Q 1%
Water quantity [m³/s]
Time [h]
Δt = 70
min
Q input
Q output

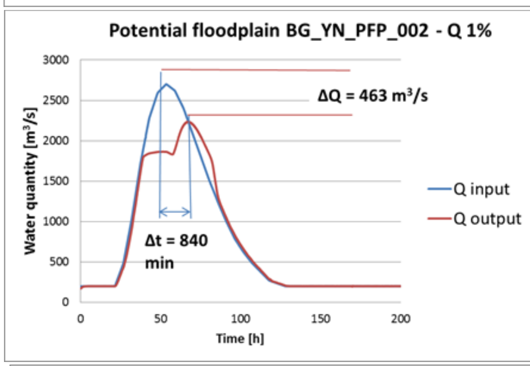

Active floodplain BG_YN_AFP_008 - Q 0.1%
Water quantity [m³/s]
Time [h]
Δt = 43min
Q input
Q output

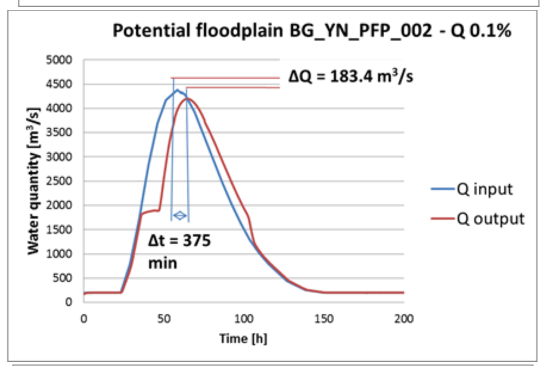

Active floodplain BG_YN_AFP_009 - Q 1%
Water quantity [m³/s]
Time [h]
ΔQ = 2 m³/s
Δt =15min
Q input
Q output

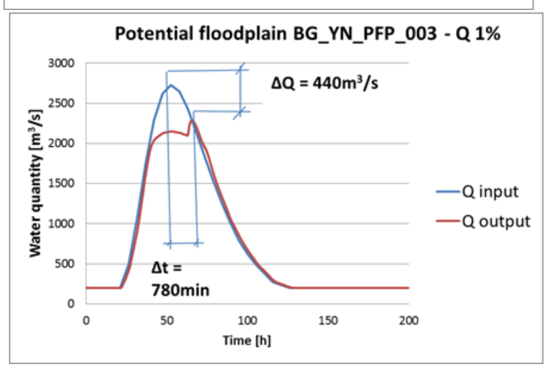

Active floodplain BG_YN_AFP_009 - Q 0.1%
Water quantity [m³/s]
Time [h]
ΔQ = 7 m³/s
Δt = 18min
Q input
Q output

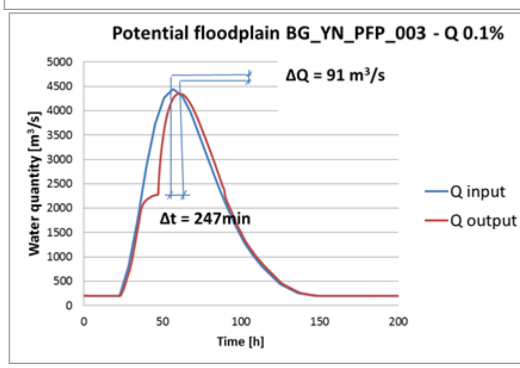

Potential floodplain BG_YN_PFP_001 - Q 1%
ΔQ = 792 m3/s
Δt = 25 min
Water quantity [m³/s]
Time [h]
Q input
Q output

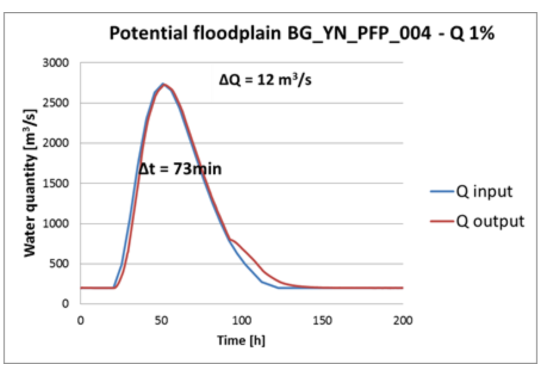

Potential floodplain BG_YN_PFP_001 - Q 0.1%
ΔQ = 145 m³/s
Δt = 336min
Water quantity [m³/s]
Time [h]
Q input
Q output

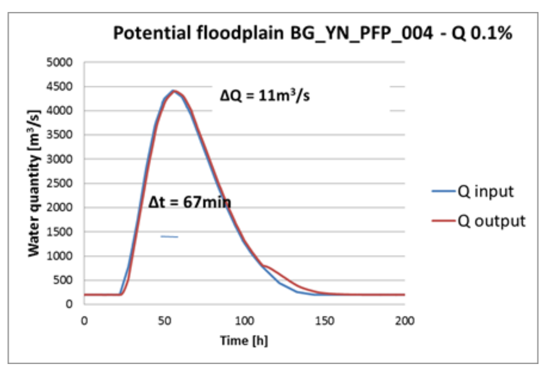

Potential floodplain BG_YN_PFP_002 - Q 1%
ΔQ = 463 m³/s
Δt = 840 min
Water quantity [m³/s]
Time [h]
Q input
Q output


Potential floodplain BG_YN_PFP_002 - Q 0.1%
ΔQ = 183.4 m³/s
Δt = 375 min
Water quantity [m³/s]
Time [h]
Q input
Q output


Potential floodplain BG_YN_PFP_003 - Q 1%
ΔQ = 440m³/s
Δt = 780min
Water quantity [m³/s]
Time [h]
Q input
Q output


Potential floodplain BG_YN_PFP_003 - Q 0.1%
ΔQ = 91 m³/s
Δt = 247min
Water quantity [m³/s]
Time [h]
Q input
Q output


Potential floodplain BG_YN_PFP_004 - Q 1%
ΔQ = 12 m³/s
Δt = 73min
Water quantity [m³/s]
Time [h]
Q input
Q output


Potential floodplain BG_YN_PFP_004 - Q 0.1%
ΔQ = 11m³/s
Δt = 67min
Water quantity [m³/s]
Time [h]
Q input
Q output

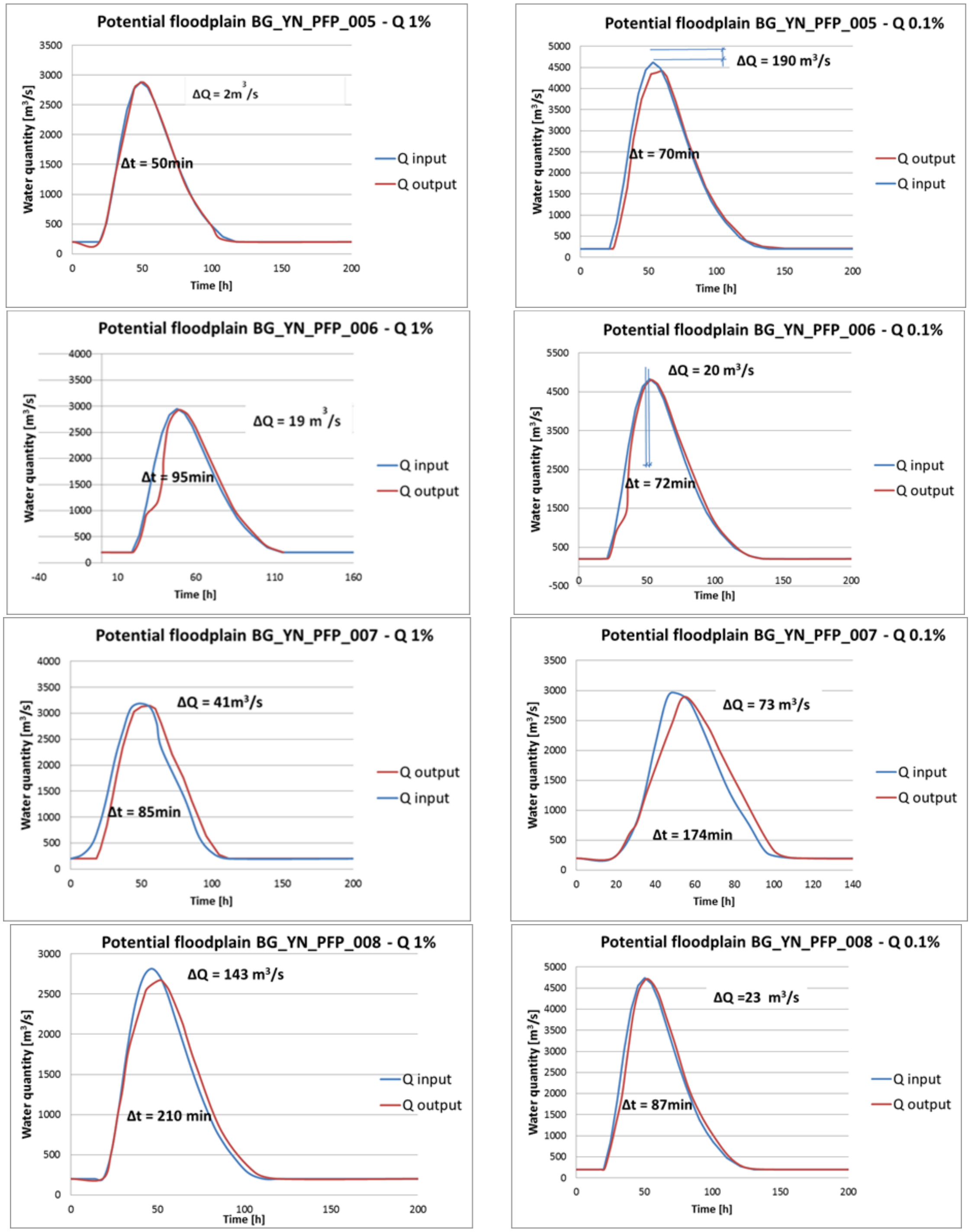


Figure 20: Hydrographs for evaluated floodplains on Yantra River floodplains

2.1.3. Desnăţui

- The Desnăţui River, a direct tributary of the Danube, is a small plain river, which is located in the south of Romania and is 115 km long, with an average altitude of 129 m and an area of 2015 km2. It springs from an altitude of only 260 m in the Bălăcițel Plain, with an initial flow direction from NV to SE, so that near the confluence with Terpezita River, at the exit of the Fântânele Reservoir, it will change its direction of flow towards the south, having the discharge into Bistreț Lake. The Desnăţui River has 12 main tributaries (figure 21), the most important are: Terpezita, Baboia and Valea Rea river, the total length of the water courses on the catchment area being 516 km (River Basin Management Plan, 2009 source; Water Cadastre Atlas, 1992).

- The Desnăţui River, a direct tributary of the Danube, was selected in the Danube Floodplain project mainly because of the identification of large flood areas (APFSR no.16 – declared in Flood Risk Management Plan of Jiu River Basin Administration) and risks of floods, where damage reduction measures are envisaged - (PMRI BH JIU source), but also due to technical considerations of connection with the pilot area on the Danube river.

- The hydrological data which have been updated at the level of 2019 (NIHWM source) show the high capacity of Fântânele Reservoir to mitigate the flood with probability of occurrence of 100 years, this being almost 93% (from 280 m^3/s to 20 mc/s). In table 1, the flows along the Desnăţui River for different probabilities of occurrence are presented.

- From the administrative point of view 76 settlements are located on its territory (1 urban and 75 rural localities) with approximately 91,000 inhabitants.

- For Danube Floodplain Project was considered the sector located in the lower part of the Desnățui river basin, downstream of Fântânele Reservoir, with the length of the 62 km and a catchment area of 1 589 km2.

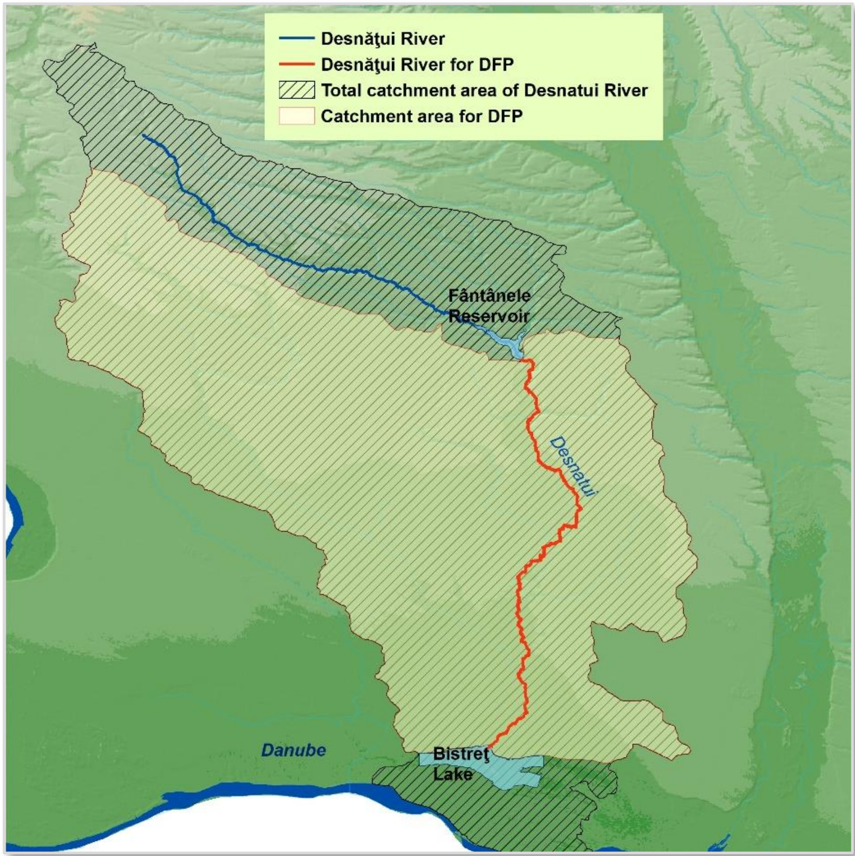


Figure 21: Desnăţui River basin considered for Danube Floodplain Project

- In order to delineate flooded area an unsteady 1D hydrodynamic model was elaborated on the river sector between Fântânele Reservoir and Bistreţ Lake, about 60 km length, using as input data measured cross-sections and LIDAR DTM obtained at the level of 2011, for drawing up the hazard and risk maps at national level.

- **The calibration of the hydraulic model** aimed that the calculated levels for the maximum flows transited through both the minor and major channel, as well as the through major channel in the sections of the gauging stations, to overlap over the levels indicated from the rating curve of the respective gauging stations. In this case, the model calibration has mainly achieved using the existing rating curve at the Goicea gauging station from the Desnațui River.

- Mainly this calibration has achieved by changing the values of the coefficients of Manning roughness from the minor and major channels. The roughness coefficient, adopted in accord with „HEC - RAS –

River Analysis System – Hydraulic Reference Manual" recommendation, taking into account the characteristics of the study area and based on orthophotoplans, had values between 0.035 and 0.04 in river channel and between 0.065 and 0.070 in floodplains.

- The downstream boundary condition used in the hydraulic model was considered the normal depth and the actual slope of the Desnăţui River in the downstream area, which is less than 1 ‰.

For the purpose of the evaluation of the FEM the hydrological models were using following assumptions:

- Definition for the Actual Floodplain (AFP): 100 year return period was used using actual floodplains and their geometry.
- Potential floodplains (PFP):200 year return period was used.
- Former floodplains (FFP): 1000 year return period was used.

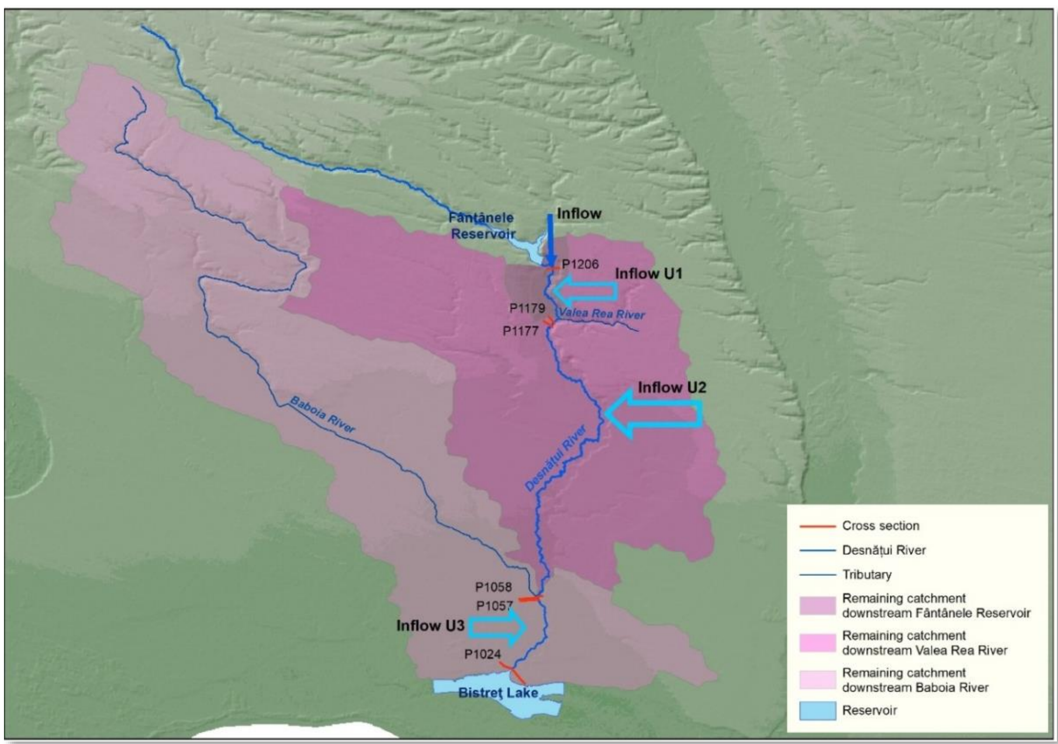


Figure 22: The distribution of inflow hydrographs and Locations for applied inflows for modelling actual floodplain (AFP) Q100

2.1.4. Morava

- Morava River Basin is located in the North of the Danube River Basin and spreads across three countries – Czech Republic, Slovakia and Austria with the total area of around 27.000 km2 (Figure 23). Morava River with its total length of 329 km is a leftside tributary of the Danube River with confluence near Bratislava-Devín. The Morava River creates natural border between Czech Republic and Slovakia and Austria and Slovakia.

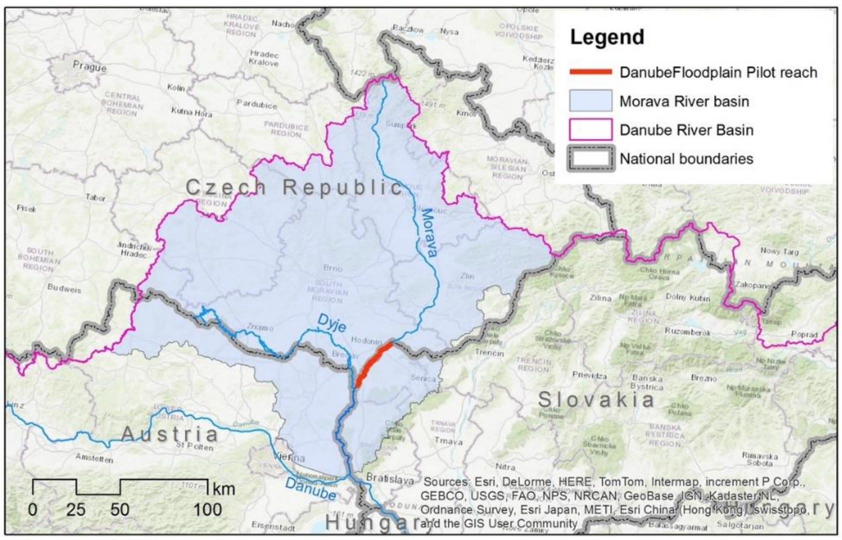


Figure 23: Morava River basin and the DanubeFloodplain pilot reach

- Pilot area of the Danube Floodplain project is Morava river reach from km 69 to 100 on the border between Czech Republic and Slovakia. The 2D modelling was performed at the area of 147 km2 (Figure 24). Morava in this section is a typical lowland river, originally strongly meandering (Figure 25). Since the 19th century, extensive river training works were performed, such as straightening of the river channel with a uniform cross-section profile, bank protection in long reaches, construction of flood protection dykes, cutting off meanders, construction of weirs and sills. River training has led to significant reduction of original floodplains as well as interruption of longitudinal continuity.

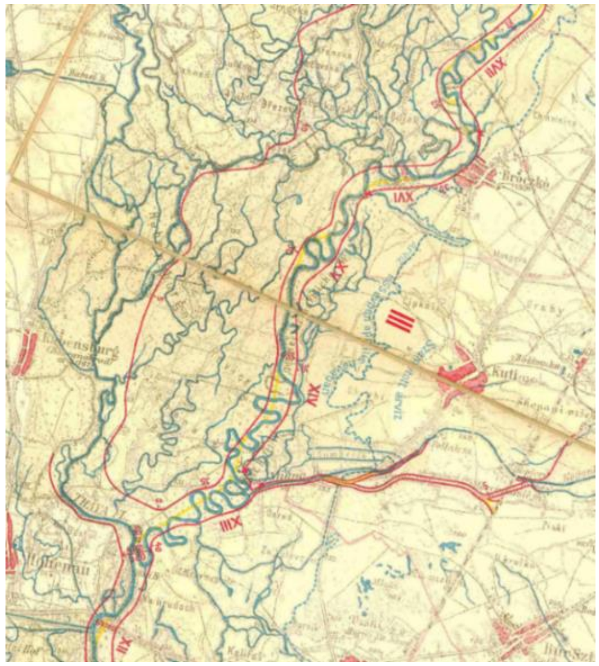


Figure 24: Original Morava river channel on the map from the beginning of 20th century

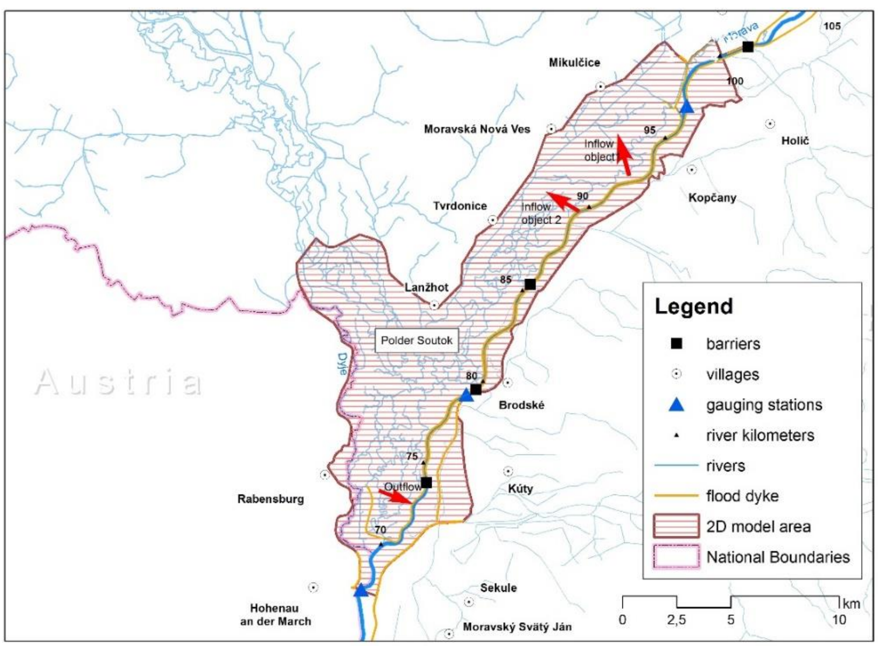


Figure 25: Morava river pilot area evaluated by 2D modelling

- Former flood plains in the pilot area were cut-off and the current floodplain within the dykes on both sides of the river is very narrow, namely only approx. 130 m. Current floodplain widens only in the lower reach of the pilot area on the Slovak side to approx. 600-1100 m (floodplain forest – Natura 2000 site).

Figure 26: Morava River between the dykes – photos taken at bankfull discharge, June 2020 (Author: VUVH)

- During flood events, large retention area Polder Soutok at Morava and Dyje confluence is used for releasing flood discharges. The retention area is behind the flood protection dyke on the right bank (Czech republic). Two inflow and an outflow object in the Morava dyke are used to release discharges higher than 600 m3/s. Water is released to the floodplain forest (Natura 2000 site).

Figure 27: Inflow object to the retention area behind the flood protection dyke (Author: VUVH)

- There are no settlements directly in the modelled floodplain area.
- Proposed restoration measures within DanubeFloodplain project were focused on improvement of flow conditions and water regime in the floodplains with respect to flood protection and nature protection, as well as improvement of conditions for fish migration and diverse biotopes in the area. For FEM analysis, Restoration scenario RS2 was evaluated with proposed measures: relocation of flood dykes (to include cut-off side arms), reconnection of oxbows, lowering of barriers (weirs, sills) in the channel (medium discharge), renewal of river pattern – design of a meandering channel.
- 1D and 2D model of the pilot area were set-up, calibrated and verified to analyse hydraulic conditions of the current state and evaluate the effect of proposed restoration measures. Hydrological data from stations Lanžhot, Kopčany and Moravský Svätý Ján were used (1 hour step). Real floodwaves of 2009 and 2010 were simulated (HQ5, HQ10-30, HQ100).
- Only one active floodplain was identified within the pilot area at current state.
- 5 potential floodplains were identified (proposed) in case proposed measures are applied, the dyke shifting towards the former floodplains was inevitable.
- To estimate the FEM parameters according to the given methodology, 1D model results were used. The parameters were estimated in cross section profiles within the identified active and potential floodplains (at upstream and downstream boundary).

Figure 28: Cut-off side arm (Author: VUVH)

2.1.5. Tisza (HU)

The Tisza River Basin drains an area of 157,186 km². Five countries are sharing this largest sub-basin of the Danube River Basin (Romania, Ukraine, Slovakia, Hungary, and Serbia). The Tisza River is the longest tributary of the Danube (966 km), and the second largest by flow, after the Sava River.

The Tisza River Basin can be divided into two main parts:

- The mountainous Upper Tisza and the tributaries in Ukraine, Romania and the eastern part of the Slovak Republic,
- The lowland parts mainly in Hungary and in Serbia surrounded by the East-Slovak Plain, the Transcarpathian lowland in Ukraine and the plains on the western fringes of Romania.

The Tisza River itself can be divided into three main parts:

- **The Upper Tisza** upstream from the confluence with the Somes/Szamos River,
- **The Middle Tisza** in Hungary which receives the largest right-hand tributaries: the Bodrog and Slaná/Sajó Rivers together with the Hornád/Hernád River collect water from the Carpathian Mountains in Slovakia and Ukraine, and the Zagyva River drains the Mátra and Bükk, as well as the largest left-hand tributaries: the Szamos/Somes River, the Körös/Crisuri River System and Maros/Mures River draining Transylvania in Romania,
- **The Lower Tisza** downstream from the mouth of the Maros/Mures River where it receives the Begej/Bega River and other tributaries indirectly through the Danube – Tisza – Danube Canal system.

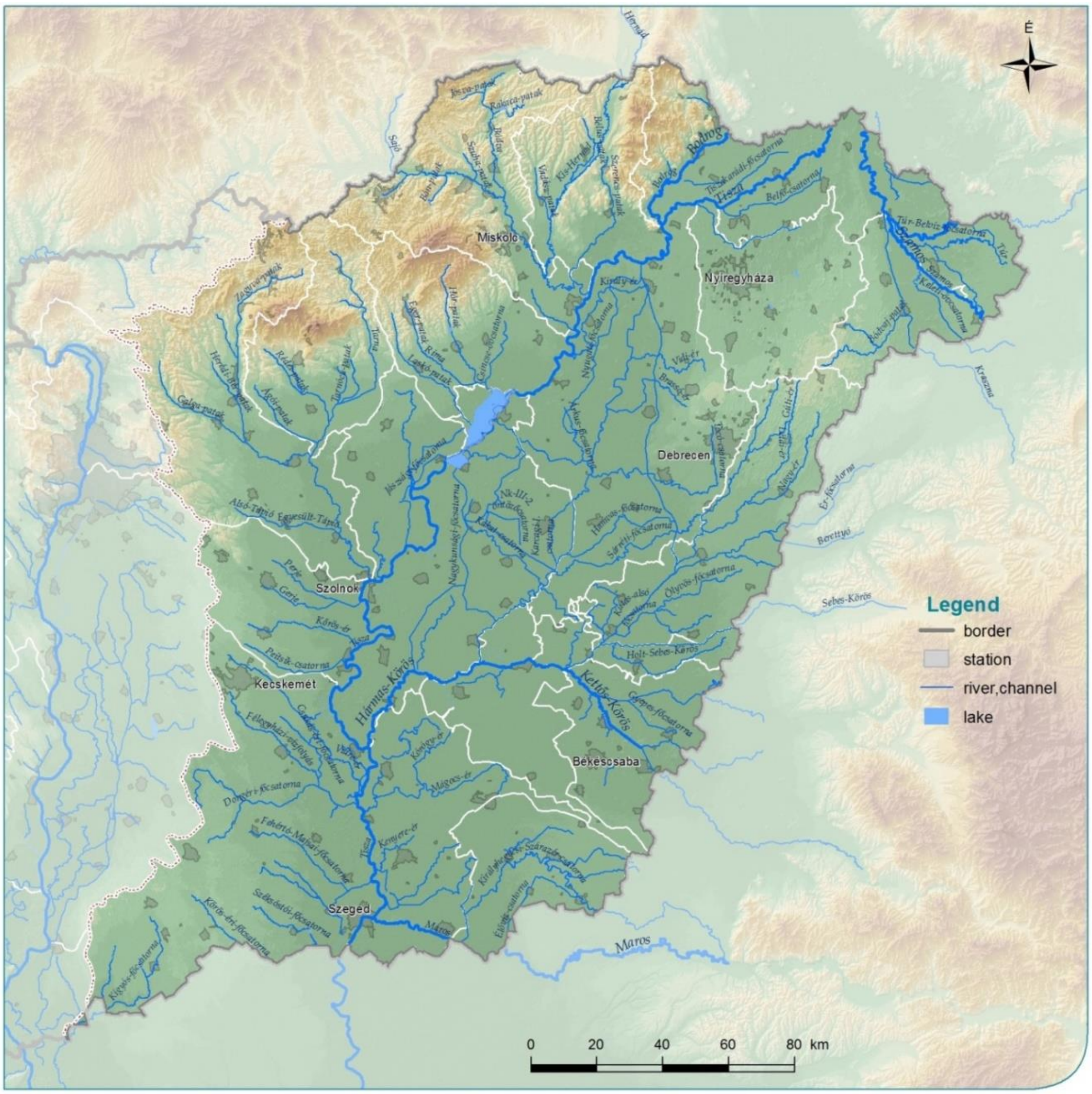


Figure 29: Tisza River Network in Hungary

Over the past decades, several extraordinary floods have drifted off the rivers in the Danube River Basin, especially in 2000, 2002, 2006, 2013 and 2014. Each of the flooding levels that emerged were one of the 100-year return waves that caused significant human and economic damage in the affected countries.

To handle increasing flood risks within the European Union the No. 2007/60/EK Directive requires almost all river basin districts to identify areas where is a significant potential flood risk or likely to occur. The identified flood risks are needed to be reduced as much as possible to ensure greater human and material security. In addition to recognize and reduce risk factors, the Water Framework Directive states, that all surface and groundwater in the EU Member States in a good condition must be kept sustainable and water status deterioration must be prevented.

The primary objective of the project is to examine the Danube and its main tributaries, to identify the potentially recoverable active and potential floodplains and to describe the necessary measures, in which flood-peak interventions are identified, and most importantly to have an ecologically positive impact. The river basin was selected for the Danube floodplain project mainly due to large identified floodplains and identified flood risks in some of them where flood damage reduction measures are anticipated.

In the Hungarian section of the river Tisza, 17 active and 7 potential floodplains were identified in this project.

For the active floodplains the delineation criteria were:

- Min area: 500 ha
- Hydraulically connected area
- Ratio factor 10:1 of Width of floodplain / Width of river

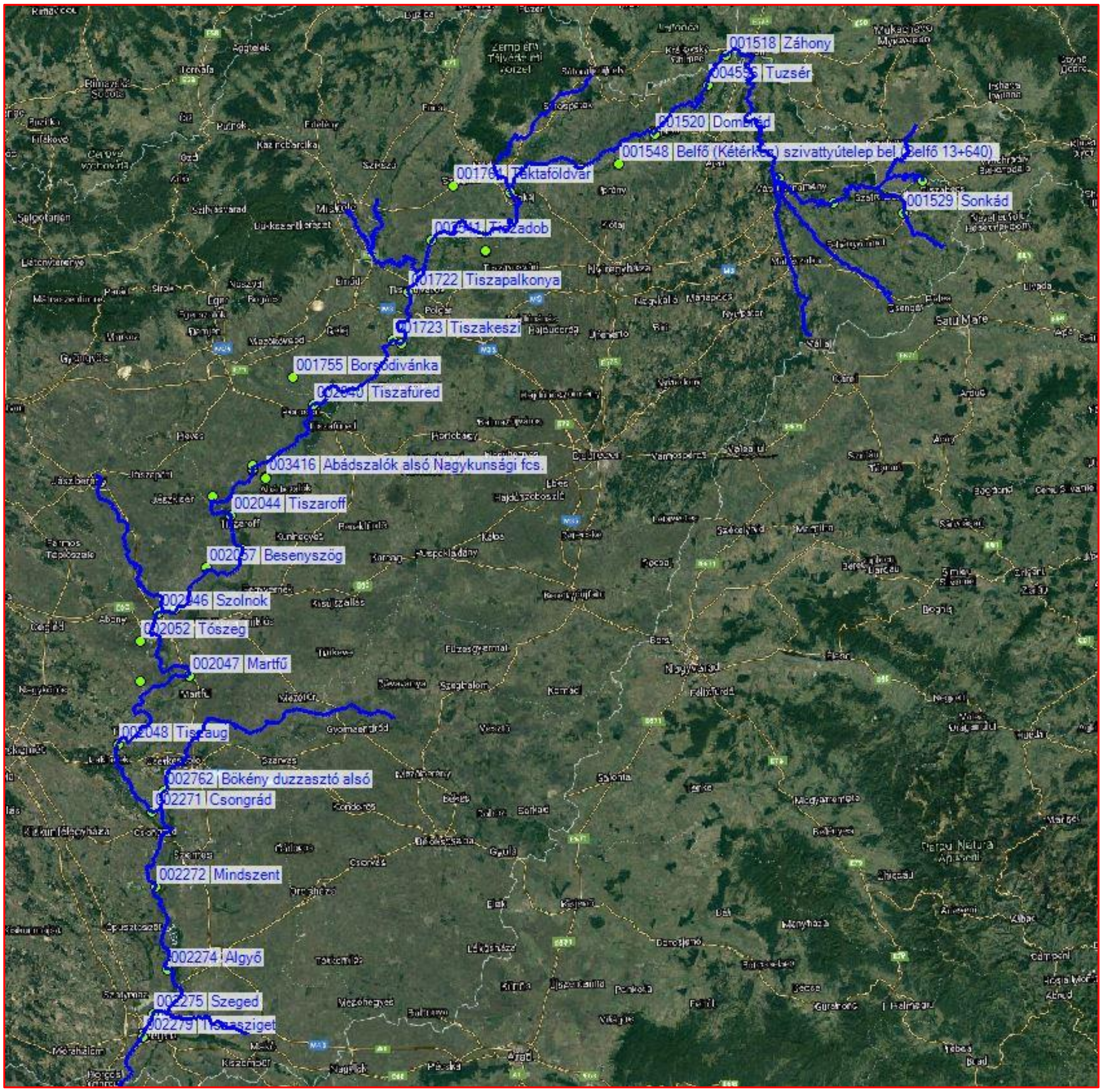


Figure 30: Most important hydrological measurement stations along the Tisza river (highlight only the Hungarian section)

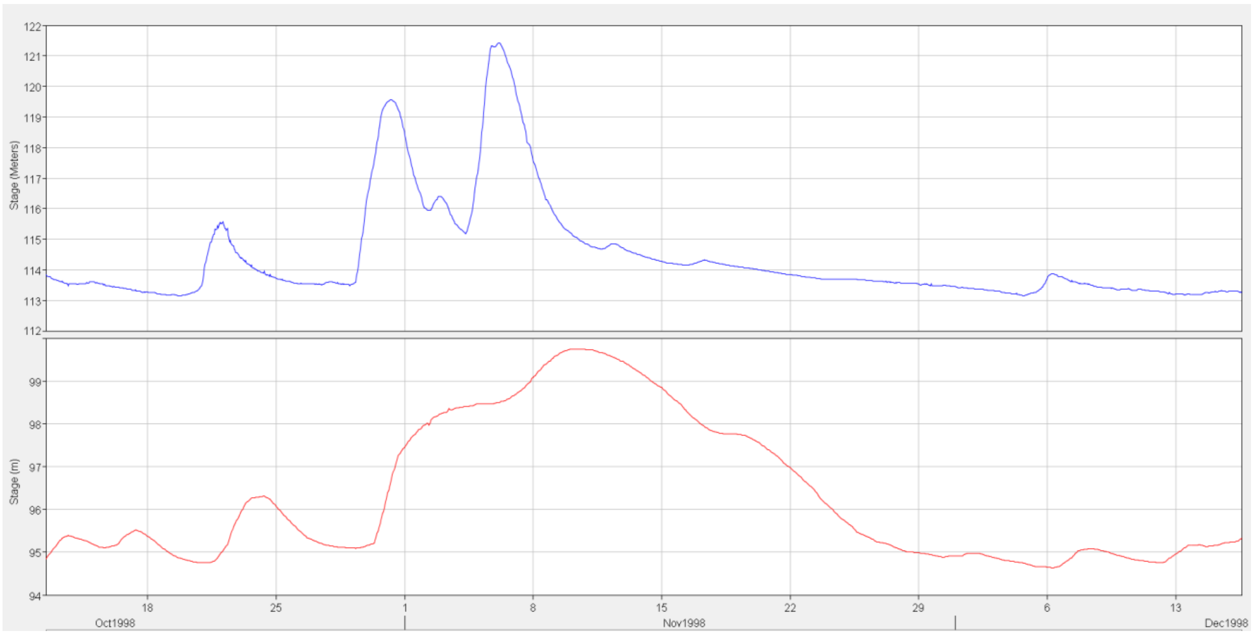


Figure 31: Applied boundary conditions time series on Upper Tisza model domain (Flood event 1998 -HQ100)

2.1.6. Tisa (RS)

The Tisza/Tisa River Basin drains an area of almost 160.000 km². The average discharge of the Tisa River at the mouth to the Danube is about 800 m^3/s. Five countries are sharing this largest subbasin of the Danube River Basin (Ukraine, Romania Slovakia, Hungary, and Serbia). The Tisza River is the longest tributary of the Danube (966 km), and the second-largest by flow, after the Sava River.

Serbian part belongs to the Lower Tisza downstream part starting from the mouth of the Maros/Mures River where it receives the Begej/Bega River and other tributaries indirectly through the Danube – Tisa – Danube Canal system and ending at the confluence with the Danube River near the village of Slankamen.

Flood protection along the Serbian section of the Tisa River (Figure 32) is based on the 296 km long levee lines along both riverbanks. The first levees were constructed in the XVIII century and in the period that followed they were heightened and improved after every large flood. However, such levees were not safe enough and additional efforts were required to ensure flood defence. After a long-lasting, hard, and costly flood defence in 1970, a systematic approach was applied to ensure a secure flood protection system. Reconstruction of the existing and erection of some new, reallocated levees were grounded on equal standard - to enable the protection from 1% probability floods, with 1 m additional freeboard above the design flood level. The last section of an old levee was reconstructed after a demanding flood defence in 2006. The conditions of floodwater conveyance were also considerably improved by engineering works in the riverbed (enlargement and shortcutting) and on the floodplains (correction of levee lines). Along some river sections “summer dikes” protect cultivated floodplains from 10% probability floods. There are some vulnerable points on the levees, where pumping stations and drainage outlets exist, or the levee line crosses abandoned riverbed.

Flood hazard and flood risk maps show that in the case of overtopping and breach of levees floods may endanger many settlements, some of which were built right next to the river. They host the inhabitants and their property, public institutions, economic activities, cultural heritage, infrastructure (within and between settlements). Flood hazard area also encompasses several protected areas while its largest portion is used for agricultural production.

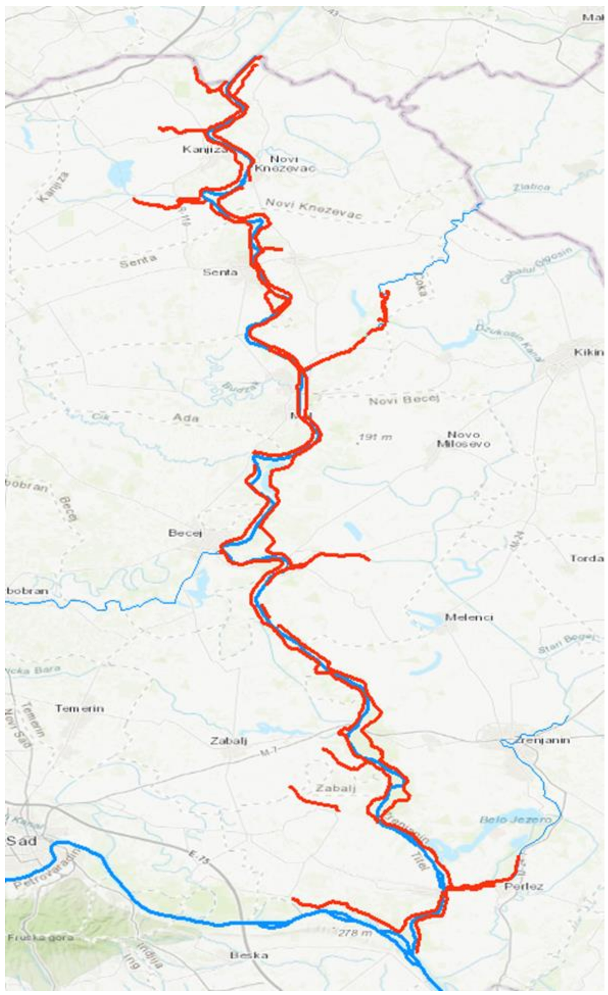


Figure 32: Overview of the flood defence system at the Tisa River and main tributaries in Serbia

Riparian land of the Tisa River is mostly agricultural (around 50%) while forests are presented with around 25%. There are several significant industrial centres, Kanjiža, Novi Kneževac, Senta, Novi Bečej, and some smaller settlements mostly dedicated to agricultural production.

The most significant protected areas along the Tisa River are Special nature reserve “Ritovi Donjeg Potisja” and Nature park “Stara Tisa kod Bisernog ostrva” (Old Tisa near the Pearl island).

The special nature reserve "Ritovi donjeg Potisja" includes eight old meanders and a belt of floodplain forests in the Tisa foreland located on the area between the Nature Park "Stara Tisa" near the Pearl Island and the Special nature reserve "Titelski breg". They are located on the left and right of the present course of the Tisa river and connected by a continuous to a large extent preserved forest complex. The basic characteristics of this protected area are preservation and diversity of original orographic and hydrographic forms of marshes (meanders, shallow and deep depressions and ponds) in the Tisa floodplain, preservation of ecosystem diversity characteristic for the large river's floodplains of the floodplain of the large plains and preservation and representativeness of native plant communities of marshes. This protected area belongs to the IUCN Category IV, it is a part of the Tisa River international ecological corridor and will be nominated as Natura 2000 area in the Republic of Serbia based on Council Directive 92/43/EEC.

The Nature park “Stara Tisa kod Bisernog ostrva” is especially important from the hydrological point of view due to its uniqueness and preservation. The length of about 24 km makes it the longest Tisa River oxbow. The Old Tisza has preserved its natural values from the 19th century, when it was cut off from its course. The most important characteristics of natural habitats are determined by the geographical position, geomorphological and hydrological characteristics of the area. The mosaic of aquatic, marsh, meadow, and salt marshes habitats, with the presence of a large number of rare and endangered species, is a unique complex important for protection not only nationally but also internationally. This protected area belongs to the IUCN Category V, it is a part of the Tisa River international ecological corridor, it was declared as the international Important Bird Area (IBA) in 1997 and will be nominated as Natura 2000 area.

In addition to these, there is also the area Mrtvaje Gornjeg Potisja that is planned for protection as a Nature Park. This area is located in the upper part of the Serbian stretch of the Tisa River. It belongs to the IUCN Category V, it is a part of the Tisa River international ecological corridor and will be nominated as Natura 2000 area. The area consists of 4 oxbow lakes that represent one of the preserved aquatic habitats due to the presence of numerous rare species characteristic for marshes, meadows, salt marshes and steppe habitats.

Given that the Tisa River in Serbia have all characteristics of large lowland rivers, the same approach for the identification of the active floodplains (AFP) was used as for the Danube River:

- the inundation outlines of an HQ100 identify active floodplains; for the Tisa River locations of dikes and/or high terrain defines the inundation,

- the ratio factor 1:1 of Widthfloodplain / Widthriver is used for AFP delineation,
- the AFP area is larger than 500 ha,
- defined floodplains have to be hydraulically connected.

Based on applied criteria, three AFPs were identified on the Tisa River in Serbia.

No PFP were identified on the Tisa River in Serbia. The decision is made based on the "Study on possibilities for water retention in the Tisa River riparian zone", Jaroslav Černi Water Institute, Belgrade, 1992, and supported by the fact that recent national strategic and planning documents related to the flood protection don't foresee measures of flood retention along the Tisa River in Serbia. The study examined only the Tisa river reach upstream of the Novi Bečej dam, given that flood retention would have no effects at the most downstream part near the confluence with the Danube. Three potential areas for flood retention were identified based on volume capacity, land use, topography, and existing infrastructure. The Study concludes that only the simultaneous use of all of them would be effective but probably not economically feasible.

2.1.7. Sava (RS)

The Sava River Basin is one of the most significant sub-basins of the Danube River Basin with a total area of almost 98,000 km^2. The average discharge of the Sava River at the mouth to the Danube is about 1700 m^3/s. The basin area is shared among six countries: Slovenia, Croatia, Bosnia and Herzegovina, Albania, Montenegro and Serbia. The Sava River is very important for the Danube River Basin for its biological and landscape diversity. It hosts the largest complex of alluvial wetlands in the Danube Basin and large lowland forest complexes. The Sava River is a unique example of a river with some of the floodplains still intact, thus supporting the flood alleviation and biodiversity.

The lowest part of the Sava River belongs to the territory of the Republic of Serbia. It is about 210 km long, stretching from the HR-RS state border near the village of Jamena to the confluence with the Danube River in Belgrade. At this section, the Sava flows through a distinct plain area and has all the characteristics of an alluvial river (deformable bed, meandering course, etc.). It receives many tributaries and the most significant are the Bosut at the left and the Drina and the Kolubara at the right bank.

The flood defence system along the Sava River section in Serbia is not continual (Figure 34). There are still natural floodplains capable to store and attenuate a part of flood wave.

The history of flood protection system development along the Sava is very long and related to the establishment of numerous settlements and agricultural development. The levee reconstruction to so-called "Sava levee profile" was initiated after extremely complex and expensive flood protection activities in 1974 and 1981. Reconstruction of the flood defence lines along the Sava and its tributaries in the mouth sections has not been completed so far and some works are currently ongoing, as described in the following text.

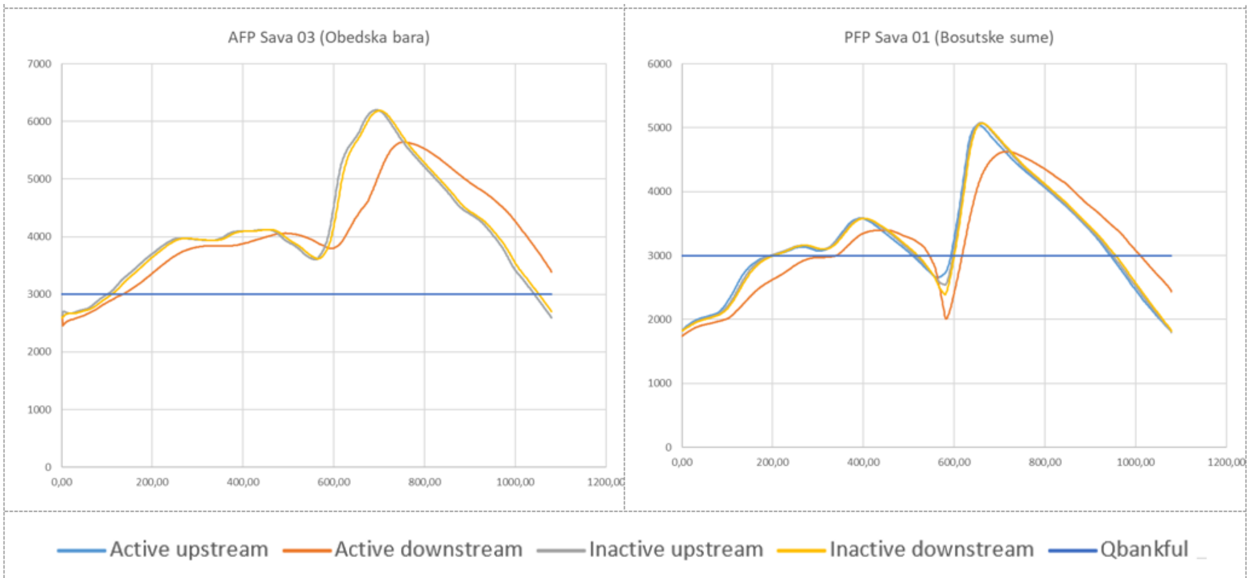


Figure 33: Hydrographs for the Sava River FPs

The left-bank levees of the Sava River protect the lowland area of Srem. The defence line is not continuous, and three different sections can be distinguished:

From the Sava mouth into the Danube River to Kupinovo village, a 51.3 km long protection line is continuous, protecting around 13,000 ha of agricultural land, 1,300 ha of urban territory including the Belgrade area, and a few villages. Densely populated area of New Belgrade is protected by 8.5 km of the quay wall and by the levee on a short section. One part of these structures is below the design protection level.

Riparian lands between the Kupinovo village and the city of Sremska Mitrovica are not protected, except two short stretches by the villages. The terrain is low, and high waters inundate 12,000 ha. Nature reserve "Obedska bara" is located in this area (near Kupinovo).

From Sremska Mitrovica to the state border with Croatia a 70 km long levee protects around 48,000 ha of fertile agricultural land and forests, city of Sremska Mitrovica and numerous smaller settlements, traffic infrastructure and industry. Drainage water from dense channel network is discharged into the Sava River by gravity or pumping.

Flood protection line on the right bank of the Sava River also has three specific sections:

From the Sava River mouth to Skela (km 0 to km 55.1) flood protection line is interrupted by numerous smaller and larger tributaries. The protected area is thus divided into several flood cells protected by levees along the Sava and its tributaries. Quay walls and levees protect the central Belgrade area. Levees upstream of the Kolubara mouth protect 12,000 ha of agricultural land, numerous settlements, and part of Obrenovac, industrial facilities and infrastructure.

Between Skela and the city of Šabac, only short levees are built to protect agricultural land and small settlements.

Between Šabac and the Drina River mouth, a 70 km long and continuous defence line protects the Mačva region. It extends 18 km along the right bank of the Drina River to Badovinci. Within protected area, there is the city of Šabac and numerous smaller settlements, 30,000 ha of agricultural land, industrial facilities and infrastructure, and drainage systems.

Figure 34: Overview of the flood system at the Sava River and main tributaries in Serbia

Forest land is dominating at the left while agricultural land is more represented at the right bank of the Sava River in Serbia. There are four significant industrial centres, Sremska Mitrovica, Šabac, Obrenovac and Belgrade and some smaller settlements mostly dedicated to agricultural production.

The most significant protected areas along the Sava River are the Special Nature Reserves Obedska bara (the Obed swamp) and Zasavica.

The greatest value of Obedska bara lies in its authentic combination of stagnant tributaries, ponds, pits, swamp vegetation, wet meadows, and forests with exceptional diversity of ecosystems and species, especially the endangered ones. It is one of the few remaining inundated marshes with distinctive features, such as hundred years old mixed English oak forests, waterfowl colonies and numerous natural rarities. This swamp actually represents a remnant of the former meander of the Sava, located along its old riverbed. Obedska bara has been included in the Ramsar Convention list in 1977 and is the first protected site of such kind in Serbia. In 1989 it was declared the international Important Bird Area (IBA).

Zasavica is dominated by a reverie biotope of the Zasavica River. It is mosaic of aquatic and wetland ecosystems with fragments of flooded forests. The backbone of the Reserve makes canals, creeks and the Zasavica river which is connected to the Sava River directly through Bogaz canal. The Zasavica River is also supplied by groundwaters from the Drina River. The whole system presents one of the few authentic and preserved wetlands of the region. This area was put under protection in 1997 and is a part of a national network of Ramsar sites (wetlands protected according to the Ramsar Convention), and according to IUCN management categories, it is Habitat and species management area – category IV.

Given that the Sava River in Serbia have all characteristics of large lowland rivers, the same approach for the identification of the active floodplains (AFP) was used as for the Danube River:

- the inundation outlines of an HQ100 identify active floodplains; for the Sava River locations of dikes and/or high terrain defines the inundation,
- the ratio factor 1:1 of Widthfloodplain / Widthriver is used for AFP delineation,
- the AFP area is larger than 500 ha,
- defined floodplains have to be hydraulically connected.

Based on applied criteria, three AFPs were identified on the Sava River in Serbia.

Identification of the potential floodplains (PFP) on the Sava River is based on the extreme flood event in May 2014 when a three-months amount of rain fell onto the region in just three days. Enormous inflow lead to a fast increase of the Sava water levels, in the bordering sections between Bosnia and Herzegovina and Croatia and in Serbia. On May 17, the Sava River breached left-bank levee at two locations, flooding several settlements in eastern Croatia, and water progressed over flat areas towards lower terrain in Serbia and flooded several settlements there as well (Figure 7, red hatch area). After this event, HR and RS initiated the Interreg Project called FORRET (https://www.interreg-croatia-serbia2014-2020.eu/project/forret/) striving to significantly increase the disaster response capability related to the risk of disasters from floods in the area. One of the flood wave reduction options was the relieving a part of the flood wave into the transboundary natural forest retention areas of Spačva-Morović, covering approximately 38, 000 ha in Croatia and Serbia, while also improving the ecological status of the area. At the very beginning of the Danube Floodplain Project, the HR and RS partners decided not to examine this area as a common potential FP given that the same exercise should be done through the FORRET Project. The FORRET project failed in the meantime and JCWI decided to examine the RS part of the area (Figure 7, blue area) as a potential FP at the territory of Serbia as presented in Figure 5 (PFP Sava 01, Bosutske šume, aka Morović).

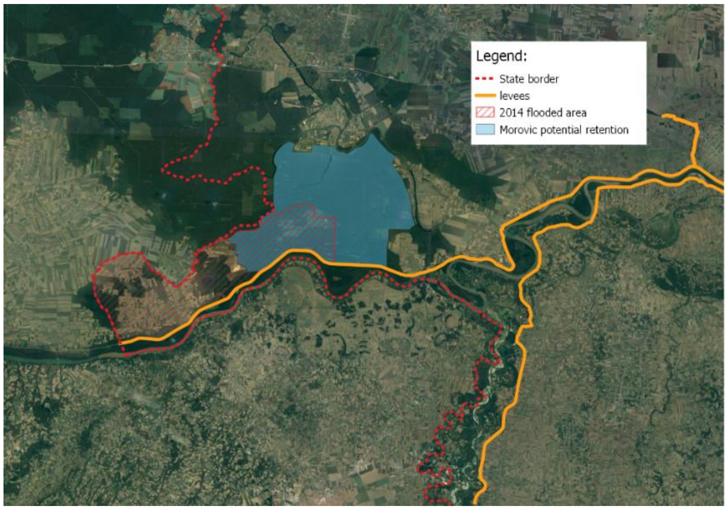


Figure 35: 2014 flood event impacted area on the Sava River left bank in HR and RS

2.2. Results

Maps of active and potential floodplains on the six selected tributaries are given in this chapter. Shapefiles of all identified floodplains and associated data will be available on the Danube Floodplain GIS server.

2.2.1. Krka

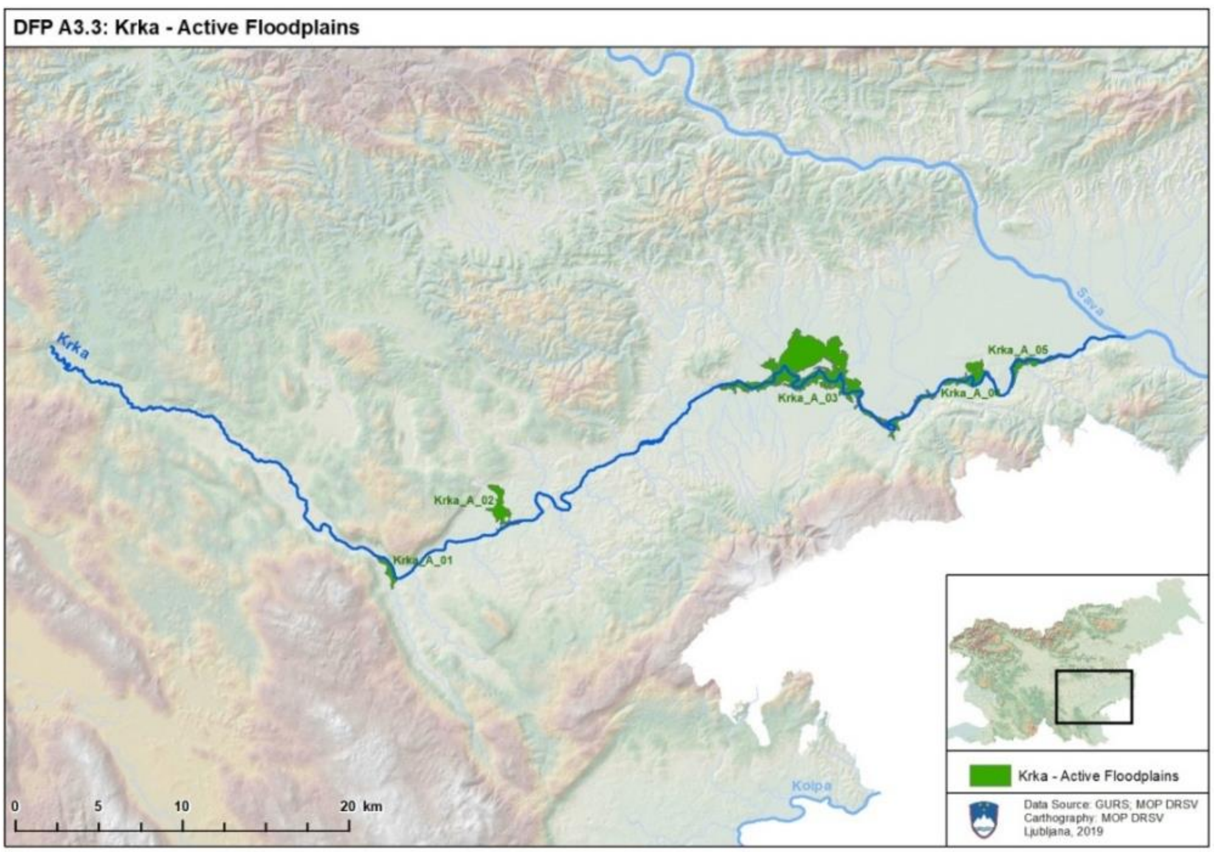


Figure 36: Extent and position of the Active floodplains identified on the Krka river

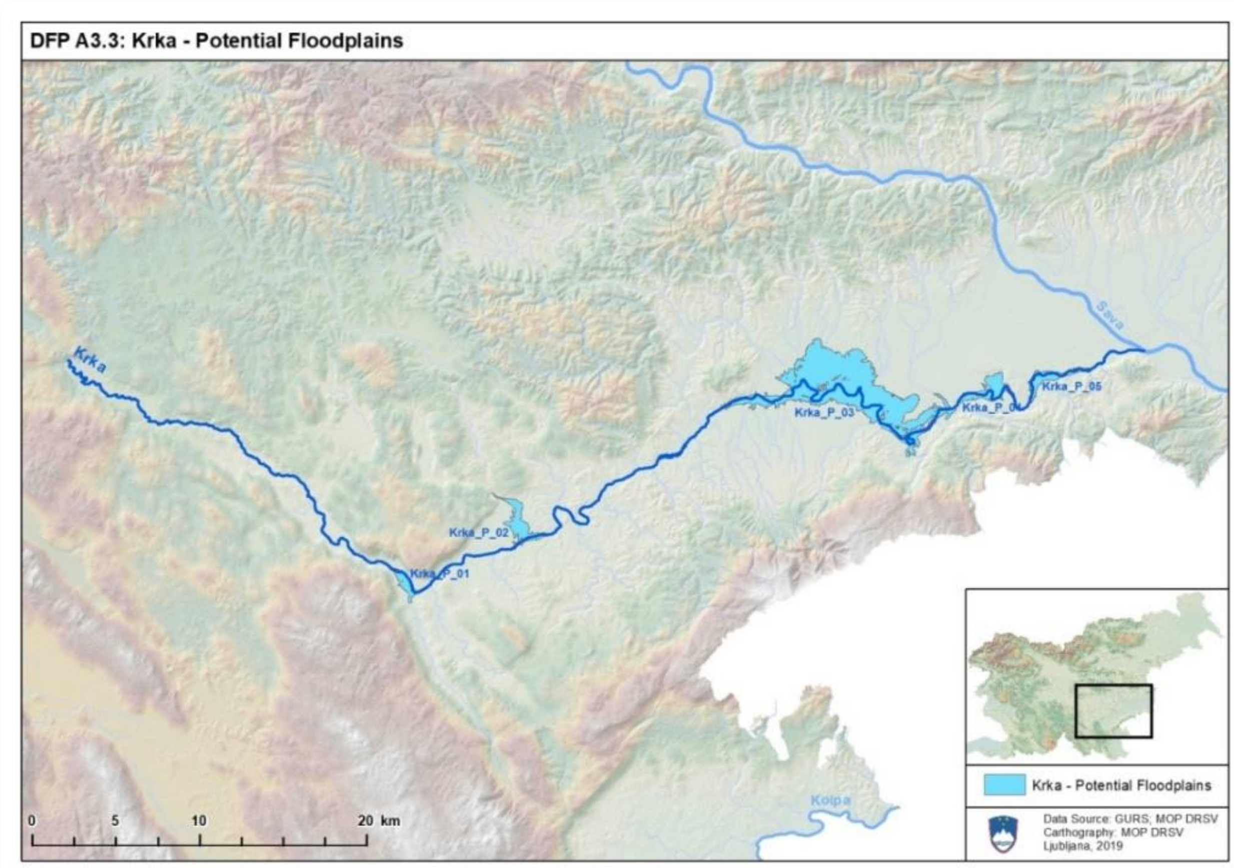


Figure 37: Extent and position of the potential floodplains identified on the Krka river

2.2.2. Yantra

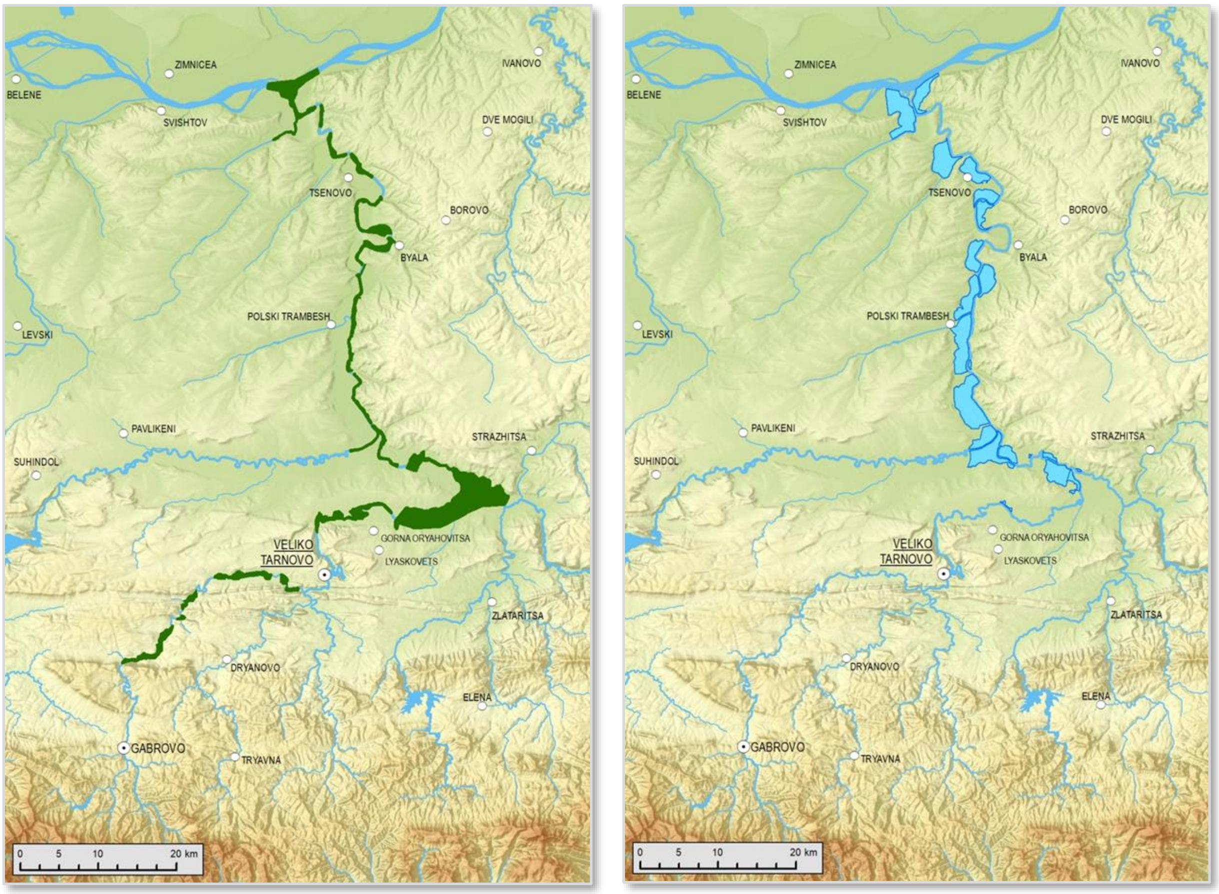


Figure 38: Extent and position of the Active and Potential floodplains identified on the Yantra river

2.2.3. Desnăţui

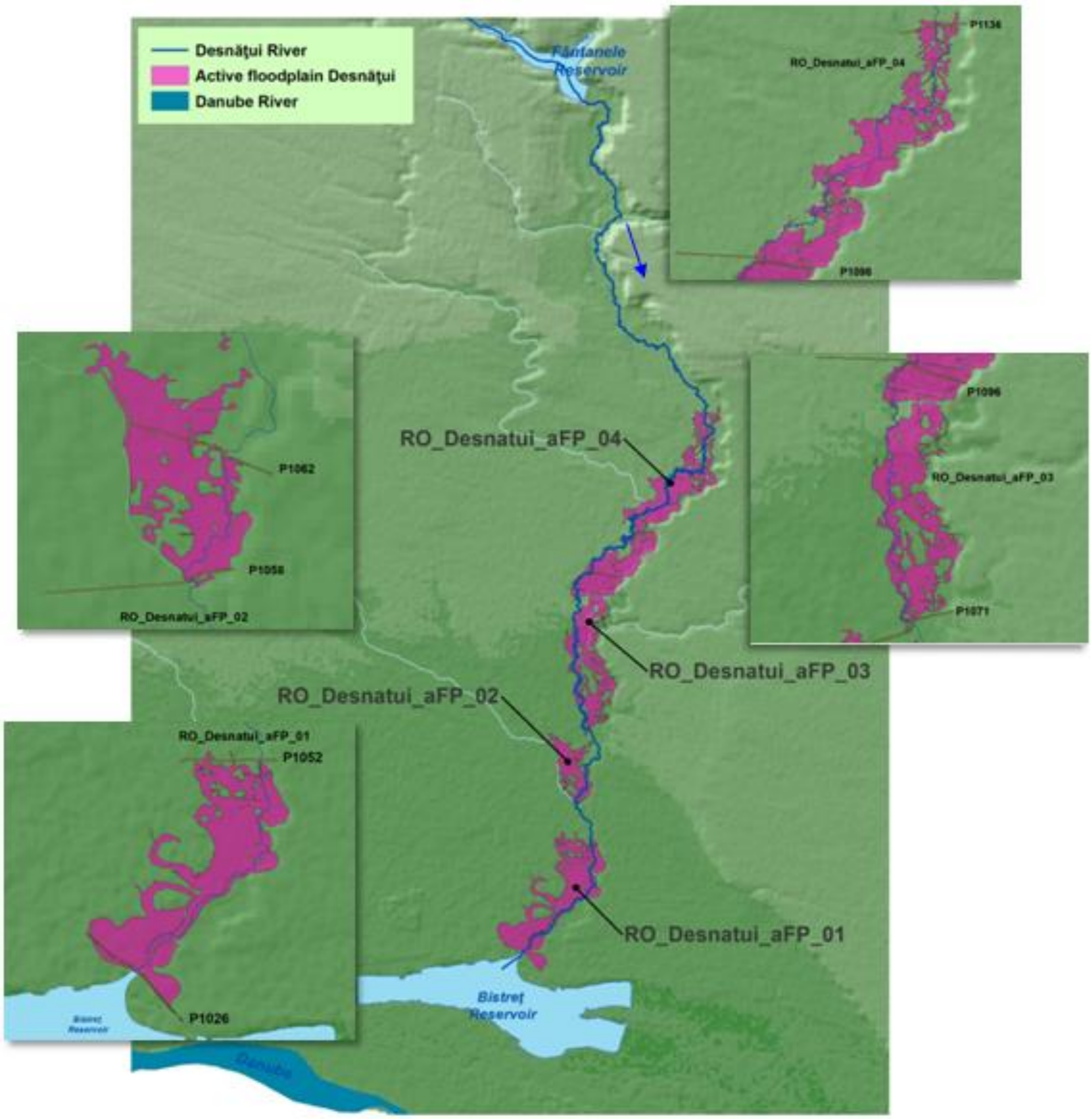


Figure 39: Extent and position of the active floodplains identified on Desnăţui River

2.2.4. Tisza (HU)

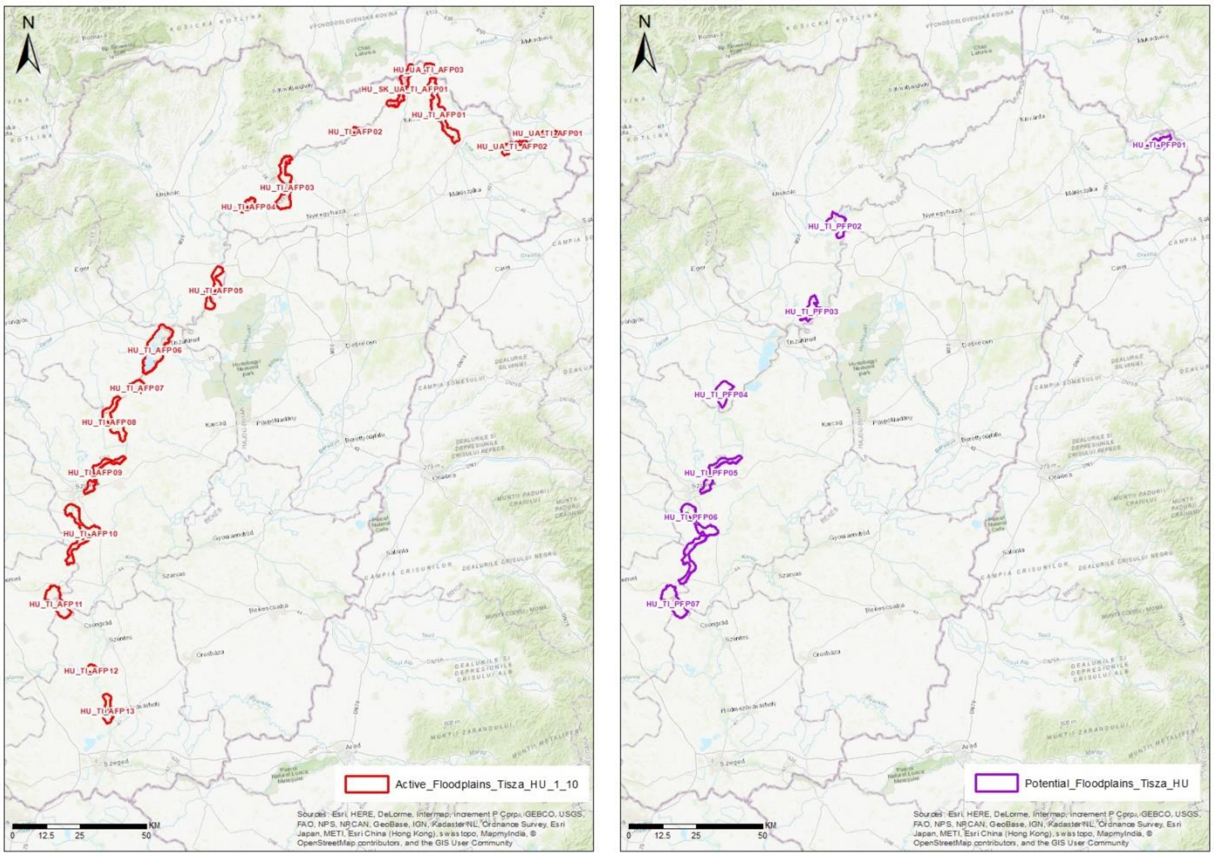


Figure 40: Extent and position of the Active floodplains identified on the Tisza river (HU)

2.2.5. Tisa (RS)

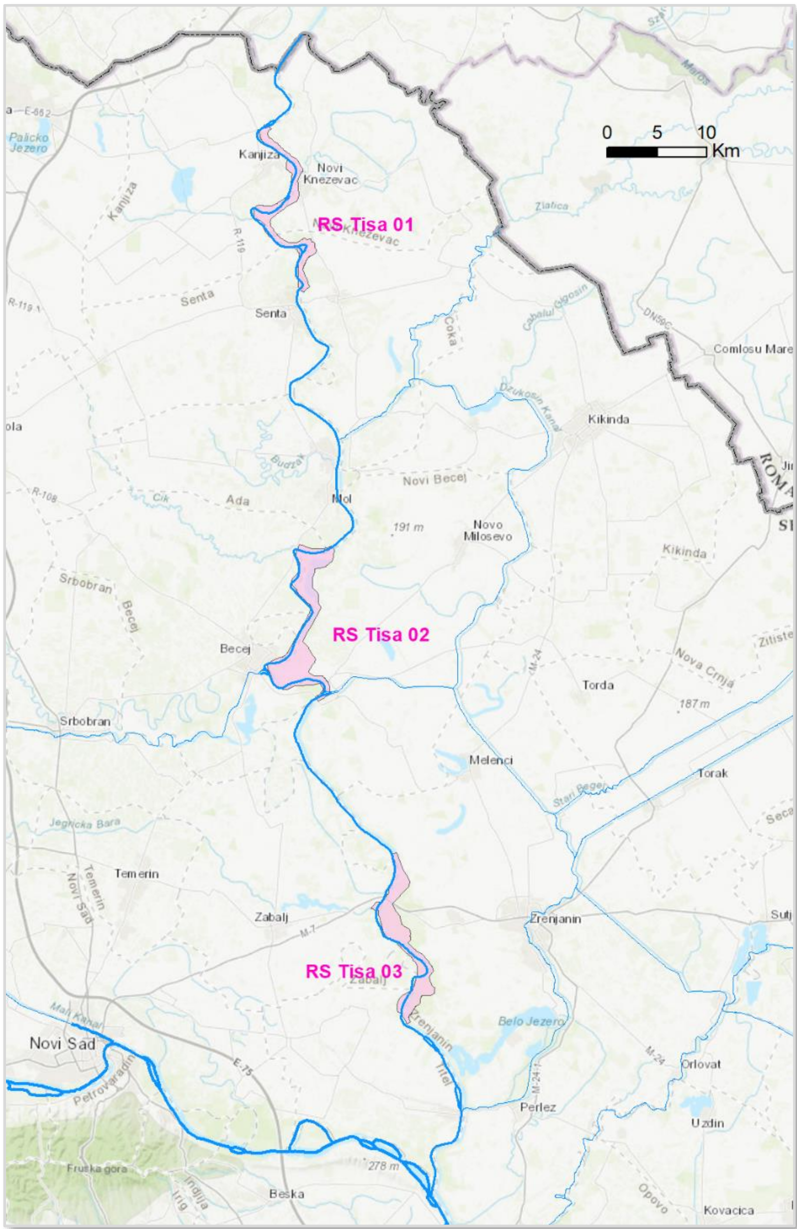


Figure 41: Extent and position of the Active floodplains identified on the Tisa river (RS)

2.2.6. Morava

Only one active floodplain larger than 500 ha was identified within the pilot area (Figure 41). At this locality, the flood protection dyke is further from the Morava river and the area is naturally flooded at higher discharges.

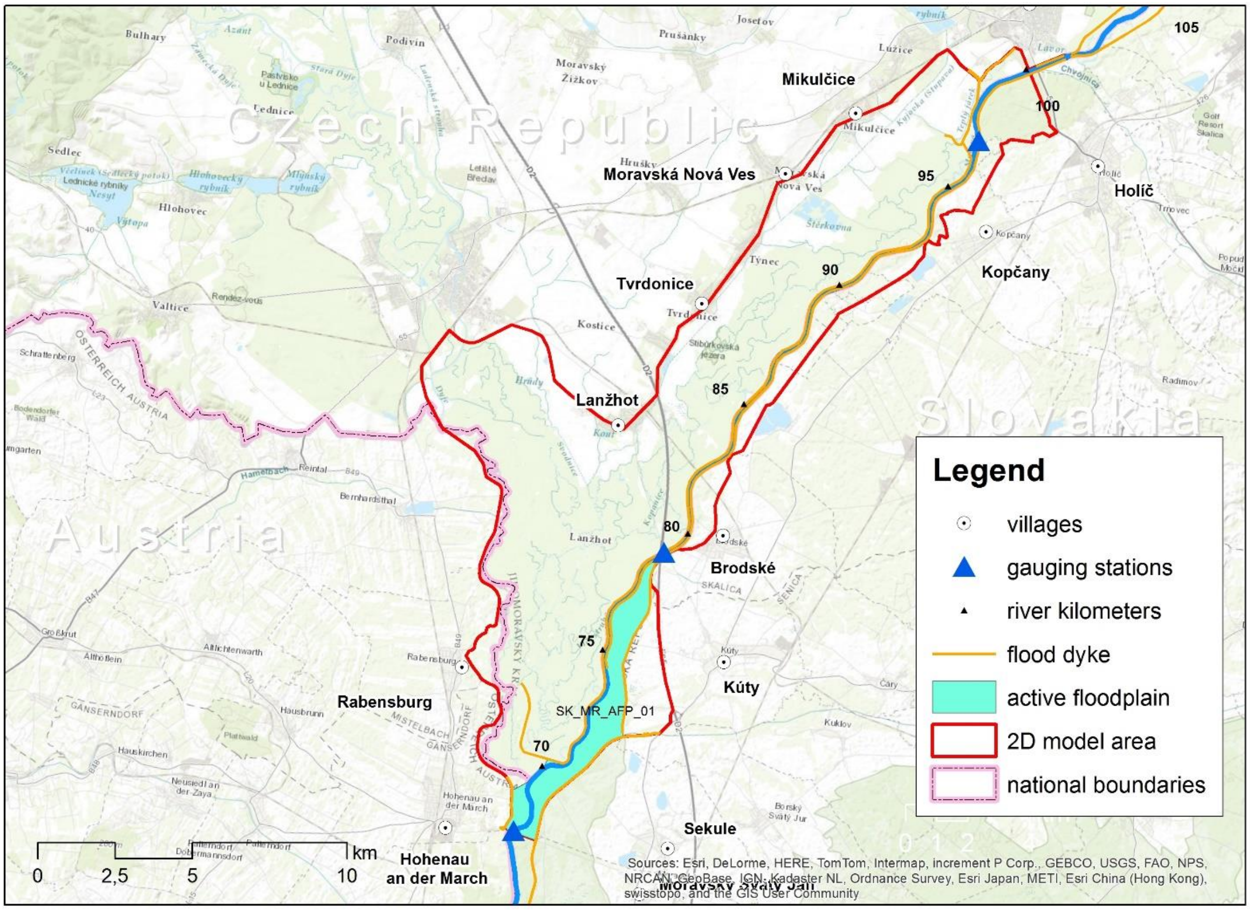


Figure 42: Extent and position of the active floodplain identified on the Morava river (CZ, SVK)

After the proposed measures are implemented, 5 potential floodplains could be created to communicate with the main river course during floods (Figure 42). Dyke shifting on both sides of the border was proposed. Current active floodplain was proposed to be widened.

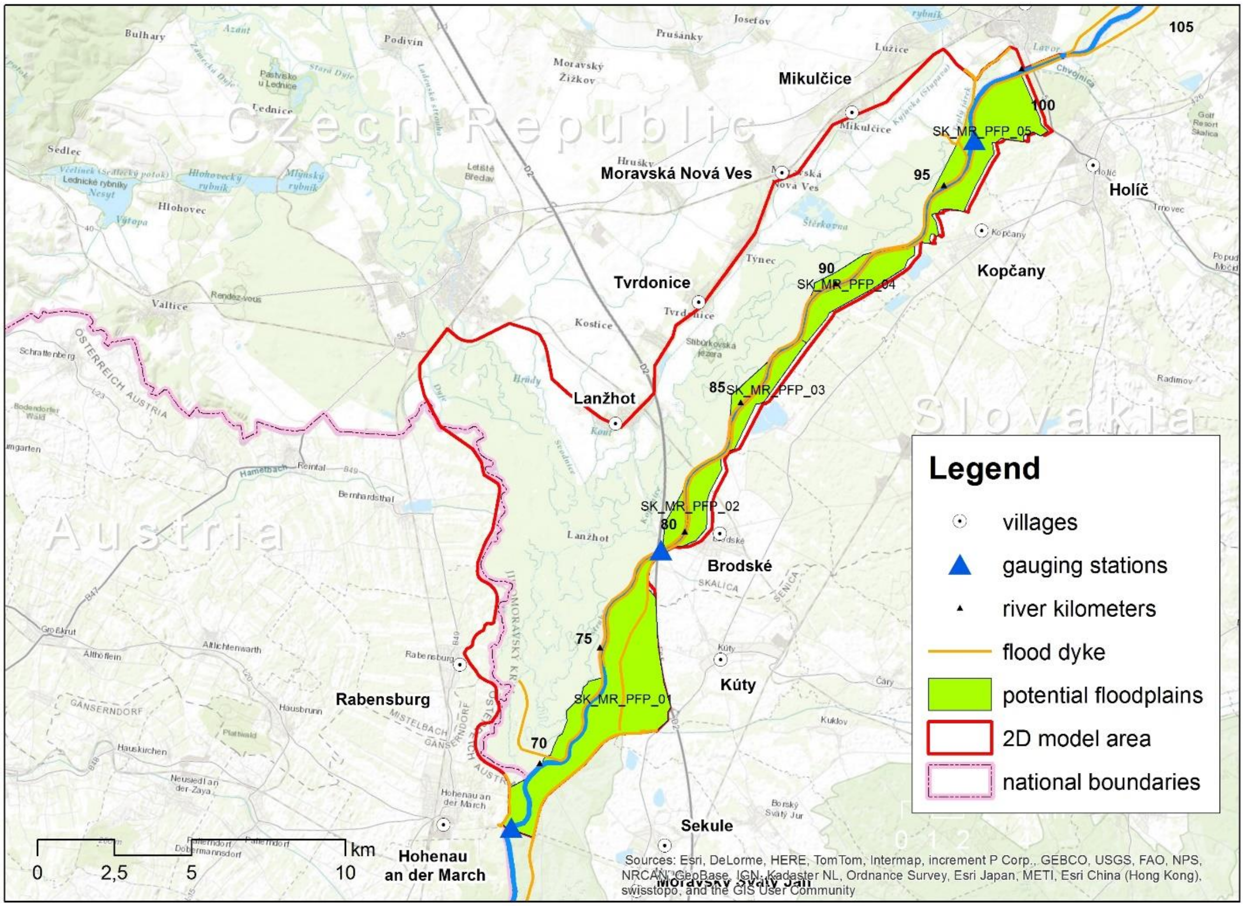


Figure 43: Extent and position of the potential floodplains identified on the Morava river (CZ, SK)

2.2.7. Sava (HR)

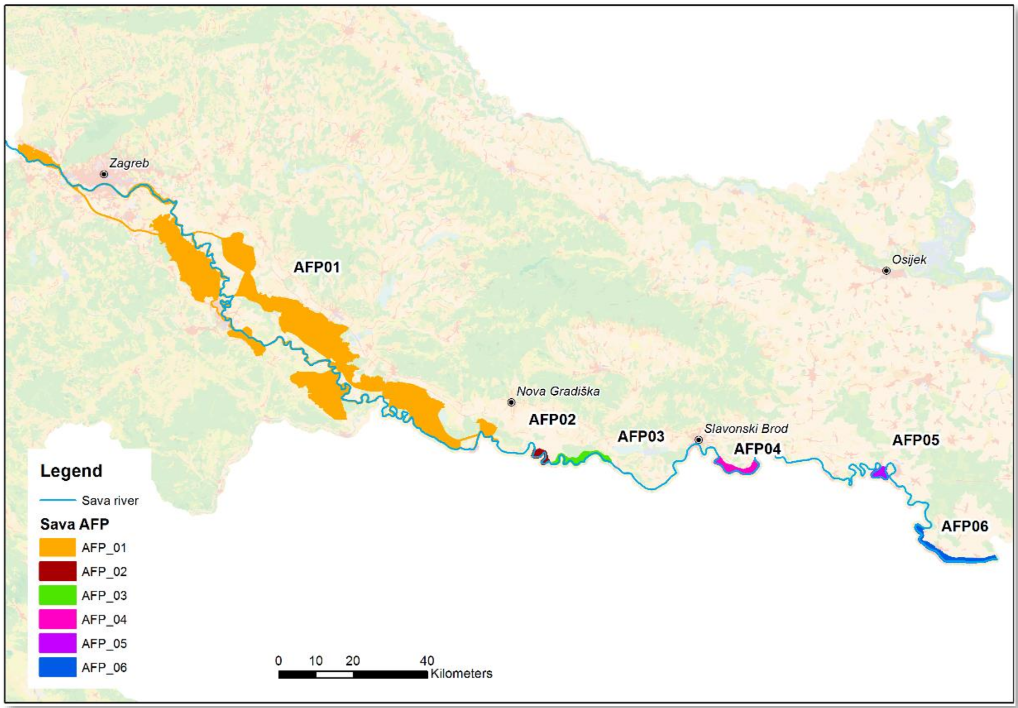


Figure 44: Extent and position of the Active floodplains identified on the Sava river (HR)

2.2.8. Sava (RS)

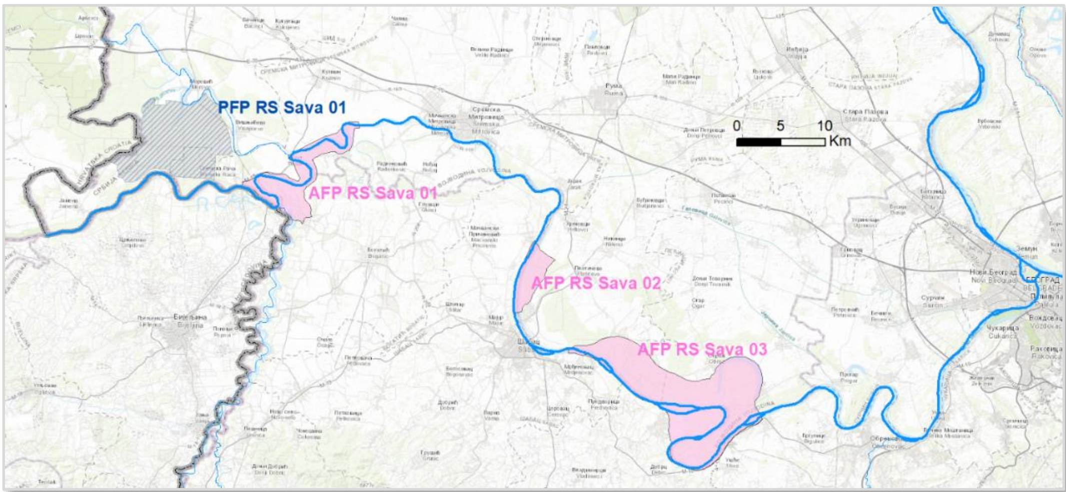


Figure 45: Extent and position of the Active floodplains identified on the Sava river (RS)

3. List of floodplains, their characteristics, restoration/preservation potential and associated measures

3.1. Methodology

The main activity objective is the evaluation of active and former floodplains along selected tributaries (or their river sections) with relevant multi-criteria decision analysis methods considering the FEM (Floodplain Evaluation Matrix) ranking method and results from Activity 3.2 and D3.3.1. The deliverable consists of:

- determining relevant parameters and indices for floodplain preservation and restoration suitability considering multiple objectives;
- determining relevant scale for each parameter to assess it;
- classification of floodplains according to each parameter by defining relevant thresholds;
- final ranking of floodplains.

The FEM priority ranking indicates where non-structural measures are most powerful with regard to hydromorphology, ecology and socio-economics and where effort should be made first.

Among the PPs working on tributaries, it was agreed that:

- For the identification of the former floodplains the historical maps should be used;
- For the identification of the active floodplains, the following conditions should be fulfilled:
  - a ratio factor of $width_{floodplain}/width_{river} > 2:1$[2];
  - a minimum floodplain size of 500 ha on larger (Tisza/Tisa, Morava, Sava), and 100 ha on smaller tributaries (Krka, Desnăţui and Yantra);
  - floodplain must be hydraulically connected and characteristic flow behaviour is given.

- For the purpose of the floodplain characteristic description, their evaluation and ranking, all of the FEM parameters from the Minimum set should be implemented:
  - Hydrology:
    - Peak reduction ΔQ
    - Flood wave translation Δt
  - Hydraulics:
    - Water level Δh
  - Ecology:
    - Connectivity of floodplain water bodies
    - Existence of protected species

[2] The Hungarian section of the Tisza the Ratio factor of Width of floodplain / Width of river > 10:1

- Socio-Economics:
  - Potentially affected buildings
  - Land use

Hydrology	Hydraulics	Ecology	Socio-Economics
peak reduction ΔQ	water level Δh	connectivity of floodplain water bodies	Potentially affected buildings
flood wave translation Δt	flow velocity Δv	Existence of protected species	Land use
effects (pos./neg.) in case of extreme discharges	bottom shear stress	Existence of protected habitats	Precence of documented planning interests
		Vegetation naturalness	
		water level dynamics	
		Potential for typical habitats	
		ecological, chemical and ground water status	

Figure 46: Floodplain Evaluation Matrix - in blue: minimum set, in green: medium set, in yellow: extended set of parameters

During A 3.2 the FEM parameters were defined and agreed among all PPs. It was agreed which parameters should be in the minimum set of parameters and are mandatory for all partners to be calculated. A medium and extended set of parameters were also prepared, out of the favoured parameters by all partners which serve as additional information in the Danube Floodplain GIS but will not be taken into account for the ranking list. The results will nevertheless be a valuable information for decision makers.
An Activity leader of A 3.2 (BOKU) responsible for methodological frame and support in implementation of FEM also coordinated the definition of the thresholds between the values of each parameter. After some modifications and harmonization mostly with an Activity leader 3.3 (DRSV), the thresholds were presented and agreed among PPs on the last expert meeting Bratislava. Here are the results (only for the parameters from the minimum set):

Thresholds ΔQrel	
1	< 1 %
3	1 - 2 %
5	> 2 %

Thresholds Δt	
1	< 1 h
3	1 - 5 h
5	> 5 h

Thresholds Δh	
1	< 10 cm
3	10 - 50 cm
5	> 50 cm

Thresholds protected species	
1	< 1
3	1 - 20
5	> 20

Connectivity of FP water bodies	
1	< 50 %
3	50 % - 80 %
5	> 80 %

Thresholds affected buildings	
1	> 5 [n/km²]
3	1 - 5 [n/km²]
5	< 1 [n/km²]

Thresholds land use	
1	< 2
3	2 - 4
5	> 4

Figure 47: Thresholds for the parameters from the minimum set

FEM-Ranking
High performance = 5
Medium performance = 3
Low performance = 1

Figure 48: Thresholds for the Ranking of parameters from the minimum set

3.2. Floodplain evaluation, classification and ranking on tributaries

Due to the fact that the methodology of the floodplains identification, delineation, evaluation, classification and ranking was agreed upon among the PPs, the process will be described with the emphasis on the Krka river, while all other details for the Krka river and for some other tributaries are in the reports attached.

As decided in our past expert meetings, the PPs should implement the FEM parameters from the minimum set. However, in a few cases the PPs also found adequate some parameters from the medium and extended set, in some cases even additional parameters were introduced – all in a view of getting as much as possible good picture of the conditions on the specific flooplains. The data gained with those parameters can be used for better informing of stakeholders and for easier decisioning of responsible institutions.

3.2.1. Krka

The Krka sub-basin has an area of 2 315 km^2 with approximately 120 000 inhabitants. From administrative point of view, 23 municipalities are located on its territory. It is a tributary of the Sava river to which the Krka river discharges just some 11 km upstream the cross section where Sava flows from Slovenia to Croatia. Beside the main watercourse of the river in the length of 94 km its tributaries and springs in the upper part of the river basin are mainly karstic, as shown on Figure 48 with absence of surface watercourses.

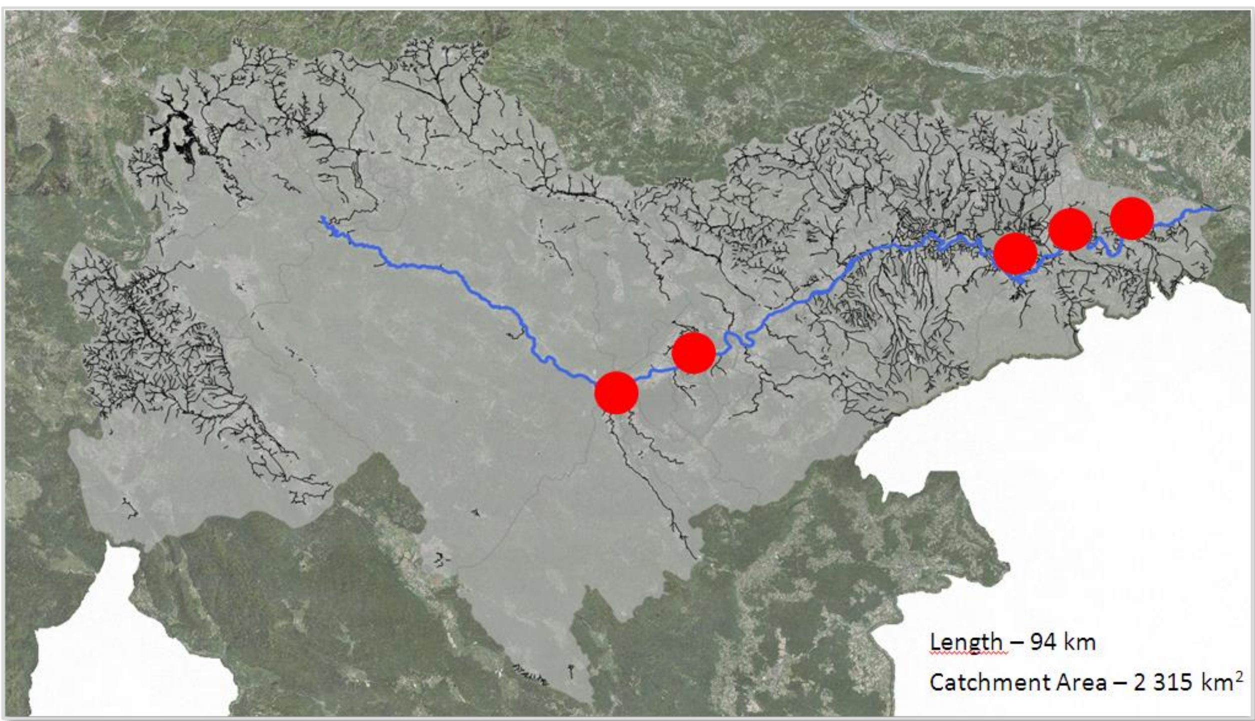


Figure 49: Overview of the Krka river basin with locations of the floodplains and indication of main watercourse and tributaries - not karstic watersheds with no surface runoff or formation of watercourses

The FEM priority ranking was implemented considering five identified floodplains on the Krka river.

a) Hydrology / Hydraulics
From this sections only the parameters from the minimum set were used:

- Peak Reduction ΔQ
- Floodwave Translation Δt
- Water Level Change Δh

For the purpose of FEM scenario analysis the hydrographs were applied in two developed hydraulic models (for two models). Δt and ΔQ were identified for the modelled floodplains. The using the FEM guidebook the shift in time and discharge downstreams was observed on different cross sections. The using of the FEM guidebook the shift in time and discharge were observed on different cross sections.

b) Ecology
From this sections the following parameters were assessed:

- Connectivity of Floodplain Water Bodies,
- Existence of Protected Species,
- Existence of Protected Habitats.

The analysed floodplains of Krka river are completely connected in the terms of longitudinal connectivity with its historical floodplains. Therefore, the analysed scenarios are not subject of 2D modelling for this specific case:

1. mean water level (from gauging stations)
2. bankfull flow (1D/2D modelling)
3. above bankfull flow

The Connectivity determination is not applicable for the Krka floodplains as there are no oxbows and branches to define at which discharge the water bodies are connected.
For determination the "natural (historic)" status of water bodies on the floodplain historic maps were checked. There were noticed no major changes since the first mapping – more than 230 years ago. The condition: "If the river system is meandering, the connectivity is naturally beginning at bankfull discharge so, if this is given, it gets the best rating (5) in the FEM and no further steps are needed." applies and all analysed floodplains are evaluated with 5 – High performance according to the FEM evaluation procedure.

Considering the floodplains with **Existence of protected species** FEM parameter, layers of Natura2000 and List of protected species data were used. Sticking to the stipulation that a floodplain is valuable and should be preserved if red list species or species and habitats (recognized by Natura2000) are found on the area, we evaluated all five AFP and PFP as valuable. According to our classification (see DRSV, 2020. A 3.3 – Floodplain assessment on selected tributaries - Results. Ljubljana) and presence of the protected species on the floodplains, all five floodplains are evaluated as 5 – High performance.

The **Existence of protected habitats** FEM parameter shows what part of the floodplain area is designated as protected area according to the Natura 2000 or other documents about protected species of habitats – the higher the share of protected areas, the more “valuable” is the floodplain. All five floodplains are partly (in two cases even mostly) in Natura2000 zone (see Figure 49).

c) Socio – Economics

From this section, the following parameters were assessed:

- Land Use,
- Potentially Affected Buildings,
- Presence of Documented Planning Interests.

For the implementation of the **Land use** FEM parameter, the land use Shape file from the 1st of January 2019 was taken into account. For the purposes of Danube Floodplain project, the original land use categories were aggregated into 14 main categories. Each category was then given a FEM grade (1, 3 or 5) depending on the degree of suitability for such type of land use to be used as a potential flood retention area. Generally speaking, built-up areas were graded as being unsuitable (grade 1), intensive agricultural land as being partly suitable (grade 3), and the rest as being very suitable (grade 5).

LANDUSE_DESCR	GRADE
Built-up Areas	1
Greenhouses	1
Fields	3
Olive Grove	3
Orchards	3
Other permanent crops	3
Tree Plantation	3
Vineyards	3
Dry Open Land	5
Forest	5
Meadows	5
Overgrown Agricultural Land	5
Swamp	5
Water	5

Figure 50: Assigned grades to land use categories

The three areas within a specific floodplain were then divided by the total area of that floodplain, yielding percentages of the floodplain marked with certain grade. Every percentage and its respective grade in turn yield subtotal grade.

	Abs. Value	Final Mark
	Weighted Avg.	
SI_KR_AFP_01	4,75	5
SI_KR_AFP_02	4,78	5
SI_KR_AFP_03	4,67	5
SI_KR_AFP_04	4,42	5
SI_KR_AFP_05	4,54	5
SI_KR_FFP_01	4,69	5
SI_KR_FFP_02	4,45	5
SI_KR_FFP_03	4,58	5
SI_KR_FFP_04	4,34	5
SI_KR_FFP_05	4,45	5

Figure 51: Land use – AFP and PFP assessment

For the purpose of flood damage evaluation, Slovenia has already a well established practice for the evaluation of annual expected flood damage which also includes the number of affected buildings population and other vulnerable categories. For the implementation of the **Potentially affected buildings** FEM parameter there are adequate data available.

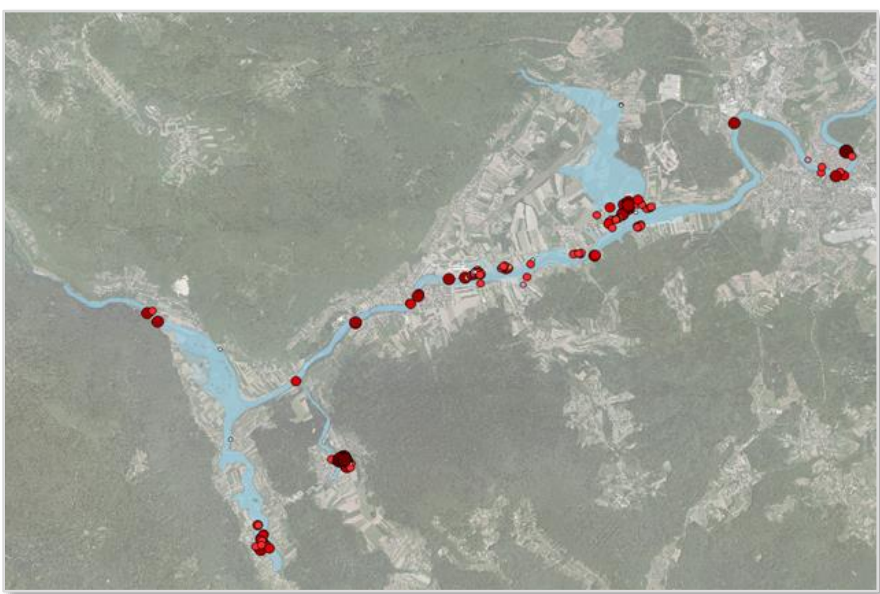


Figure 52: Potentially affected buildings on Floodplain 1- Soteska, and on Floodplain 2 – Prečna

For comparing the results of this parameter, number of the buildings by the area of the floodplain was performed. Because of the fact that the floodplain area around the Krka river is quite urbanized, only one of the active floodplains gain the highest 5 grade.

For the implementation of the **Presence of documented planning interests** a specific analysis were performed in order to identify potential conflict between the identified floodplains and the spatial planning documents applicable for each specific zone.
This analysis is providing us interesting insight regarding what the local communities are planning for the floodplains (planned land use) and potential conflict between the planned land use and existing floodplains as well as former floodplains.

For this purpose active spatial plans were collected and harmonized from the local communities and compared with the extent of active floodplains and former floodplains.

An analysis is providing disclosing the defined categories of land used applicable in the Slovenian legislation on spatial planning. They are sorted by the matching land use and potential conflict use with the potential floodplain areas. The figures for the analysed 5 former floodplains result in the span between 0,95% (PFP 4) and 6,84% (PFP 2). They should be used as potential indicator for the existing conflict on land use as also PFP 2 has notable number of houses and people recognized to be exposed to flood hazard.

			PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
			Rel. value	Abs. value	Abs. value	Rel. value %	Abs. value	Abs. Value	Rel. value
		AREA [ha]	ΔQ / Q [%]	Δt [h]	Δh [m]	d(natural) / d	n	Weighted Avg.	No. houses / km^2
KRKA	SI_KR_AFP_02	177,7	1,5	2	0,01	100	34	4,78	7,9
	SI_KR_AFP_03	1524,2	10	13	0,95	100	46	4,67	1,1
	SI_KR_AFP_04	194,5	1	4	0,40	100	29	4,42	0,0
	SI_KR_AFP_05	145,5	0	1	0,25	100	29	4,54	10,3
	SI_KR_PFP_01	121,6	< 1	2	0,50	100	30	4,69	38,5
	SI_KR_PFP_02	248	< 1	4	0,10	100	34	4,45	26,6
	SI_KR_PFP_03	2626,7	4	19	2,10	100	46	4,58	6,3
	SI_KR_PFP_04	241,3	2	14	1,20	100	29	4,34	3,3
	SI_KR_PFP_05	177,7	0	2	0,70	100	29	4,45	42,7

Figure 53: Results of FEM Floodplain Evaluation of AFP and PFP of the Krka river with the parameters values

3.2.2. Yantra

			FLOOD PEAK REDUCTION	FLOOD WAVE TRANSLATION	WATER LEVEL	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
			Rel.Value	Abs. value	Abs. value	Rel.value	Abs. value	Abs. value	Rel.value
		AREA [ha]	ΔQ/Q [%]	Δt [min]	Δh [m]	d(natural)/d	n	Weighted Avg	No build./km²
YANTRA	BG_YN_AFP_001	569.0	27.67	25	0.05	5	96.79	1.23	0.2
	BG_YN_AFP_002	141.0	0.12	14	0.57	5	29.97	3.85	2.3
	BG_YN_AFP_003	238.0	0.23	42	0.64	5	30.78	3.03	1.7
	BG_YN_AFP_004	2 129.0	7.21	525	0.11	5	263.14	4.25	1.3
	BG_YN_AFP_005	700.0	1.64	208	0.64	5	91.26	3.62	2.6
	BG_YN_AFP_006	64.0	0.21	32	1.38	5	11.97	2.28	9.4
	BG_YN_AFP_007	458.0	7.5	360	2.15	5	43.98	3.44	1.3
	BG_YN_AFP_008	112.0	0.57	70	1.51	5	12.58	2.73	0
	BG_YN_AFP_009	24.0	0.24	15	4.83	5	3.7	1.48	4.1
	BG_YN_PFP_001	3 276.0	3.1	336	0.05	4.5	225.2	4.41	0.7
	BG_YN_PFP_002	1 130.0	4.18	375	0.64	4.5	85.76	4.35	0
	BG_YN_PFP_003	794.0	2.01	247	0.01	4.5	80.1	3.79	0
	BG_YN_PFP_004	1 040.0	0.25	67	0.58	4.5	91.32	3.99	0.3
	BG_YN_PFP_005	595.0	4.01	70	2.11	4.5	68.81	3.11	0.5
	BG_YN_PFP_006	1 606.0	0.41	72	0.31	4.5	145.77	4.03	2.3
	BG_YN_PFP_007	1 375.0	2.44	174	0.95	4.5	140.33	4.16	0.7
	BG_YN_PFP_008	2 403.0	0.49	87	1.16	4.5	249.34	4.03	0.3

Figure 54: Results of FEM Floodplain Evaluation of AFP and PFP of the Yantra river with the parameters values

3.2.3. Desnăţui

			PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
			Rel. value	Abs. value	Abs. value	Rel. value %	Abs. value	Abs. Value	Rel. value
		AREA [ha]	ΔQ / Q [%]	Δt [h]	Δh [m]	d(natural) / d	n	Weighted Avg.	No. houses / km²
DESNATUI	RO_DE_AFP_01	684,9	1,77%	290	6,9	< Q 50%	57	3,0	9,350
	RO_DE_AFP_02	198,4	0,10%	50	1,4	< Q 50%	16	2,9	7,560
	RO_DE_AFP_03	605,2	0,05%	180	4,4	< Q 50%	18	3,4	0,500
	RO_DE_AFP_04	732,1	0,22%	430	7,0	< Q 50%	10	3,4	5,330
	RO_DE_PFP_01	1148,2	0,45%	180	8,0	< Q 50%	57	3,0	15,100
	RO_DE_PFP_02	676	0,13%	130	5,3	< Q 50%	18	3,4	0,400
	RO_DE_PFP_03	901,7	0,07%	410	8,3	< Q 50%	13	3,4	4,200

Figure 55: Results of FEM Floodplain Evaluation of AFP and PFP of the Desnațui river with the parameters values

3.2.4. Tisza (HU)

The calculation methodology of the parameters are similar than Krka river, the detailed information can be found at "Activity 3.3 Floodplain assessment on selected tributaries FLOODPLAIN TISZA (Hungary) REPORT" project document. The summary results are given in the following table:

				PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
				Rel. value	Abs. value	Abs. value	Rel. value %	Abs. value	Abs. Value	Rel. value
			AREA [ha]	ΔQ / Q [%]	Δt [h]	Δh [cm]	d(natural) / d	n	Weighted Avg.	No. houses / km^2
Tisza (HU)	Active FP	HU_UA_TI_AFP01	1015.5	8.2	3	-41		76	3.76	0.0
		HU_UA_TI_AFP02	1861.8	9.2	5	-60		76	3.42	0.0
		HU_TI_AFP01	8757.1	30.1	11	-71		76	3.89	1.1
		HU_UA_TI_AFP03	927.5	0.6	1	-34		40	3.46	0.4
		HU_SK_UA_TI_AFP01	4015.9	11.6	7	-41		57	3.90	2.3
		HU_TI_AFP02	578.9	0.1	1	-34		57	4.31	0.3
		HU_TI_AFP03/A	1958.9	1.7	3	-107		57	3.80	5.7
		HU_TI_AFP03/B	4368.0	5.5	11	-108				
		HU_TI_AFP04	1539.5	0.5	4	-103		40	4.56	0.3
		HU_TI_AFP05	4004.2	0.8	11	-129		118	4.32	0.9
		HU_TI_AFP06	10116.6	1.4	14	-139		108	4.98	0.2
		HU_TI_AFP07	2038.8	0.8	4	-85		108	4.98	0.0
		HU_TI_AFP08	5211.1	2.8	19	-77		54	4.56	0.1
		HU_TI_AFP09	3702.6	0.3	9	-65		53	4.36	9.6
		HU_TI_AFP10	7330.9	3.5	20	-75		53	3.87	0.8
		HU_TI_AFP11	5541.5	0.7	8	-67		100	3.88	2.2
		HU_TI_AFP12	718.4	0.4	5	-72		98	4.44	0.1
		HU_TI_AFP13	2882.1	1.2	8	-64		98	4.80	12.7
	Potential FP	HU_TI_PFP01	2089.3	11.9	2	-45		36	3.6	3.7
		HU_TI_PFP02	3944.7	5.4	3	-18		115	4.3	1.3
		HU_TI_PFP03	3107.4	3.5	3	-8		216	3.2	0.3
		HU_TI_PFP04	3618.1	6.5	12	-14		79	3.1	0.9
		HU_TI_PFP05	98.3	1.4	14	-70		53	4.2	9.0
		HU_TI_PFP06	196.2	1.2	3	-68		53	3.8	1.3
		HU_TI_PFP07	86.1	0.9	4	-78		100	3.8	0.0

Figure 56: Results of FEM Floodplain Evaluation of AFP and PFP of the Tisza river (HU) with the parameters values[3]

[3] *In case of Tisza River (Hungarian section) we have used different working method regarding the hydraulic parameters. We assumed a hypothetical loss of all floodplains along the Tisza and we used this scenario to calculate the water level change, which is a different approach as the other partners had. Modeling technically, the HU_TI_AFP03 floodplain had to be divided into two parts to determine the hydraulic / hydrological parameters.*

3.2.5. Tisa (RS)

Hydrological and hydraulic parameters were provided using HEC RAS model for the Tisa River in Serbia, created and calibrated by JCWI.

The Tisa river unsteady model is developed in HEC–RAS 5.0.7. Model includes the Tisa river from the confluence with the Danube River near Slankamen up to the border between Serbia and Hungary. The Novi Bečej dam was also integrated into the model. The upstream boundary condition of the model is unsteady flow hydrograph, while downstream boundary condition is specified in the form of a rating curve. The model of the Tisa river is incorporated in the model of the Danube river which includes the Serbian part of the Danube river with tributaries.

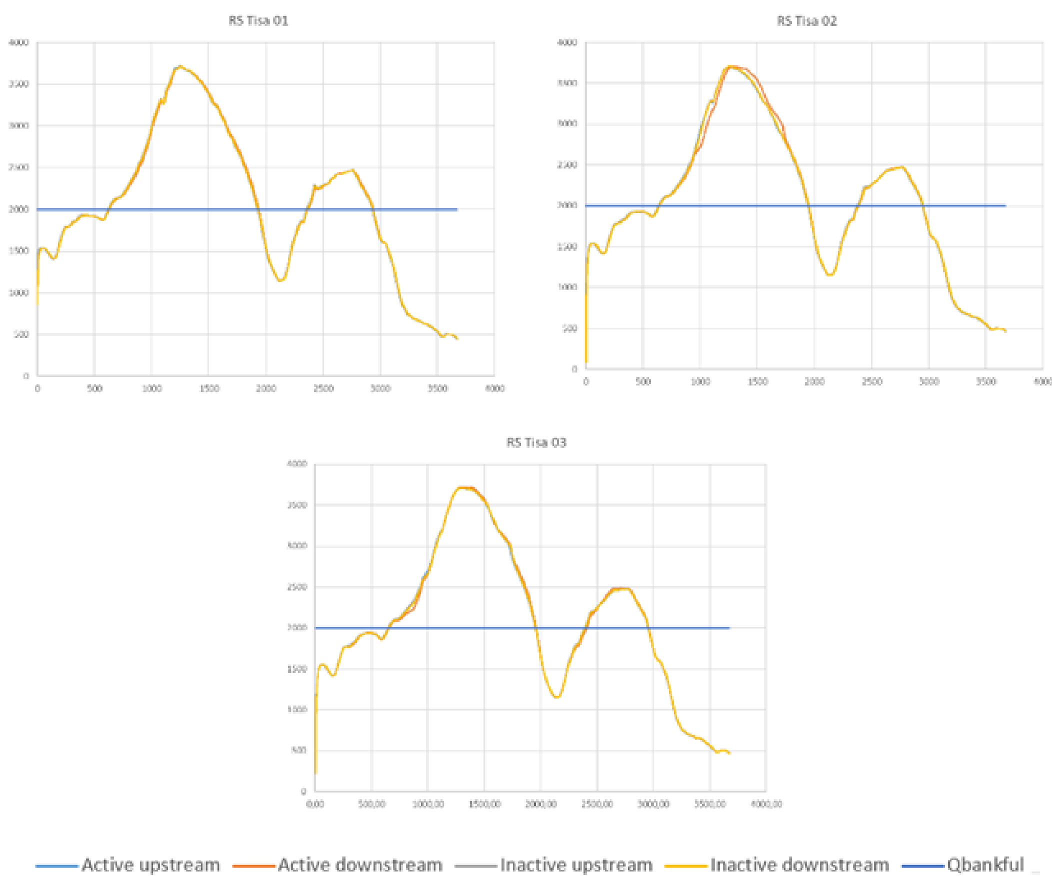


Figure 57: Hydrographs for the Tisa River FPs

A simplified method for the continuity assessment, taking into account only the lateral direction, is applied for the Tisa River, based on historical maps (3rd Military Mapping Survey of Austria-Hungary), locations of the flood defence structures (dikes) and expert judgment.

Serbia is not in the NATURA 2000 network and the respective number of protected species is not available. However, ecologically significant areas of the European Union NATURA 2000 will be identified and become part of the European ecological network NATURA 2000 on the day of accession of the Republic of Serbia to the European Union. Therefore, the information on the number of protected species is based on the national law and bylaw (Rulebook on the proclamation and protection of strictly protected and protected wild species of plants, animals and fungi, OG no. 5/2010, 47/2011, 32/2016 and 98/2016).

The number of buildings is derived from the Serbian Geoportal (https://a3.geosrbija.rs/) that provides information on buildings and other structures from the digital cadastral plan as separate parts of plots. It is important to emphasize that only information on the existence and not the legality of constructed buildings were considered.

The parameter Land use is assessed based on the Corine Land Cover (CLC)

			PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
			Rel. value	Abs. value	Abs. value	Rel. value %	Abs. value	Abs. Value	Rel. value
		AREA [ha]	ΔQ / Q [%]	Δt [h]	Δh [m]	d(natural) / d	n	Weighted Avg.	No. houses / km²
TISA (RS)	RS_TI_AFP_01	2017	0,41	3	0,26		178	4,8	1,7
	RS_TI_AFP_02	3444	0,23	24,5	0,19		120	4,0	3,6
	RS_TI_AFP_03	2692	0	22	0,13		205	4,9	1,1

Figure 58: Results of FEM Floodplain Evaluation of AFP and PFP of the Tisa river (RS) with the parameters values

Serbia is not in the NATURA 2000 network and the respective number of protected species is not available. Ecologically significant areas of the European Union NATURA 2000 will be identified and become part of the European ecological network NATURA 2000 on the day of accession of the Republic of Serbia to the European Union (Law on Nature Protection, OG nr. 36/2009, 88/2010, 91/2010, 14/2016, 95/2018). For each FP a source of information is stated. In some cases information is based on an email received from the Institute for Nature Conservation of Serbia on June 24, 2019, while in other cases an assessed (unofficial) number of protected species by relevant experts is stated. Both statements were done in accordance with the Rulebook on the proclamation and protection of strictly protected and protected wild species of plants, animals and fungi, OG no. 5/2010, 47/2011, 32/2016 and 98/2016.

3.2.6. Morava

Floodplain evaluation was done following the methodology given above. The minimum as well as some of the medium set of parameters were evaluated for hydrology, hydraulics, ecology and socio-economics. Current status and the most optimistic scenario RS2 were compared.
To evaluate the effect of potential floodplains for hydrological and hydraulic parameters from the 1D numerical modelling, the retention area Polder Soutok was neglected, meaning that water was not released to the retention area at flood discharges as inflow objects were simulated to be closed. Therefore, water level reduction parameter shows rather high values (Δh up to 2,66 m) as the theoretical current state water levels are high without water released into the polder (Figure 44). On the other hand, peak reduction of ΔQ is rather low (less than 1% in most of the potential floodplains) (Figure 44).. Flood wave translation also got a final ranking mark 1 in two of the potential floodplains (RANKING TABLE IS MISSING). It has to be noted, that new restoration measures proposed a strongly meandering river channel which influences these parameters. At HQ100 overbank flow pattern across the meandering channel appears, as the water flows through the whole floodplain, the new channel as well as the original channel. The water level in the main channel will decrease as the water will spread into the floodplains on both sides of the river which will be 10 times wider than the current floodplains. FEM parameters were calculated for each floodplain separately, while within 1D and 2D modelling the whole Morava pilot area was evaluated as a whole system, where it was proved by the output hydrographs that the peak discharge will decrease at the downstream point (Moravský Sv. Ján) (WP4 results – Deliverable D 4.1.1). As a result, flood protection will not be endangered, but the restoration measures will improve ecological status of the pilot area.

In the past, Morava at the area of interest was a strongly meandering river. Historical maps from the 2nd Military Mapping (1806-1869) were used to identify natural (historic) water bodies on the floodplain and to compare former and present connectivity of water bodies. In the most optimistic RS2 scenario, reconnection of former meanders was proposed as part of the main channel – return to the original state which was altered by straightening of the river channel. Present channel is planned to be filled up in some parts, and in some parts it will play a role of a cut-off water body filled at Q >100 m^3/s.
Therefore, connectivity parameters were calculated for 2 hydrological scenarios: below and above 100 m^3/s. The whole Morava pilot area was cut-off from the former floodplains by flood protection dykes. As there is only one active floodplain at present status, only this one has been evaluated according to the methodology, having 57% of water body length in natural state (Figure 57). The potential floodplains with a proposed meandering channel are expected to have connectivity Ranking mark 5 (more than 80% of the water body length in natural state).

			PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
			Rel. value	Abs. value	Abs. value	Rel. value %	Abs. value	Abs. Value	Rel. value
		AREA [ha]	ΔQ / Q [%]	Δt [h]	Δh [m]	d(natural) / d	n	Weighted Avg.	No. houses / km²
MORAVA	SK_MR_AFP_01	860,94	-0,42	-6	-1,79	57	187	4,69	0
	SK_MR_PFP_01	1483,8	-0,94	-9	-2,32	100	187	4,24	0
	SK_MR_PFP_02	289,94	> -1	-2	-2,66	81	59	4,25	0
	SK_MR_PFP_03	270,41	> -1	-1	-2,37	84	66	3,71	0
	SK_MR_PFP_04	411,88	> -1	-1	-2,34	83	62	3,82	0
	SK_MR_PFP_05	744,74	-3,52	-17	-1,92	84	62	4,59	0

Figure 59: Results of FEM Floodplain Evaluation of AFP and PFP of the Morava river with the parameters values

For the Socio-economic parameters, land use and potentially affected buildings were evaluated. For evaluation of Landuse FEM parameter, Corine land cover data set was used. In current AFP, broad-leaved forest is the most extensive land cover. Within PFPs, broad-leaved forest and arable land are mostly represented land cover category. PFPs 03 and 04 with higher percentage of arable land were ranked 3, and all other PFPs with higher percentage of forests were ranked 5.
As there are no villages within the pilot area, FEM parameter Potentially affected buildings was set to 5.

3.2.7. Sava (HR)

			PEAK REDUCTIO N ΔQ	FLOOD WAVE TRANSLATIO N Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
			Rel. value	Abs. value	Abs. value	Rel. value %	Abs. value	Abs. Value	Rel. value
		AREA [ha]	ΔQ / Q [%]	Δt [h]	Δh [m]	d(natural) / d	n	Weighted Avg.	No. houses / km²
SAVA (HR)	CRO_SA_AFP_01	89850	45,26	19,5	2,62		162	4,47	3,57
	CRO_SA_AFP_02	683,7	0,61	4	1,53		85	4,16	0,29
	CRO_SA_AFP_03	1545	0,51	2	0,16		85	4,83	0,45
	CRO_SA_AFP_04	1691,1	1,29	4	0,1		78	3,96	0,71
	CRO_SA_AFP_05	894	8,24	22	1		82	3,96	2,24
	CRO_SA_AFP_06	2193,7	23,35	0	0,51		82	4,81	0,36

Figure 60: Results of FEM Floodplain Evaluation of AFP and PFP of the Sava river (HR) with the parameters values

3.2.8. Sava (RS)

Hydrological and hydraulic parameters were provided using HEC RAS model for the Sava River obtained from the Sava Commission. The model includes the Sava River from the border between Slovenia and Croatia up to Belgrade, and the major tributaries up to the Sava River backwaters and more. The Sava HEC-RAS is coupled with the Sava HEC-HMS model which output locations match the (lateral) inflow points of the HEC-RAS model. Model is incorporated into the Sava Flood Forecasting and Warning System.

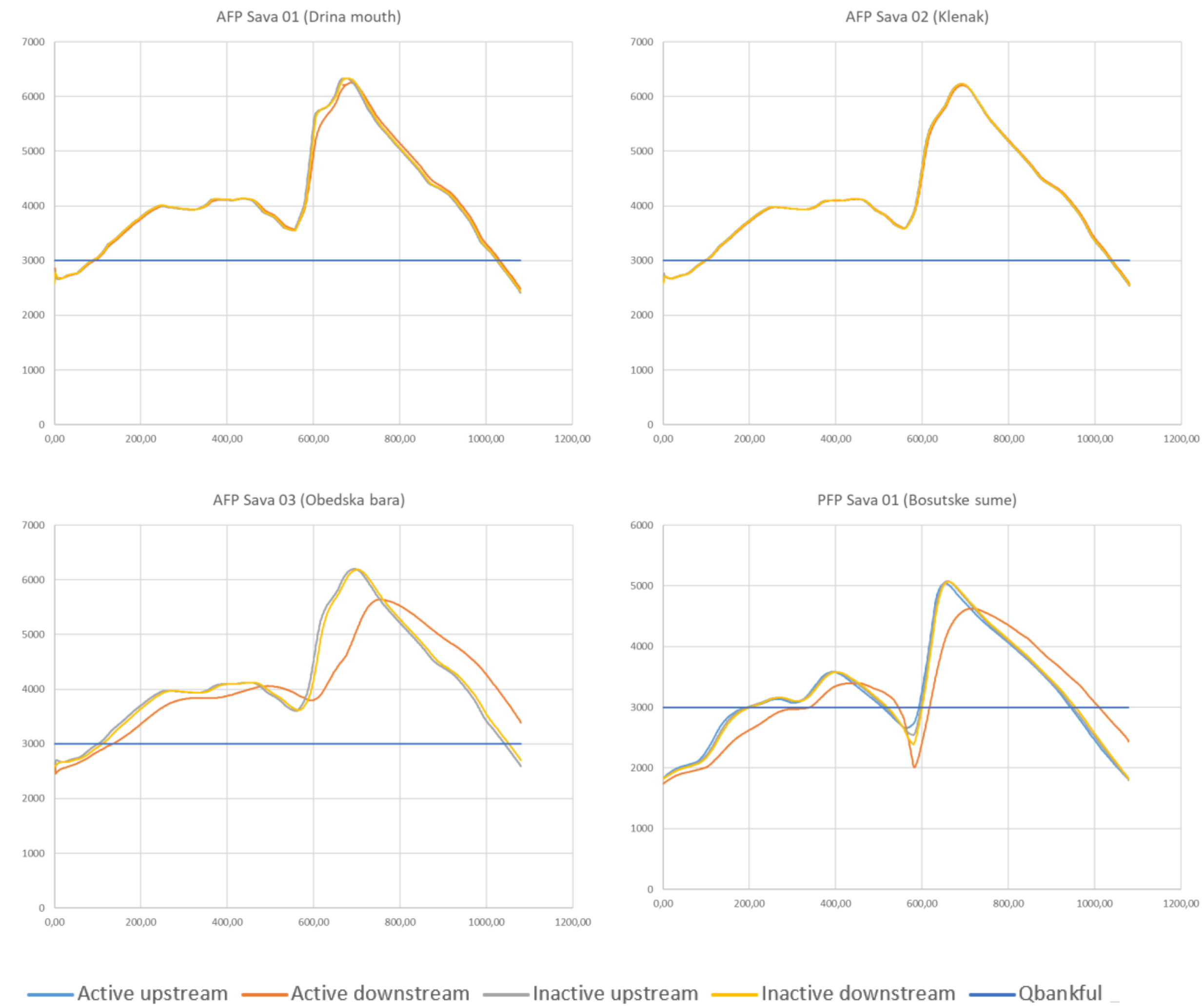


Figure 61: Hydrographs for the Sava River FPs

A simplified method for the continuity assessment, taking into account only the lateral direction, is applied for the Sava River, based on historical maps (3rd Military Mapping Survey of Austria-Hungary), locations of the flood defence structures (dikes) and expert judgment.

Serbia is not in the NATURA 2000 network and the respective number of protected species is not available. However, ecologically significant areas of the European Union NATURA 2000 will be identified and become part of the European ecological network NATURA 2000 on the day of accession of the Republic of Serbia to the European Union. Therefore, the information on the number of protected species is based on the national law and bylaw (Rulebook on the proclamation and protection of strictly protected and protected wild species of plants, animals and fungi, OG no. 5/2010, 47/2011, 32/2016 and 98/2016).

The number of buildings is derived from the Serbian Geoportal (https://a3.geosrbija.rs/) that provides information on buildings and other structures from the digital cadastral plan as separate parts of plots. It is important to emphasize that only information on the existence and not the legality of constructed buildings were considered.

The parameter Land use is assessed based on the Corine Land Cover (CLC).

			PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	POTENTIALLY AFFECTED BUILDINGS
			Rel. value	Abs. value	Abs. value	Rel. value %	Abs. value	Abs. Value	Rel. value
		AREA [ha]	ΔQ / Q [%]	Δt [h]	Δh [m]	d(natural) / d	n	Weighted Avg.	No. houses / km^2
SAVA (RS)	RS_SA_AFP_01	4387	2,3	6	0,57		120	4,4	0,0
	RS_SA_AFP_02	1728	0,7	2	0,16		105	4,9	3,0
	RS_SA_AFP_03	13887	17,1	54	1,58		136	4,8	0,5
	RS_SA_PFP_01	8526	19,7	59	0,95		225	5,0	0,0

Figure 62: Results of FEM Floodplain Evaluation of AFP and PFP of the Sava river (RS) with the parameters values

3.3. Final Ranking

The final ranking of the floodplains is based on the methodology proposed by the A 3.2 coordinator who presented their similar approach on the Danube river on the last two expert meetings in March in Banska Stiavnica and Bratislava. The methodology was commonly accepted by all PPs.

For fulfilling of the requirements of the overall ranking of **Active floodplains**, a method of a 2-step approach is used:

- **Step 1:** Identifying the need for preservation

  → If at least one parameter of the minimum set is evaluated with a 5 (high performance), than the floodplain **has to be preserved**.

  The analyses showed that every single AFP on each of 6 tributaries considered with FEM evaluation and applied thresholds, has at least one parameter evaluated with 5, therefore all of 49 floodplains have a need for preservation.

- **Step 2:** Identifying the restoration priority of the Active floodplains

  → divided into 3 groups of:

  - **Lower demand → AFPs in this group have the lowest priority for restoration measures**
  - **Medium demand → AFPs in this group have a medium priority for restoration measures**
  - **Higher demand → AFPs in this group have the highest priority for restoration measures**

For each tributary a priority list with potential preservation degree was made. The FEM final values from the FEM Floodplain evaluation of the Active floodplains were categorized according to these criteria:

Lower demand:

- 4 parameters (P) evaluated with 5 (blue), 1 P with 3 (green), 2 P with 1 (yellow); or
- 3 P evaluated with 5, 3 P with 3, 1 P with 1

Medium demand:

- 2 P evaluated with 5, 3 P with 3, 2 P with 1; or
- 3 P evaluated with 5, 1 P with 3, 3 P with 1

Higher demand:

- Every FP, where the sum of the values is < 21 (if all 7 parameters are evaluated).

According to the results, in some cases floodplain could be ranked into each of adjacent categories. Than the floodplain was ranked into the class with higher demand for restoration to avoid disregarding of the possible adverse circumstances on the specific floodplain. The following find the results of the FEM Floodplain evaluation and ranking.

3.3.1. Krka

TRIBUTARY	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	RESTORATION PRIORITY
KRKA	SI_KR_AFP_03	1524,2	5	5	5	5	5	5	3	LOW
	SI_KR_AFP_04	194,5	3	3	3	5	5	5	5	LOW
	SI_KR_AFP_01	113,8	1	3	1	5	5	5	1	MEDIUM
	SI_KR_AFP_02	177,7	3	3	1	5	5	5	1	MEDIUM
	SI_KR_AFP_05	145,5	1	3	3	5	5	5	1	MEDIUM

Figure 63: Results of FEM Floodplain Evaluation and ranking of AFP on the Krka river with the final FEM values

3.3.2. Yantra

TRIBUTARY	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	RESTORATION PRIORITY
YANTRA	BG_YN_AFP_001	568,0	5	1	1	5	3	5	5	LOW
	BG_YN_AFP_004	2.129,0	5	5	1	5	5	1	3	LOW
	BG_YN_AFP_007	458,0	5	5	5	5	3	3	3	LOW
	BG_YN_AFP_005	700,0	3	5	5	5	3	3	3	LOW
	BG_YN_AFP_008	112,0	1	3	5	5	1	3	5	MEDIUM
	BG_YN_AFP_009	24,0	1	1	5	5	1	5	3	MEDIUM
	BG_YN_AFP_002	141,0	1	1	5	5	1	3	3	HIGH
	BG_YN_AFP_003	238,0	1	1	5	5	1	3	3	HIGH
	BG_YN_AFP_006	64,0	1	1	5	5	1	5	1	HIGH

Figure 64: Results of FEM Floodplain Evaluation and ranking of AFP on the Yantra river with the final FEM values

3.3.3. Desnăţui

TRIBUTARY	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	RESTORATION PRIORITY
DESNATUI (RO)	RO_DE_AFP_01	684,9	3	3	5	3	3	3	1	HIGH
	RO_DE_AFP_02	198,4	1	1	5	3	1	3	1	HIGH
	RO_DE_AFP_03	605,2	1	3	5	3	1	3	5	HIGH
	RO_DE_AFP_04	732,1	1	5	5	3	1	3	1	HIGH

Figure 65: Results of FEM Floodplain Evaluation and ranking of AFP on the Desnațui river with the final FEM values

3.3.4. Tisza (HU)

	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	Restoration priority
Tisza (HU)	HU_UA_TI_AFP01	1015.5	5	3	3	1	5	3	5	Medium
	HU_UA_TI_AFP02	1861.8	5	3	5	1	5	3	5	Low
	HU_TI_AFP01	8757.1	5	5	5	3	5	3	3	Low
	HU_UA_TI_AFP03	927.5	1	1	3	1	3	3	5	High
	HU_SK_UA_TI_AFP01	4015.9	5	5	3	3	5	3	3	Low
	HU_TI_AFP02	578.9	1	1	3	3	5	5	5	Medium
	HU_TI_AFP03/A	1958.9	3	3	5	1	5	3	3	Medium
	HU_TI_AFP03/B	4368.0	5	5	5					
	HU_TI_AFP04	1539.5	1	3	5	1	3	5	5	Medium
	HU_TI_AFP05	4004.2	1	5	5	1	5	5	5	Low
	HU_TI_AFP06	10116.6	3	5	5	5	5	5	5	Low
	HU_TI_AFP07	2038.8	1	3	5	5	5	5	5	Low
	HU_TI_AFP08	5211.1	5	5	5	3	5	5	5	Low
	HU_TI_AFP09	3702.6	1	5	5	1	5	5	1	Medium
	HU_TI_AFP10	7330.9	5	5	5	1	5	3	5	Low
	HU_TI_AFP11	5541.5	1	5	5	5	5	3	3	Low
	HU_TI_AFP12	718.4	1	3	5	3	5	5	5	Low
	HU_TI_AFP13	2882.1	3	5	5	3	5	5	1	Low

Figure 66: Results of FEM Floodplain Evaluation and ranking of AFP on the Tisza river (HU) with the final FEM values

3.3.5. Tisa (RS)

TRIBUTARY	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	RESTORATION PRIORITY
TISA (RS)	RS_TI_AFP_01	2017	1	3	3	1	5	5	3	MEDIUM
	RS_TI_AFP_02	3444	1	5	3	1	5	5	3	MEDIUM
	RS_TI_AFP_03	2692	1	5	3	1	5	5	3	MEDIUM

Figure 67: Results of FEM Floodplain Evaluation and ranking of AFP on the Tisa river (RS) with the final FEM values

3.3.6. Morava

TRIBUTARY	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	RESTORATION PRIORITY
MORAVA	SK_MR_AFP_01	860,941	1	3	5	3	5	5	5	LOW

Figure 68: Results of FEM Floodplain Evaluation and ranking of AFP on the Morava river with the final FEM values

3.3.7. Sava (HR)

TRIBUTARY	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	RESTORATION PRIORITY
SAVA (HR)	CRO_SA_AFP_01	89850	5	5	5	3	5	5	3	LOW
	CRO_SA_AFP_02	683,7	1	3	5	1	5	5	5	LOW
	CRO_SA_AFP_05	894	5	5	5	1	5	3	3	LOW
	CRO_SA_AFP_06	2193,7	5	1	5	1	5	5	5	LOW
	CRO_SA_AFP_03	1545	1	3	3	1	5	5	5	MEDIUM
	CRO_SA_AFP_04	1691,1	3	3	1	1	5	3	5	MEDIUM

Figure 69: Results of FEM Floodplain Evaluation and ranking of AFP on the Sava (HR) river with the final FEM values

3.3.8. Sava (RS)

TRIBUTARY	FP	AREA [ha]	PEAK REDUCTION ΔQ	FLOOD WAVE TRANSLATION Δt	WATER LEVEL Δh	CONNECTIVITY OF FP WATER BODIES	EXISTENCE OF PROTECTED SPECIES	LAND USE	AFFECTED BUILDINGS	RESTORATION PRIORITY
SAVA (RS)	RS_SA_AFP_01	4387	5	5	5	1	5	5	5	LOW
	RS_SA_AFP_03	13887	5	5	5	5	5	5	5	LOW
	RS_SA_AFP_02	1728	1	3	3	3	5	5	3	MEDIUM

Figure 70: Results of FEM Floodplain Evaluation and ranking of AFP on the Sava river (RS) with the final FEM values

3.4. Analysis of the results

- 14 Active floodplains are ranked into Medium (Restoration priority), and 8 into High (Restoration priority) category. These would have to be the first to be restored.
- Among 49 Active floodplains observed 27 are ranked into Low (Restoration priority) category.

- On 3 of 6 tributaries the AFP with High (Restoration priority) category can be found.
  - Tisza river (HU) has most of the identified AFP (18), one of them is in High (Restoration priority) category.
  - On Yantra river there are 3 (of 9) in this less promising category.
  - But, on Desnațui all 4 AFP are categorized with High Restoration priority.

- 8 AFP (16 % of all) on Tisza, Yantra and Desnațui are evaluated and ranked into High (Restoration priority) category, there some measures (in dependence of the national capacities) for the status improvement should be considered, especially on Desnațui river, where all four AFP are in this less favourable category. However, on the tributaries with the AFP ranked into Medium (Restoration priority) category, some effort and caution should be put into further management and monitoring of the conditions.

4. Recommendations for floodplain assessment on tributaries including the description of implemented methods and classification criteria

Partners on the tributaries assessed the floodplains due to the commonly agreed methodology based on the previous experiences on the national level, and due to the previous experiences of the partners from the Danube river basin. Several meetings and web conferences were needed to achieve a common agreement among the project partners about the data which should be considered, methodology, and overall approach. The differences between the partners stem from the fact that the tributaries, local and national circumstances and water management can quite differ from one participating country to another.

- As it was proven on the partners level, an efficient and sufficient communication between project partners on one side, and stakeholders from the area of the considered floodplains on the other side, proved to be essential for the positive outcome of the project. Through the preparation phase of the project, that is the way to gain as much as possible opinions, remarks, and suggestions about the circumstances, open issues and obstacles on the local level, which can otherwise postpone or even prevent the implementation of the project and its measures for flood risk reduction, prevention of the habitats, and water protection.

- According to this preparation phase, the project can be properly prepared and implemented. Stakeholders should be constantly informed with the interim outcomes during whole process of the project to avoid misunderstandings and obstruction of the implementation.

- Even though the FEM method is quite new, it can be applicable and useful with relatively small effort to a wide spectre of users. So the initial, or several presentations of the method to the users and decision makers is not a waste of time. Even more – now, when we gain the results of this project, they can be used as an example of a good practice in water management and flood risk reduction.

- The approach of DFP can be applicable under various conditions and can satisfy wide spectrum of interests, needs and requirements, so don't hesitate to introduce it to the possible users, stakeholders and decision makers. However, catchment, country or region specific conditions are to be taken into account when defining parameter thresholds and criteria for ranking.

3.5.1 Krka (Floodplain Krakovski gozd – Kostanjevica na Krki)

Restoration measures in the Krakovo Forest (Krakovski gozd) must aim at facilitating the water flow from the Krka river bed itself into the floodplain, which basically means opening up certain meanders. There are three slight but perceivable depressions within the forest, which means that the measures for floodplain activation should also enable the floodwater to flow freely among them. Moreover, as the restoration measures also aim at improving the water levels during low flow periods within the forest itself, the measures must be designed in a way to prevent the forest from draining.

- Extending the floodplain;
- Reducing the extent of drainage systems;
- Opening up of certain meanders to facilitate water flow into the floodplain.

3.5.2 Desnatui (Floodplain Bistret on the Danube junction area)

- Construction of a recreational and fishfarming lake (200 ha) in the area of Rast.
- Relocation of the dikes in the confluent area of Desnaţui River with Bistret Lake.
- Creation of a large water drainage channel to supply Lake Bistret and to facilitate the natural flow of Desnaţui River back in the Danube.
- Additional dike reloca-tion from the Danube close to the villages along the alluvial terraces.

3.5.3 Tisza (HU)

Field of action	Measure Category	Type of measure
Prevention	Organizational measures (legislative, institutional ...)	The definition of a legislative, organizational and technical framework for Floods Directive implementation
		Reviewing and updating plans for flood risk management
		Coordination of territorial planning strategies (plans for development of planning at national, county and regional) and urban plans (Regional/Urban/Zonal/Plans) with plans for flood risk management
Protection	Natural water retention measures - associated to watercourses, wetlands,	Measures to restore retention areas (creating wetlands, floodplain reconnection, renaturation etc.)

	natural lakes, in accordance with Directive 2000/60 /EC	
	Change or adapt land use practices (partial recovery of ecosystem functions or structures modified by changing or adapting land use practices) for forest management	Natural water retention measures by changing or adapting land use practices in forest management
	Other water retention measures	Other measures to reduce water levels; Structural and Non-Structural protection measures in connection with EU Flood Directive Risk management plan *
		Measures to improve retention capacity at the level of river basin by construction of polders and small retention reservoirs (made in the upper part of the river basin)
		Structural protection measures (planning and accomplishing)
Protection	Inspection measures and maintenance of watercourses and of the hydraulic flood defense infrastructure	Surveillance, behaviour monitoring, expertise, strengthening interventions, rehabilitation and maintenance of watercourses and hydraulic flood defence infrastructure
	Adapting of the existing defense structures at climate change conditions	Adapting of the construction, infrastructure and existing defence structures in terms of climate change

*(e.g. : Building a new dikes, relocation of the dikes, landuse change on the floodplain; changing vegetation, riverbed stabilizations, *removal of summer dams and small dike, established lateral retention basins etc.)*

3.5.4 Morava

- Removal of weirs.
- Removal or adjustment of selected barriers (weirs, sills).
- Removal of levees.
- Relocation of flood dykes (to include the cut off side-arms in the floodplain area).
- Relocation of flood dykes.
- Renewal of river pattern.
- Reconnection of oxbows with the main Morava channel.
- Deepening of existing oxbows.

3.5.5 Yantra

- Preservation of the existing natural floodplain vegetation and forests
- Creation of vegetation buffer strips
- Restoration of the riparian vegetation, afforestation
- Connection/reconnection of side arms, meanders, branches, channels or backwaters
- Removal of sediments / lowering of the floodplain
- Adoption of legislative regulations for floodplain management
- Land use change - replacement arable land with pastures
- Dike relocation
- Connection/reconnection of side arms, meanders, branches, channels or backwaters
- Construction of facilities for controlled flooding of selected areas
- Construction of new dikes – for protection of roads and infrastructure, adjacent to the floodplain

3.5.6 Sava and Tisa (RS)

Based on country-specific conditions and results of the Sava and Tisa floodplains ranking, a list of measures is presented below:

The list of measures for either active or potential floodplains in Serbia is presented below:

Regulatory, institutional and other measures

- By-law on restrictions and conditions for the use of floodplains
- Increasing the efficiency of the inspection service.
  - Landscaping and construction restrictions in floodplains
- Introducing the boundaries of real and potential flood hazard areas in spatial plans when defining the rules of construction of facilities and use of flood areas
- Demarcation and introducing water estate boundaries in spatial plans
- Removal of illegally constructed facilities in floodplains
  - Maintenance of hydraulic structures and watercourses
- Monitoring and control of the state of inundation.

5. Conclusions

Although quite new, the methodology for the floodplains identification and evaluation has been proven on several occasions and projects in Danube river basin. Its most powerful characteristic – a wide applicability - is based on the fact that a wide range of scientists and engineers from different fields contributed their knowledge and experiences. The circumstances require a newer, wider approach to water and flood risk management, which would cover not only the fields of flood risk reduction, but also ecology, and socio-economics. Good transnational communication and coordination should be substantiated to avoid partial approaches to the flood risk management.

Local communities possess a huge knowledge about the environment that they live in, so they should be included in the process of water management from the beginning. Beside all of information from the field, the historical data (e.g. historical maps, documents, etc.) should be considered to identify potential floodplains – all that to get a better picture of their position and extent. Namely, nowadays 2/3 of all floodplains in the Danube river basement are urbanized, and it has become harder to see where the floodplains used to be in the past.

For verification of the first findings from the field observation and of the historical sources, the implementation of additional tools and data is needed to prepare adequate working environment for the following studies of former and active floodplains. A whole range of techniques and data sources are available nowadays (GIS, Lidar, DTM, Ortho-photo imagery, hydraulics and hydrology data, modelling tools, etc.) for the river water courses and floodplains analysis. At this point, support from the stakeholders is essential. The organization of meetings for the experts and public is very desirable to assure a wide support to this kind of water management and ecological projects.

Gained information are sorted to the specific groups of parameters of the Floodplain evaluation matrix (FEM), an efficient tool for the evaluation of the Active and Potential floodplains. There are four groups of parameters – Hydrology, Hydraulic, Ecology and Socio-Economics. A wide range of parameters are divided into three sets, Minimum, Medium, and Extended set. For the basic evaluation of the floodplains at least the implementation of the Minimum set is needed. All other parameters can be a good support for better understanding of situation on the floodplains, and easier decision making.

The procedure of Final ranking of the floodplains follows the primary evaluation. With the final ranking the insight in to the overall conditions of the floodplains on particular water course is given. The information about the need of preservation and urgency of restoration is given. According to this information the decision makers (on the local and governmental level) can get a solid and adequate basis for their further steps in direction of efficient water management with emphasis on flood risk lowering, and with respect to ecology and socio-economic process.

This document serves as a support for the next steps towards realizing floodplain projects both on Danube basin wide level, and also on national level in order to implement successful integrative floodplain restoration and management in the Danube basin countries after the Danube Floodplain project.

Recommendations for evaluation of tributary floodplains are based on knowledge exchange among the project partners, and will be incorporated into outputs of WP5.

6. Sources

- BOKU (2020): Deliverable D3.2.2 - Report on data included within database
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