REPORT ON THE Pilot areas pre-feasibility or feasibility studies (output 4.1) as a preparation of the next national approval processes, FRMP and DRBMP, including all results from WP4 activities, and recommendations for the realization.

WP	WP4: Flood prevention pilots
Activity	4.4 Activity

Deliverable	4.4.1 Pilot areas pre-feasibility or feasibility studies (output 4.1) as a preparation of tl next national approval processes, FRMP and DRBMP, including all results from WI activities, and recommendations for the realization.
Activity leader	TUM
Involved partners	DRSV, JCI, KOTIVIZIG, MRBA, NARW, NIHWM, TUM, WWF HU, WWF Romania

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1. Executive summary

Five pilot areas were selected to test a new methodology for implementing floodplain restorations on the Danube and selected tributaries. All five areas designed their feasibility studies according to the scenarios applied in the Danube Floodplain project. Additionally on the pilot area Middle Tisza, Hungary, those landuse activities were analysed which are adapted to the regular water prescence, have economic relevance and are acceptable for water management and ecological aspects as well. For supporting of ecological aspects potential vegetation of the new, regularly inundated conditions were evaluated as well. This helped to see not only those biological communities which can be the most sustainable under new conditions, but also becomes visible what effect the planned interventions have on the water balance of the area.

Setting up proper scenarios is quite important, the alternatives should be clearly separatable solutions (boundary conditions are different) or the alternatives need to be produced from an iterative process.

In the case of the project scenarios the setting of the scenarios were based mainly on time and budget factor: three scenarios were analysed, from which the first one was the “zero” scenario, one was a “basic” scenario with minimum possible interventions to achieve a positive effect. The third one was more an “idealistic” scenario – what would be achievable if time and budget would not be a factor.

Selection of proper interventions is also a crucial factor, this was supported in the project the regulative ecosystem services-based indicator which already indicates if a planned intervention-combination improves water balance of the area or not. This could be a first filter in designing of such scenarios.

It can be concluded that selected methods and indicators are suitable to evaluate and test the floodplain restoration scenarios.

In cases where the scenarios brought no or small effect on flood mitigation, other possibilities should be evaluated like restoration of more floodplain areas or including bigger floodplain areas if possible.

But feasibility study as a frame for such complex process serves as a proper tool to see a holistic approach and objective methodologies.

To compile feasibility studies before starting a restoration project are obligatory in some Danube countries. The obligation might be a requirement of the funding source, or might be a legal expectation. The content of the feasibility studies based on these obligations not necessarily meet the feasibility study’s content developed in the Danube Floodplain project. This might raise some difficulties for the project partners.

The compilation of feasibility studies with a full and detailed content might be costly and if financial resources are not provided, then the project partners will probably skip this exercise or will only develop the chapters which are the most necessary ones.

If there are no incentives to compile feasibility studies then the project partners will not share this exercise among each other, but probably subcontract it. This would cause vague and not proper quality feasibility studies.

If the cost-benefit analysis doesn't influence the decision making process among the scenarios then it undermines the needs for developing a detailed and thorough feasibility study.

For all five pilot areas, feasibility studies were implemented according to the scenarios applied in the Danube Floodplain Project. On the Middle Tisza pilot area, additional analyses were conducted on land use activities, which are adapted to the regular water presence, have economic relevance, and are acceptable for water management. To support ecological aspects, potential vegetation of new regularly inundated conditions was evaluated. This helped see not only what biological communities are most sustainable under new conditions, but also made visible what effect the planned interventions have on the water balance of the area. A practical and transparent tool to compare the scenarios is to compile a table with various benefits and to give scores for each scenario, so that the scores can be summed.

In case of Begecka Jama pilot area, the improvement of the ecosystem services is the main benefit. The realistic scenario is more profitable, also reflecting the stakeholders' preferences and the compatibility with the measures of the Begecka Jama Nature Park Protection Study. For this scenario, institutional analyses were elaborated and a potential way to proceed forward was suggested, i.e. the realization of the restoration through the protected area manager's annual program of works, also based upon the Law on planning and construction.

In case of the Bistret pilot area, the scenario that meets the maximum score as a result of analyzing the impact of the project from a technical, socio-economic, environmental/sustainability and remaining risks, is an "A" scenario which creates the premises for the sustainable development of the area and ecological tourism.

In case of the Kostanjevica na Krki pilot area, measures in the riverbed and for the activation of floodplains do not bring significant improvements to the hydraulic/hydrological parameters. Thus, appropriateness of selected measures might be revised. Still, the increase of the inflow to floodplains in very frequent floods (HQ2-HQ5) is useful for other aspects (e.g. improved ecological circumstances). The economic net asset value is only positive in the optimistic scenario, which considers, among others, also protective measures within Kostanjevica itself (where the greatest effects occur, especially in terms flood risk reduction).

In case of the Middle Tisza pilot area, flood protection purposes of restoration were partly met: conveyance capacity and floodplain area were increased and show a significant effect in flood volume storage. However, a decrease of the flood hazard with the two restoration scenarios can only be considered as a local effect. It can be concluded that the more floodplains are restored on catchment level, the higher impact can be achieved in gaining all possible advantages. Also, improvement of ecological conditions and ecosystem services as from the restorations were proven. For the measures' realization, the realistic scenario was chosen, since it already has integrative benefits, which can be further developed with optimistic scenario in the future.

On Morava pilot area within the realistic scenario, all in all 7 dyke relocations are planned increasing the number of connected oxbows and thus backwater area. While most of dyke relocations seem to have the expected effect of oxbow re-connection, there are also oxbows where the connectivity is not fully restored by dyke relocation alone. Here, further measures like a deepening of the oxbow might be necessary. The effect of dyke relocation on the increase of connected floodplain area and on the development of further backwaters like e.g. ponds is still unclear due to the complex terrain. Here, further calibration and validation work is required to give reliable results.

In the optimistic restoration scenario, changes in the channel planform are intended. This is a particularity compared to all other restoration scenarios where the focus has entirely been on the modification of lateral connectivity by means of dyke relocation or establishment of connection didges. It is intended to re-establish meanders in the channelized river especially in the river section close to the confluence with the Thaya River. The planned meanders increase the area belonging to the channel habitat from 256 ha in the current state to 283 ha in the optimistic state. In addition, the flow velocity during an HQ2.5 flood event is reduced from above 1 m/s to approximately 0.7-1 m/s. This increases the habitat suitability for lowland river fish species like Gobio albipinnatus which depend on moderate flow conditions. Due to the changes in flow conditions and the general modification of the river structure also the area of backwater habitats is significantly increased by this restoration measure.

An increase in the flooded area through restoration measures mostly generates a later approach of the flood peak. The larger the expansion of the floodplain the more considerable the effectiveness of the measure for flood wave translation. However, the effect on the maximum discharge value is not that distinct by the extension of floodplain area but more by a combination of restoration measures, concerning the river channel, the floodplain extent and the character of the floodplain (natural conditions) as in the Morava R2 scenario.

The total annual added value of the ESS benefits of the “realistic” floodplain restoration measures, was estimated at approximately 0.7 million USD2019/yr in Morava. For “optimistic” restoration measures, the total annual added value of the ESS benefits was estimated at approximately 3.1 million USD(2019)/yr in Morava. Considering the costs of the measures and the discounting of the ESS added values, the extended CBA results are promising. In Morava at least one restoration measure (realistic or optimistic) lead to a benefits-costs-ratio (BCR) approximately equal or higher than 1, when using an extended CBA.

2. Introduction and objectives

The purpose of a feasibility study is to determine if a project is possible, practical, viable as well as economically justifiable (Hoagland & Williamson 2000).
A feasibility study will help decision makers make critical quick decisions to select the right opportunities. Feasibility studies that evaluate whether a restoration effort should even be attempted can enhance restoration success by highlighting potential pitfalls and gaps in knowledge before the design phase of a restoration. Feasibility studies also can bring stakeholders together before a restoration project is designed to discuss potential disagreements (Hopfensperger et al. 2007).
An extended feasibility study should analyse the current situation and describe the transformation process of reaching the desired state of floodplains, including proposals on land use conversion and water regulation systems within the landscape. These opportunities should be investigated before planning floodplain rehabilitation interventions.

3. Methodology

The goal of the DanubeFloodplain project is to promote reducing flood risk through floodplain restoration, integrating ecological and economic benefits. This approach is modelled and evaluated in several floodplains along the Danube and its tributaries during the project. The pre-feasibility and/or feasibility studies to be made in this project will summarize methods, results and lessons learnt from selected pilot areas in five countries.

In the project restoration measures on five selected pilot areas in different countries along the Danube and tributaries were tested. These measures aim to improve catastrophic flood risk, ecological and socioeconomic conditions.

To achieve this aim, three different scenarios with complex methodology were tested. The feasibility study attempts to describe and summarize the current situation and problems that initiated the necessary development, methodologies, different aspects of the feasibility and the constraints and challenges that the project may face during and after the implementation.

Before setting up scenarios, technical, economic, legal and operational circumstances should be stated. First of all a good definition of a problem is needed. As a second step good practices should be collected which already dealt with solutions for similar problems. Then those methodologies should be chosen which can be used to examine and solve the situation. For successful implementation those indicators should be selected which can best describe the expected changes. This is followed by setting the scenarios and for these scenarios feedbacks from various stakeholders should be collected which can be incorporated into the scenarios. Then the scenarios are tested and the feasible option can be selected.

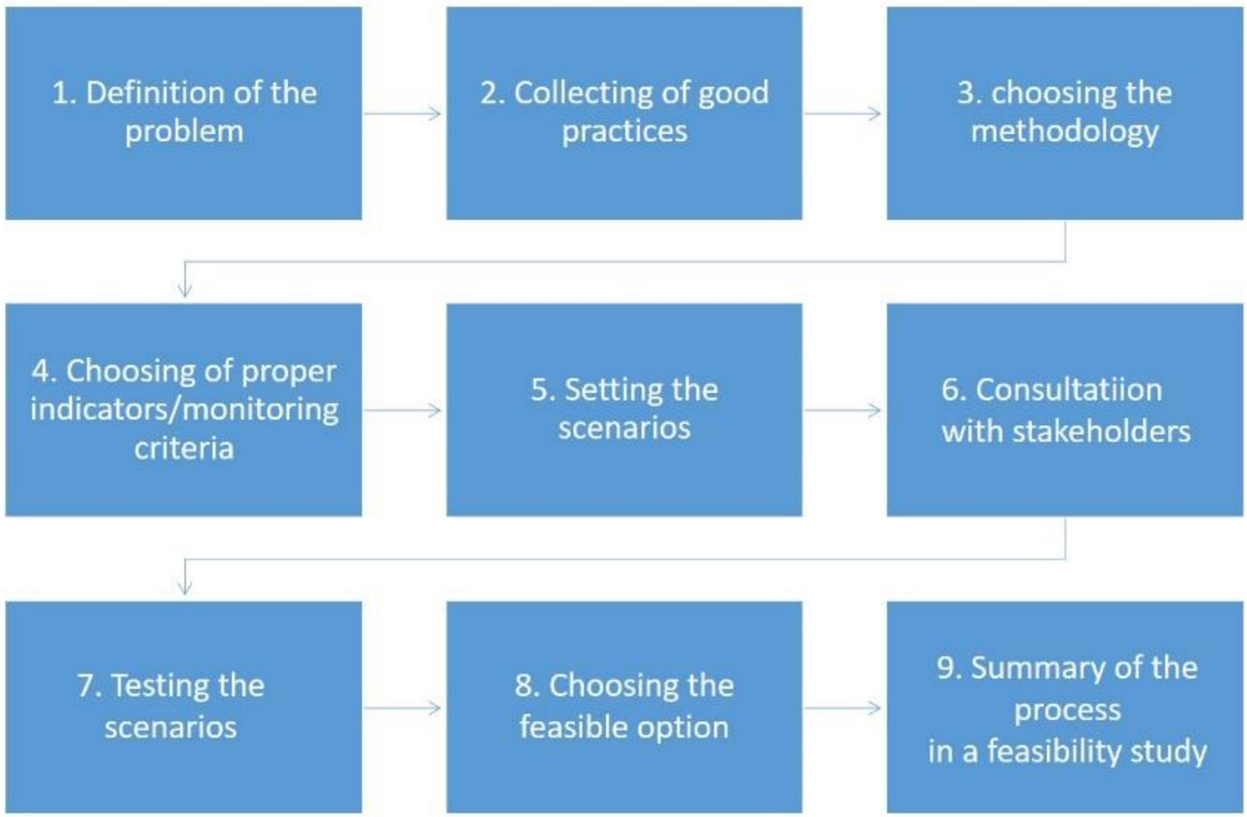


Fig. 1: Steps to perform a feasibility study

3.1 Proposed content of the feasibility study

I. Content

II. Executive summary

III. Introduction to the project idea – necessity of the proposed project activities

III.1 Assessment of the situation & problems

III.2 Goals & target groups

III.3 Indicators

IV. Evaluation of background and environment

IV.1 Introduction of the geographical environment of the area

IV.2 Introduction of the socio-economic environment of the area

IV.3 Legal and policy background

V. Scenario analysis

V.1 Methodology of the scenario analysis

V.2. Preliminary analysis for identification of scenarios

V.3 The case without project – scenario "0"

V.4 Introduction of project scenarios (A/B/C) – Examined scenarios in the project should be described.

V.4.1 Scenario A

V.4.1.1 Technical analysis

V.4.1.2 Effects

V.4.1.3 Economic & financial cost estimation

V.4.2 Scenario B, subparagraphs see under: scenario A

3.2 Explanation of the chapters

I. Content

II. Executive summary – Max. 1 page summary of the feasibility study and the conclusions of the selected and proposed scenario. Do not work on this chapter during preparing the 1st draft of the document. This should be completed after the work package's responsible partners checked and approved the 1st draft.

III. Introduction to the project idea – necessity of the proposed project activities

III.1 Assessment of the situation – Includes the description of the project site and the results of the implemented management practice in the previous years or decades. It is helpful if the pilot site background is presented not as taken out of the context, but as part of a full picture. It is useful if this chapter includes a map of the project site, or the map of the relevant longer/bigger area. The description should be short, since the longer explanation will come in chapter IV, which is about the evaluation of background and environment.

III.2 Definition of the problem – short and clear explanation why the current management and land use of the project site is problematic. Problems should be presented from the aspects of the sectors/stakeholders who have any interest on the project site. The problem analyses should follow multi-sectorial approach. It is important that the problem is not only presented from one aspect, but from integrated view. If data is available, then at dimension of the problems can also be presented, or if the changes speed up, then the signs of that can also be referred here.

III.3 Goals – explanation of the expected result of any kind of land use change or modifying the water management on the project site. The chapter needs to answer to the following question: What type of land use and management should be implemented in order to solve the problems, which are presented in the previous chapter (III.2) The project goals need to present the expected changes and potential benefits.

III.4 Indicators – this chapter includes some potential indicators, which would indicate the progress of the proposed field works on the project site. The indicators mirror the expected results, which are in chapter III.3. The indicators should be measurable and it is recommended that the baseline values of the indicators are available. If no data is available about the baseline, it is more difficult to evaluate the progress. The indicators should cover the interests and aspects of the sectors/stakeholders who are presented in chapter III.2. At least one indicator should be referred to all the interest/aspect. Complex picture and evaluation of the proposed scenarios should be helped by choosing proper indicators.

III.5 Target groups – the list of stakeholders, who have any interest on the project site, or who can be somehow influenced by any field works on the project site. The stakeholders can be grouped based on how closely they are influenced by the project. From this aspect a core stakeholder group and a wide stakeholder group formulation is recommended (source: D 4.2.1.) The groups can also be formulated whether the stakeholders should be involved into the project development and implementation or only informed about the proposed activities. The grouping of the stakeholders depends on the project sites, but it is strongly recommended to do this grouping exercise since it helps the smooth implementation of the project.

Any kind of scenario is assessed the stakeholders are normally the same ones, so this exercise is independent from the scenario analyses.

IV. Evaluation of background and environment

IV.1 Introduction of the geographical environment of the area – longer and concrete description of the project site, which can refer to the definition of the problem and the project goals. Please include all necessary data and maps, which help understanding the description. This chapter should practically include the water management, the land use and the nature conservation aspects.

IV.2 Introduction of the socio-economic environment of the area – this chapter needs to give a wider view of the project site and bring those aspects into the picture, which are indirectly influenced. This chapter is in correlation of the target groups and stakeholders. It is recommended to present concrete examples of communities or stakeholders, which are directly or indirectly influenced on the project site.

IV.3 Legal and policy background - This chapter includes evidences how the proposed project contributes to the implementation of relevant directives (Water Framework Directive, Flood Directive and some any others, e.g. Bird and Habitat Directive). The chapter should also explain how the project meets the national legislation, but since it is probably in line with the EU Directives, the description of the national legislation's comparability doesn't need to be very detailed. It is recommended to explain if some contradictions might appear during the relevant directives' implementation and should be reflected whether these contradictions are assessed in the scenario analysis.

V. Scenario analysis – In this chapter all scenarios examined in the project should be shortly introduced including a scenario "0" which describes a future situation (in specific timeframe, eg. 10-20 years) without the project. At the end of the chapter scenarios should be evaluated and explained why the one for implementation is chosen.

V.1 Methodology of the scenario analysis – This contains a summary about the methodology used in project for fulfilling all three target goals (catastrophic flood risk reduction, improved environmental indicators and socioeconomic conditions).

Evaluation and comparison of scenarios would be completed according to chosen indicators (eg. minimum parameters from FEM matrix).

V.2. Preliminary analysis for identification of scenarios – In this chapter those criteria/methodology should be described according to which scenarios were chosen.

For this chapter WWF HU will give also a summary of recommendations how one can ideally proceed in setting the scenarios.

V.3 The case without project – Here should be introduced how the problems described in 'necessity of the proposed project activities' (catastrophic flood risk, environmental and socioeconomic conditions) and what kind of state would evolve on the area or in a broader level evolve without the project in the investigated timeframe.

It should be examined how sustainable is the whole system this way, what the project owner could do to sustain at least the current service niveau with regard on the resources that can be realistically planned.

What are financial implications of this case and what kind of risk would rise without the project (technical, legal, social, environmental, financial, economic).

V.4 Introduction of project scenarios (A/B/C) – Examined scenarios in the project should be described.

V.4.1 Scenario A

V.4.1.1 – Technical analysis – Description of main technical parameters, the actions to be implemented and timeframe. Indication of those parameters which are covered by standards, regulations is necessary.

V.4.1.2 – Effects – It should be explained how the specific scenario can achieve the project objectives, what would be the economic, social and environmental effects and the excitation area during and after the specific scenario.

V.4.1.3 – Economic & financial cost estimation – This chapter contains a cost estimation for the specific scenarios (investment, maintenance, residual value) and describes economic viability

V.4.2 Scenario B, subparagraphs see under: scenario A

V.4.3 Scenario C, subparagraphs see under: scenario A

V.5. Evaluation of the scenarios and selection of the chosen/proposed scenario – In this chapter a comparison of the scenarios should be accomplished (eg. according to FEM minimum parameters), results of the comparison should be outlined and the one chosen for realization should be described.

VI. Detailed evaluation of the chosen scenario

VI. 1 Description of the technical background of the chosen scenario

VI. 2 Institutional, operational analysis: could you please describe this session?

VI. 3 Summary of the environmental effects and achieving the sustainable development goals

VI. 4 Financial sustainability of the project and cost-benefit analysis – Methodology and results of the CBA used in the project should be described.

VI.6. Risk evaluation of the chosen scenario and risk management strategy – The detailed risk evaluation, which follows some methodologies will need to be part of the work plans of the projects. But the feasibility study also needs to include some information on the risks. This chapter needs to explain what bottlenecks may appear during the project implementation and what type of risks may threaten the successful project. This explanation could practically be a summary of risks of the administrative and operational tasks and the risks of technical planning and economic viability. The chapter should write about the management strategy to handle these risks and the proposed solutions to overcome on them.

VI.7 Implementation of the project and timeline – This chapter includes a realistic timeline of the project implementation and a gap analysis of the implementation. What is missing for the project? Financial support, cooperation and partnership, etc.?

VI.8 Communication and publicity – this is a short explanation of the communication potential of the project and the necessary documents/home page/info table to be developed and spread for the public. This chapter is about the potential communication actions, which are proposed beside the stakeholder involvement activities.

VI.9 Monitoring requirements – This chapter is in close correlation with the indicators. It should include the realistic monitoring requirements during the project implementation and in at least 5-year timeline after the project end. The realistic means that it is more than the necessary minimum and satisfies a moderate level. The monitoring recommendations need to cover all the identified indicators in chapter III.4 and should include ideas how the monitoring can be financed. But the chapter doesn't need to include the financial monitoring requirements, which is an administrative task. The financial monitoring should be part of the project work plan, but would be too early to write about it in the feasibility study.

VII. Appendixes – list of the documents, which are helpful to understand the feasibility study and are not included in the text. These can be assessments, figures or maps from the past and also updated documents.

VIII. Literature

4. Results

4.1. Hungary

Feasibility study Middle Tisza

prepared by: Middle-Tisza District Water Directorate

I. Executive Summary

Over the past decades, several extraordinary floods have drifted off the rivers in the Danube River Basin where like worldwide, rivers are heavily regulated and significant amount of floodplains were cut from rivers. As a result of this, extreme flooding levels and drought became more frequent and caused significant human and economic damage in the affected countries. To handle complex problems which arise from too tight floodplains, like increasing flood risk, poor ecological state and decreased capacity of wetland ecosystems to provide a variety of ecosystem services, river basin districts should identify those floodplain areas along the rivers which can be restored. Multiplicated advantages bring higher flood security and improving ecological and economic conditions.

According to our measurements, floodplain restorations, especially dyke relocation has a significant effect on the runoff ability of the floodplain directly and indirectly also.

Land use on floodplains have changed continuously in the last decades. In connection with river regulation the native floodplain forest reduced with 96 % and heavy alteration of the remaining more than 3 % resulted among others in spreading of invasive species.

After river regulation on the new floodplain area the proportion of forest areas has been steadily increasing (meadow / pasture and arable land decreases) and significantly infected also with invasive species that degrade the ecological, ecosystem properties of the areas but core problem is that there is not enough room for the river. In addition, proper maintenance of areas rich in invasive species is important to reduce roughness and for improving water conveyance capacity.

Runoff conditions of extreme floods can be ensured if floodplains are wider and it is enough space for floodplain forests and water as well. In the section of the Tisza between Szolnok and Kisköre, the proportion of forests of native species in the floodplain is almost 10%, the area of which is expected to increase due to the projects implemented (in order to improve the natural state).

Following the remarkable flood events of the early 21st century, dyke sections in the Middle Tisza District were relocated to improve the runoff on the floodplain area. The other challenge is to develop new practices related to use of the landscape for maintain the conveyance capacity but keeping in mind as well that in Hungary there is a lack of precipitation, thus all possible water resources (eg. smaller floods) should be kept on floodplains. In this project complex methods were used to implement these principles and conservation of ecosystem services.

Further aim was to demonstrate the applicability of a two-dimensional hydrodynamic model to study the effects of the restoration measures. In a pilot area, we tested the optimal restoration measures (dyke relocation, land use change and afforestation technique) which can significantly improve runoff. Based on the modeling results, conveyance capacity of the floodplains can be increased. In the other hand flood risk can be reduced. If the case study gives satisfactory results in practice on the pilot area, it could be applied to other similar river sections in the Danube catchment area.

Flood protection purposes of restoration were partly met: conveyance capacity and floodplain area were increased and show a significant effect in flood volume storage. However, decrease of the flood hazard with the two restoration scenarios only can be considered as a local effect, therefore it can be concluded that the more floodplains are restored on catchment level, the higher impact can be achieved in gaining all possible advantages.

Improvement of ecological conditions and ecosystem services as a result of the restoration measures were proven in the project.

II. Introduction to the project idea – necessity of the proposed project activities

2.1 Assessment of the situation & problems

The Tisza River Basin drains an area of 156,869 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 (*ICPDR 2019*).

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.

The river regulation and dyke construction works were finished on the Hungarian section of the Tisza River in the early 20th century. These measures created a new situation for the Hungarian flood protection. Over time, we had to face with new problems after the river has been situated between the dykes. The major challenges are that the river can only deposit the transported sediment between the embankments and the percentage of floodplain plantations has increased tenfold over the last hundred years as a consequence of which morphology and pattern of the watercourse has been changed. One of the largest increases in flood waves is caused by the rise of invasive species. Lack of pests and parasites which regulate their population, deterioration of habitats due to river regulation, frequent disturbances and decline of traditional forms of farming play a major role in becoming invasive. Because they pose a serious challenge to the water management, common work with ecologists is needed to create more stable ecosystems where those invasive species have less chance to spread. These processes reduce the conveyance capacity of the floodplain areas and increase flood peaks in case of extreme flood events. As a result of these processes a lower maximum flood discharge can produce the highest ever measured water level (Figure 1.).

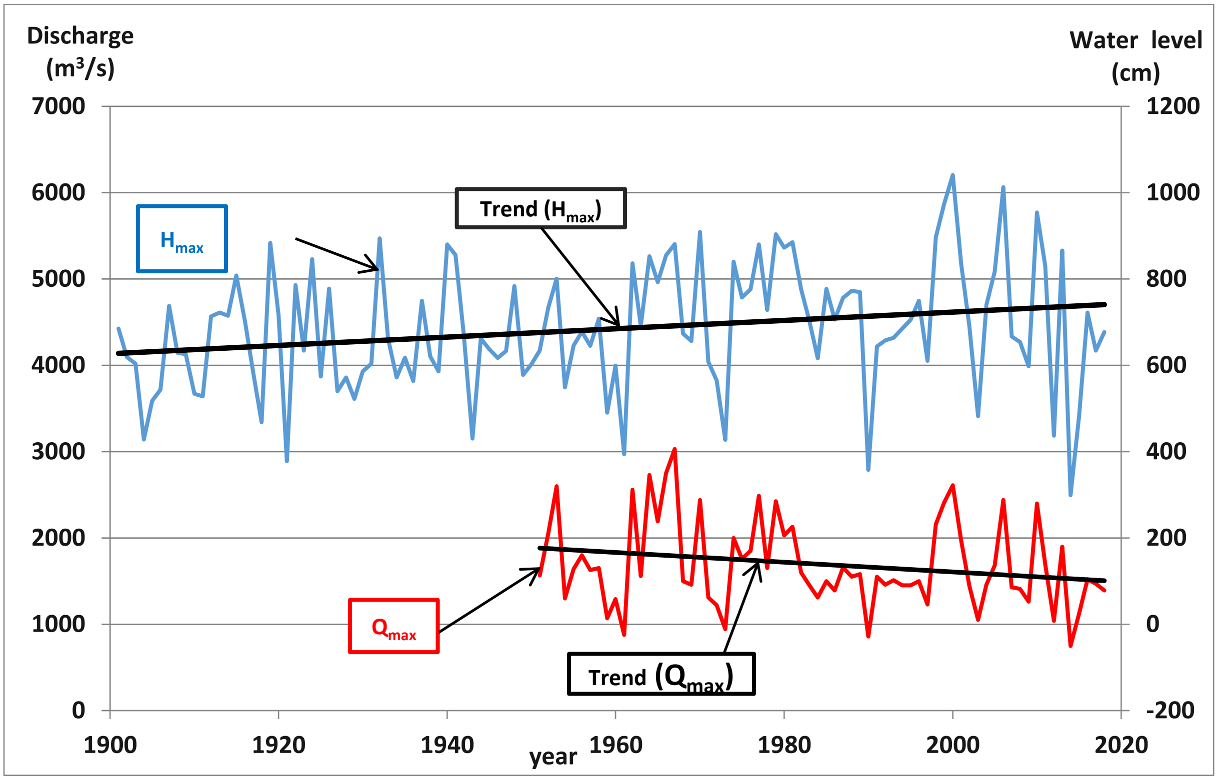


Figure 1: Maximum discharge and water-level of river Tisza at Szolnok

Climate change is also a major cause, which affects the hydrological cycle results in increasingly extreme weather (*Mauser et al 2018*). Over the past decades, several extraordinary floods have drifted off the rivers in the Danube River Basin also in the river Tisza. 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. *Vizi et al* studied the impact of increasing flood peaks caused by climate change, which is further increased by declining conveyance capacity.

The other extreme weather phenomenon is the increasing frequency of drought periods which causes also significant economic damages and losses for agriculture and environment. Thus, need rises to solve both weather extremes. Fortunately, solutions for these problems can be handled intergrated because restoration of floodplains which means more room for river and the flood waves brings multiplicated advantage.

To handle increasing flood risks within the European Union the No. *2007/60/EC 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. Following the remarkable flood events of the early 21st century, dyke sections in the Middle Tisza District were relocated to improve the runoff on the floodplain area. The other challenge is to develop a new agricultural and forestry practices related to use of the landscape for improve the conveyance capacity, taken into consideration the Water Framework Directive and the maintenance of ecosystem services.

The tool of the flood wave modelling was the two-dimensional HEC-RAS hydrodynamic modelling software. We had the opportunity to examine the impacts of different types of measures on floods. Hydrodynamic modeling has become an important tool for impact assessments. In addition to flood peak reduction, changes in flow conditions can also be analyzed.

Potential vegetation study was also performed together with land use study which could help in introducing the ideal land management and sustainable vegetation types.

Ecosystems and ecosystem services were also analysed which served as an input for the cost benefit analysis.

2.2 Goals & target groups

The goal of the Danube Floodplain project and the flood risk management project implemented in Middle-Tisza at Besenyszög-Fokorúpuszta have many overlapping elements. The flood risk management project's primary goal is to the increase the flood conveyance capacity along Middle-Tisza, while the Danube Floodplain project's goal is to identify the measures, which are win-win solutions from Water Framework Directive and Flood Directive aspects and consider the ecosystem services of healthy floodplains and also the development of cost-benefit analyses method. The harmonization of the two projects similar elements was also part of the Danube Floodplain project actions and of the pre-feasibility study.

The planned developments - using the experience of the Vásárhelyi Plan (VTT) program - originated from hydraulic problems, land use change challenges and ecosystem status deterioration. The expected results were formulated based on some relevant sectors' aspects. These aspects were to improve flood safety and reduce flood risks (for inhabitants, their belongings, infrastructure, industrial and economic facilities and to protect agricultural lands in the project area). The Danube Floodplain project also seeks to improve the ecological status of the area (by preserving or creating new habitats and propose management plans for them). To expand the ecosystem services is also considered, by identifying them with the involvement of stakeholders and gather their expectations and opportunities which they see about the restoration activities.

The reduction of flood peaks is tackled by the combination of different measures implemented in the Middle-Tisza stretches during years (also in pre- and after Danube Floodplain projects). The expected result is reducing the flood peak along the project site with 2-12 cm.

The concrete pilot site has impacts on stakeholders who have any interest right around the project site. These stakeholders can be grouped as primary target group. But in a wider context the stakeholders of Middle-Tisza's active and former floodplains from Nagykörű to Szolnok are also important partners, since the problems, difficulties and potential solutions are very similar on this Tisza river stretch. They can be evaluated as the secondary target group.

The stakeholder mapping exercise was done at the beginning of the Danube Floodplain project before the national pilot kick-off, which was organized in Szolnok in 2019. A not full list of these stakeholders (also primary and secondary target groups) are:

- Hortobágy National Park Directorate
- Department of Environmental and Nature Protection
- National Chamber of Agricultural Economics
- Csongrád Fishing Association
- Carpathian-Tisza International Development Association
- Alliance for Living Tisza
- Government of Nagykörű and Csataszög
- VCSM Zrt, Szolnok (drinking water and sewage)
- Hungarian National Fishermen's Association
- University of Szeged, Department of Physical Geography and Geoinformatics
- WWF Hungary
- General Directorate of Water Management
- Middle-Tisza District Water Management

2.3 Indicators

The indicators for the achievement of the project objectives are presented in the following tables in connection with flood risk management, ecology and ecosystem services:

sn.	The name of the indicators
1.	**Population benefiting from flood protection measures**
2.	**Number of projects prepared (flood protection)**
3.	Construction of new dyke section
4.	New drainage, permeable structures
5.	The size of the new floodplain area

sn.	The name of the indicators
6.	The number of inhabitants affected by the effect of the decrease in flood levels and the increase in flood safety
7.	Maximum flood level reducing effect in the intervention area
8.	Length of dyke lines affected by flood peak reduction

Table 1: In connection with flood management, results of the 2D simulations

Ecosystem service change that is monetised	Ecosystem service change that is not monetised
• Flood risk reduction • Greenhouse gas • Fish spawning • Grass production on meadows	• Biodiversity • Habitat for various species, more robust fauna and flora • Lower pollution • Timber production • More hunting and more game meet • Increased water infiltration into the soil, ground water recharge • Micro-climate regulation • Increasing recreational, sport, hobby and educational activities • Beekeeping

Table 2: Ecosystem services significantly affected by the dyke relocation

III. Evaluation of background and environment

3.1 Introduction of the geographical environment of the area

The settlement of Besenyszög in the northern part of the area affected by the development is located in the central part of Hungary, in Jász-Nagykun-Szolnok county, in the area of the Szolnok floodplain, with a total area of 709 km2. The micro-region is a plain between 84.5 and 91.2 m above sea level. The surface has an extremely small average relative relief, slightly more lively west of Szolnok. 70% of the topography can be classified into the topography of the floodplain level. In keeping with the floodplain nature of the micro-region, the predominant soil types are loess in the north and meadow soils with a clay and clayey loam composition in the south. In terms of the climate of the micro-region, it is moderately warm-dry and located on the border of hot-dry belts. The depth of the groundwater north of Szolnok is not even 2 m next to the Dobai main canal, 2-4 m in its wider area. The average depth south of Szolnok and on the left bank is 4-6 m.

The climatic vegetation is forest steppe. The flora and vegetation of the former floodplain and the floodplain are sharply different. The potential vegetation of the former is a forest steppe, the floodplain is a forest-swamp mosaic (forest with overweight). The area is rich in natural values, and protected and Natura 2000 areas are home to many protected, highly protected animal and plant species.

The project area is Besenyszög-Fokorúpuszta on the floodplain by the left side of the Tisza in Middle Tisza District near in Szolnok town. The Tisza's full gradient is 30 m (5 cm/km) in Hungary. Based on the Middle Tisza District Water Directorate (MTDWD)'s hydrometric data, the minimum discharge of the river is 46.9 m3/s, and the maximum discharge is 2 610 m3/s at Szolnok. The long-term average discharge is 532 m3/s at this river section. The highest ever measured water-level was 1040 cm at Szolnok in 2000. The water level fluctuation is 1320 cm between the highest and lowest values.

In frames of the Vásárhelyi Plan (VTT) project on active floodplain regulation at Middle Tisza, project preparation construction works are in progress at the project area Besenyszög-Fokorúpuszta on the floodplain by the left side of the Tisza. A central element of the investment is the planned dyke relocation. Approximately 6 km of the dyke will be relocated in the direction of the former floodplain. As a result of the relocation, the main protection line will be shortened by appx. 2 km and the flood bed will get larger by appx. 280 hectares. This intervention is following the ongoing construction works on Szolnok bypass of the M4 highway and considers its forecasted impacts. 1 km long section of the highway trace is crossing the project area. A floodplain bridge and separate dyke junctions will be constructed at enlarged flood bed. Concerned dyke sections are mainly located at the outskirts of Besenyszög, only a short section is in the outskirts.

The uncovered crest width of the existing dyke is 5 m on the average, slope inclination on the water and former floodplain side is ~1:3 on the average. Combined width of the toe and body of the relatively properly handled and grass-covered dyke is 40 m on the average.

Planned borrow pit in the extension of approximately 40 hectares at the southern part of the project area is an investment element with the highest impact on landscape, land function and usage. According to the plans, borrow pit will be partly filled up with the material from the demolished dyke. After recultivation most of the affected area will be a grassland; lower parts will be left as periodical wetland habitat without an outlet. The borrow pit is planned to be used under control. Therefore, its drainage and inevitable watering will be possible from the Tisza through a new channel.

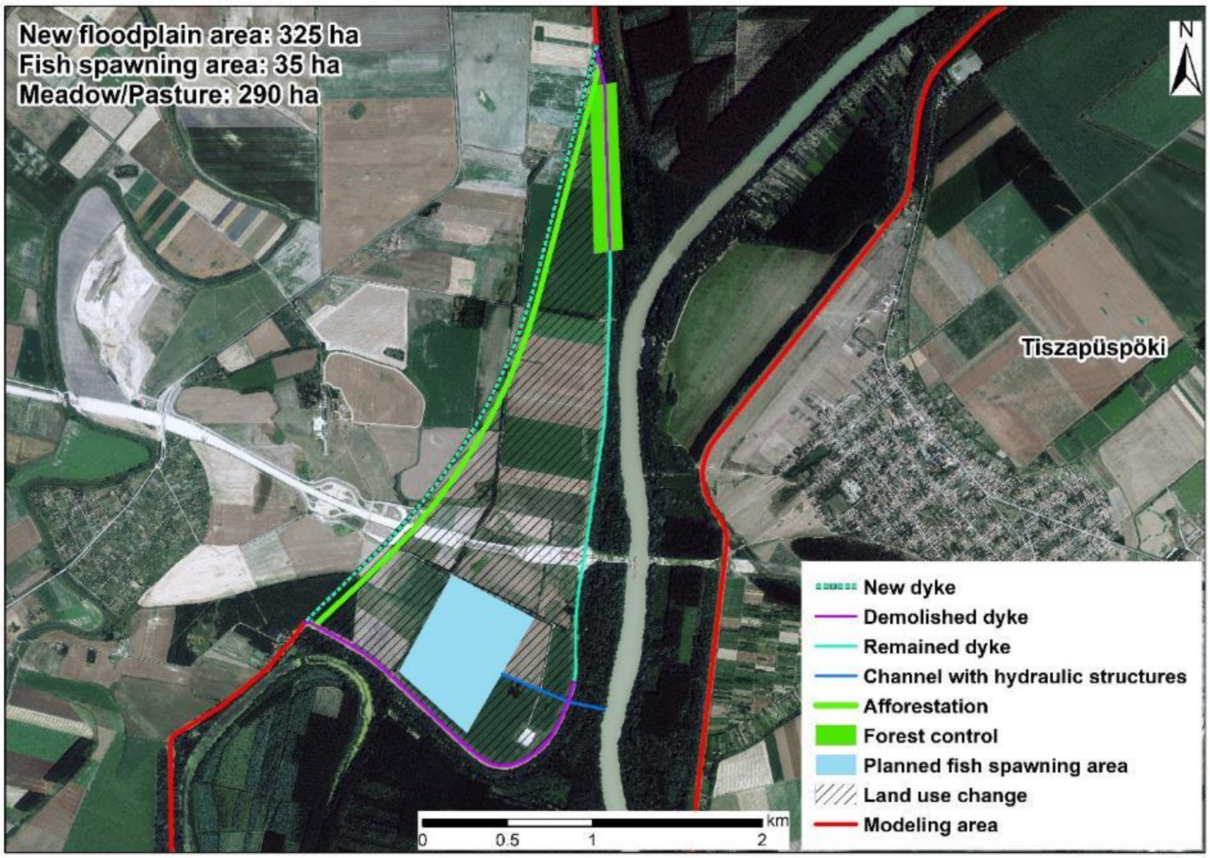


Figure 2: Location of the pilot area near Szolnok, Hungary

3.2 Introduction of the socio-economic environment of the area

The settlement structure of the area affected by the development is determined by the attraction of large cities (eg Szolnok). The classic features of the development of the Great Plain market town can also be observed here. The population density of the Szolnok (130.61 people / km2) micro-region is above the national average (108.5 people / km2). The population of the directly affected settlement, Besenyszög, is 3,364 (2014). In terms of the number of births and deaths, each of the affected settlements shows the national characteristics, the number of deaths exceeds the number of births. Regarding the age distribution of the population, the “declining population trend” occurring at the national level can be observed in the examined area as well, especially the low number of births. Thus, the number of young people aged 0-17 is lower than the number of people aged over 60.

A primary education institution can be found in almost every settlement. Institutions providing higher level and / or special training are only in the cities.

Due to its natural geographical features, the Szolnok micro-region cannot be classified as one of the most attractive tourist destinations. Its values include the thermal water resource, the high number of hours of sunshine and the unspoilt natural environment of the mosaic. The main employment sector of the county is the manufacturing industry, the retail and wholesale trade and the agricultural sector have become significant, 32% of the region's production area is located here.

The settlement structure of the development area can be said to be generally the same as the structure typical of Jász-Nagykun-Szolnok county. The Tisza River played a major role in the formation of their density and their spatial distribution. The directly affected settlements were built on the high bank of the river. According to the Jász-Nagykun-Szolnok County Regional Structural Plan, most of the affected area is a mixed land use area with forest management regional patches along the river. The Szolnok micro-region is defined by the high proportion of arable land, which is well above the national average. The land use of the county is characterized by homogeneity, wheat is grown on 34% of the harvested arable land and sunflower on 22%. Based on the land use, it can be stated that the Fokorú-puszta intervention basically affects non-irrigated arable lands, a small part (in the southern part of the planned new dyke) of deciduous forest.

We cannot find a historic settlement area or a World Heritage and World Heritage Site in the area.

3.3 Legal and policy background

The concept of the Vásárhely Plan (VTT) was approved by the Government in Decree 1022/2003. (III. 27.) entitled "On the revised development tasks of the flood protection works of the Danube and the Tisza and on the concept for increasing the flood safety of the Tisza Valley". According to the provisions of this, in order to increase the flood safety of the Tisza Valley, the flow properties and water conveyance capacity of the Tisza River must be improved, taking into account ecological aspects as well.

As described above, the content of the present project was defined by the Strategic Concept of the Tisza Valley Flood Protection Development Program.

The legislation establishing the necessity of the development is the 83/2014. (III. 14.) Government Decree, which contains rules on the use and utilization of areas endangered by floodplains, coastal strips, watercourses and flowing waters, and in the case of rivers, the procedure and content of the preparation of riverbed management plans.

The Danube Floodplain project's priority is to consider all the flood and water management and nature conservation principles during the planning or updating the management of the rivers' floodplains. This approach can deliver win-win solutions and support the harmonization of sectorial planning. The principles and aspects to be considered are also included in the legal framework and is referred shortly in the upcoming points.

The principles and norms of relevant laws of nature conservation and environment also need to be considered. The Nature Conservation Law, LIII. in 1996 (TvT) and the general regulations of the Environmental Protection Law, LIII. in 1995 (KvT) both have specific points about waters and freshwater systems. It is declared in the Tvt. 16. § (5) chapter that the natural and close to natural banks of rivers and streams must be preserved in order to protect wetlands. The green and nature friendly solutions need to have priority during water management works. The careful management/preservation of plants is also expected by the 17. § (3) chapter during any water management works' implementation. Boundary conditions are defined in the Kvt. 21. § (1) chapter, which ensure not to threaten the natural processes and do not cause any risks on restoring quality or quantity of waters.

The protection of the natural capital considering the public interest is a respective constitutional requirement in Hungary. The protection and preservation of natural resources and its responsible careful management and consideration of the social demands of future generations is a highly expected.

The water is not a commercial product, but an inherit and this must be considered in any kind of its management declared by the Water Framework Directive. The directives about the nature conservation exclude any measures, which might have significant effects on species and habitats with community interest.

The Directive on the conservation of wild birds 2009/147/EC and the Directive on the conservation of natural habitat and wild fauna and flora 92/43/EEC shortly Birds and Habitats Directives forms the cornerstone of Europe's nature conservation policy.

The Habitats Directive aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. The Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. The Birds Directive establishes a network of Special Protection Areas (SPAs) including all the most suitable territories for these species. The Birds Directive aims to protect all of the 500 wild bird species naturally occurring in the European Union.

IV. Scenario analysis

4.1 Metodology of the scenario analysis

Our aim is to achieve an additional positive impact on ecosystem services as well as reducing flood risk. A dike relocation clearly improves the flood protection in the area. The city of Szolnok is located not far from this area, which is the most densely populated area in the region. Flood risk reduction has a high priority in this region.

Connecting new areas to a floodplain can have a number of other positive effects. Periodic flooding of the area can improve certain ecosystem services in the area. A dike relocation always involves other interventions. In the Fokorúpuszta area, afforestation of plantations and invasive species and the establishment of a fish spawning are also planned. Together, these interventions could have a positive impact in economic, social and ecological terms.

Evaluating different planned versions of an intervention is a complex process. In designing the present measurement, we developed a multi-step estimating system. As a first step, we studied different conditions by hydrodynamic modeling. This made it possible to quantify the impact of the measurements on the hydrology of the river (e.g. flood peak reduction, changes in runoff conditions). The hydrodynamic model provided different data for further estimation. The cost-benefit analysis used water level time series from the modeling. The potential vegetation modeling used as input data velocity, water depth, water level, and duration result rasters.

The HEC-RAS modelling software is developed by the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. The program has been successfully used for one and two dimensional modelling in the United States of America for all major rivers, and also used in the Danube Floodplain project (US Army Corps of Engineers 2016).

The model includes approximately a 160 km long river section of the Tisza from Kisköre (403 river km) to Csongrád (246 river km). The model has two main parts: a 2D mesh between Kisköre and Szolnok, and a 1D river section between Szolnok and Csongrád (Figure 3). The 2D mesh only includes the floodplain area between the dykes, so there are no significant settlements in the area.

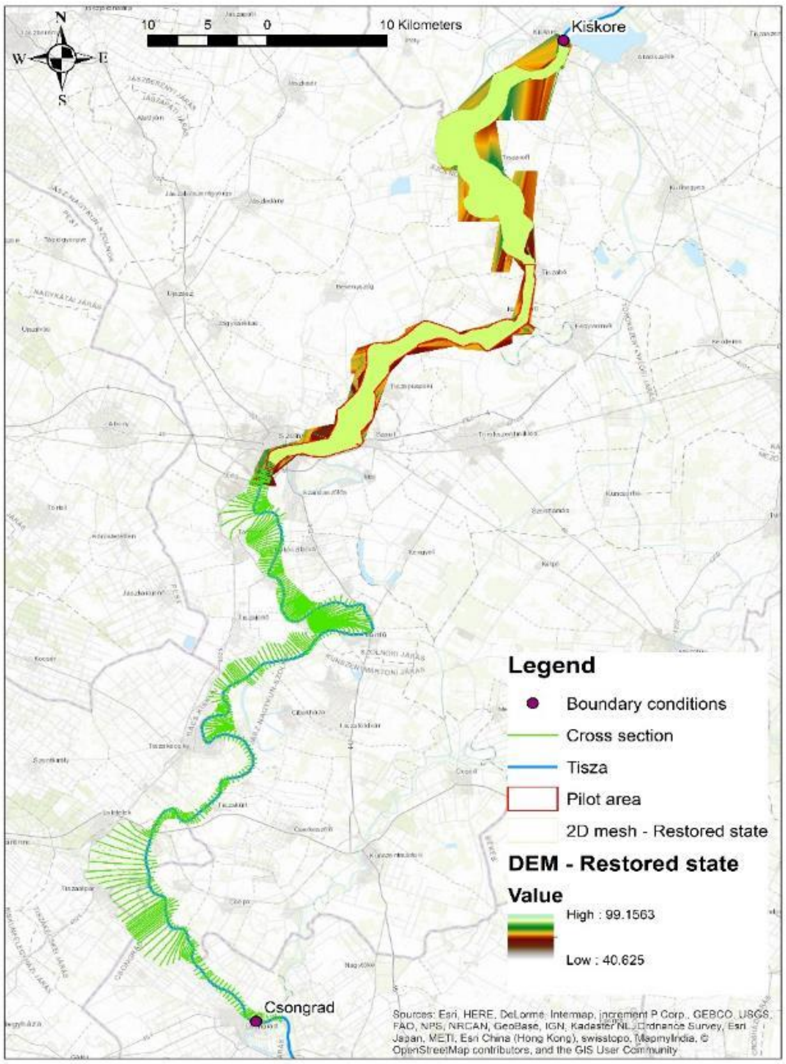


Figure 3: Combined 1D and 2D model for the pilot site

We developed three more different model geometries (original state, current state, R1, R2). The original state version does not include any dike relocation and afforestation. This model geometry represents the state of the early 2000's. We had to implement a new dyke relocation measure into the R1 and R2 versions. We also modified the roughness in every geometry version. The R2 geometry includes a fish spawning ground and a new runoff area on the floodplain.

The Middle Tisza District Water Directorate has performed a survey in 2018, which was part of a Hungarian project. The main aim was to update the river geometries along the Tisza valley. The river bed and the floodplain area were measured separately. The DEM was put together from the measurement of the river bed and floodplain, which was used in the Danube Floodplain project. The resolution of the geometry is 1 meter.

The geometries have a 2D flow area with 25x25 meters wide computation point spacing. The default Manning's value is set during the calibration and validation. The 2D mesh is the same in the R1 and R2 versions.

The cross sections are the basis of the one-dimensional models. The calibration and the roughness coefficient only partly compensate the possible inaccuracies of the cross-sections. The one-dimensional cross sections come from the same Hungarian project in 2018. Cross-sections were measured in every 100 meters in the Middle Tisza district. The model stability is greatly improving if the cross sections are as dense as possible. Based on previous modelling experiences, the optimal distance between cross sections - from model point of view - is 400 - 800 m for the Tisza. The one-dimensional river section is the same in all model geometries. Between Szolnok and Csongrád (approximately 90 km), 342 cross-section was built into the model.

We determined the cultivation branches on the flood plain by aerial photographs, i.e. by ortho-photographs, as well as by the results of on-site inspections. The roughness factor was changed crosswise according to flood plain cultivation branches. The roughness (smoothness) factor assigned to these was determined on the bases of the prescriptions of the Hungarian standard, as well as on the bases of values applied also by HEC-RAS and proposed by *Chow (1959)*. The smoothness factors assigned to individual cultivation branches overlap each other as there is no possibility for making sharp difference between the categories of "sparse thicket" and "dense thicket".

The HEC-RAS model applied for the detailed description of the entire river system provides an opportunity for taking into consideration the hydraulic engineering structures, like bridges, barrages, culverts, overflow weirs, floodgates, bottom stages, bottom sills, side overflows and gates, static reservoirs, pump head stations and water intakes.

The model contains the dikes between Kisköre and Csongrád. The dikes built into the DEM for the 2D river section. The cross-sections of the 1D river section also include the right and left dikes. The model also contains 2 bridges in the 2D mesh and one in the 1D river section near Szolnok. We took into consideration the bridges in the 2D section when we modified the DEM.

We used real events as a basis of our hydrological data. The Middle Tisza District Water Directorate has made monitoring along the Tisza River. The following events were simulated: HQ2, HQ10, HQ100. Each HQ is based on the same flood wave. We have the official HQ values for Kisköre, which is the upstream boundary condition in the model.

We modified the flood peak according to the official HQ values for each HQ. Every model run has a one month long "warmup" period with a steady state value. We made that to have a more stable unsteady flow simulation. The steady state value was 512 m3/s at Kisköre.

The main challenge was that there is not any remarkable flood wave since the dyke relocations were finished on the Middle Tisza region. The original state scenario was needed for that purpose. We used the flood wave of 2000 for calibration with an old geometry, representing the characteristic of the early 2000's. This flood wave produced the highest water levels in the Middle Tisza. There was not any dyke breach along the Tisza in 2000.The calibration of the model was accomplished gradually, starting with the shorter sections (1D and 2D separately). We assembled together the individual sections and then performed the river sections. We had 3 calibration station: Tiszaroff, Tiszabő and Martfű. The average difference between the computed and the observed data is 5-10 cm at each control point which was considered as a good result.

4.2 The case without project – scenario "0"

The current state version includes 3 dike relocations and afforestation measures between Kisköre and Szolnok which were finished in the last five years. Only the new (Fokorúpuszta) dike is not part of this scenario. The current state scenario represents the current status of the Tisza River.

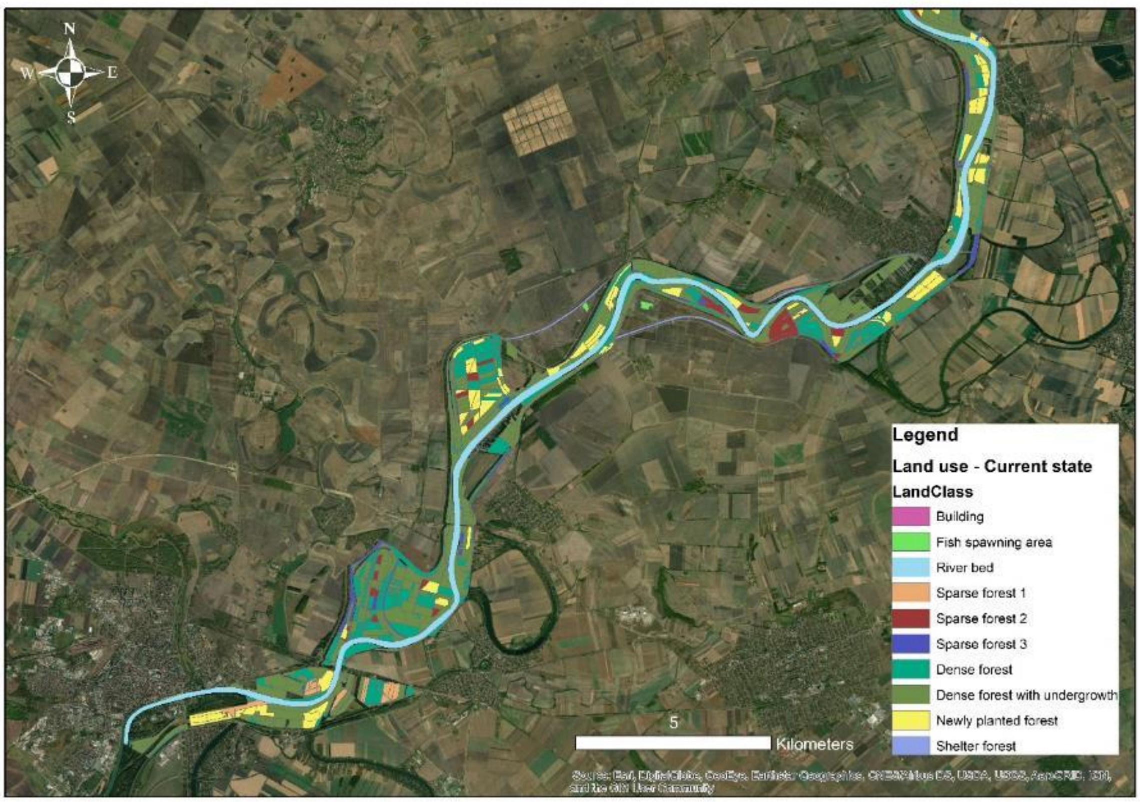


Figure 4: Land use for the current state scenario

4.3 Introduction of project scenarios

4.3.1 Scenario A

Each restoration scenario includes dyke relocation measure. The new dyke line was built into the geometry. The R1 version considers the new floodplain area as a pasture (change in land use) (fig. 5). There is an 80-meter-wide shelter forest next to the new dyke (change in land use).

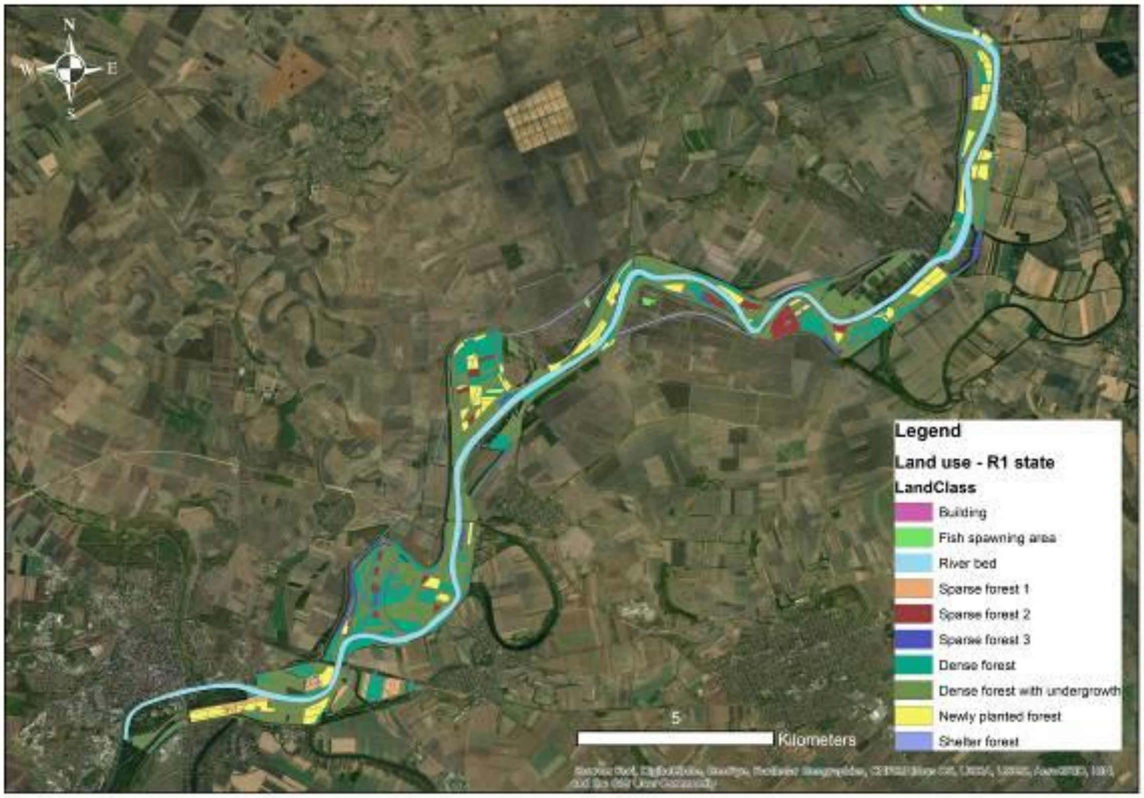


Figure 5: Land use for the R1 state scenario

4.3.2 Scenario B

Our main aim with R2 to increase the effects of the restoration measures without harming the flood protection. The R2 version has a new fish spawning area in the pilot site (change in land use). There are some forest regulation measures in this scenario: shelter forest next to the dyke, new floodplain forests on the flow stagnation regions, and increased runoff on the floodplain area with removing the invasive species in a narrow range (change in land use).

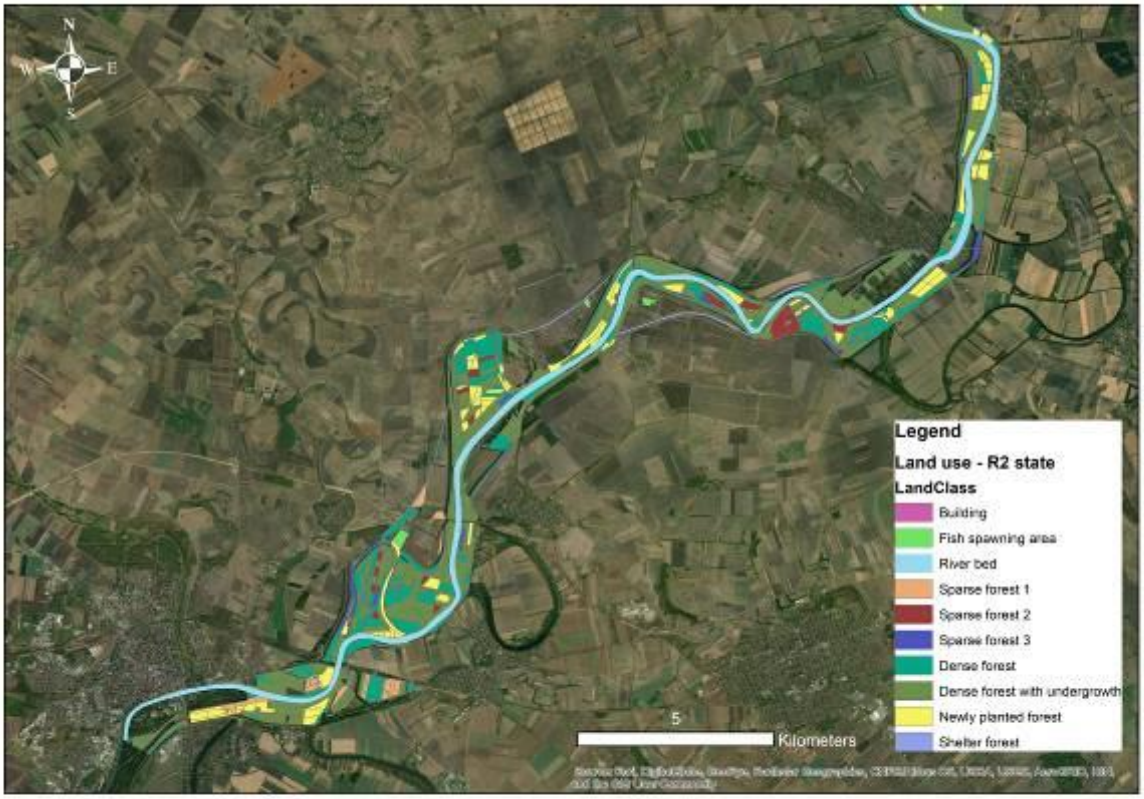


Figure 6: Land use for the R2 state scenario

4.4 Evaluation of the scenarios and selection of the proposed scenario

The flood peaks along the river Tisza have shown an increasing trend over the last decades. The process began during the dyke construction works in the 19th Century. The river trapped in a narrower floodplain area between the dykes. That is the only area where the river can deposit the carried sediment. Due to this process and the increasing size of the dense forest areas, the water conveyance capacity of the floodplain is reduced. In response to these processes, the Water Directorate in the Middle Tisza region started dyke relocations. The integrated water management is also promoted on the new floodplain areas.

In addition to increasing the conveyance capacity, more emphasis will be placed on the design of optimal land uses. Primary runoff lanes continue to serve the purpose of flood protection. On the other hand, creating the fish spawning areas are both ecologically and economically beneficial and do not pose any flood risk.

The hydraulic simulations of the different scenarios in the Middle Tisza pilot area reveal neglectable effects in the peak discharge of the flood waves of below +/- 0.5 %. The time lag of the flood peak is noteable in all events in R1 scenario with maximum 15 hours peak delay in the HQ100 event. The time difference is lower in the R2 scenario and there is no change in the HQ10 event.

The flooded area is increased through the dike relocation by ca. 4.4 to 6.2 % and thus the stored vol-ume is 3.9 to 5.0 % higher compared to the CS. The average water depth can be increased through this augmentation of the flooded area by more than 6 % in both restoration scenarios in all investigated events.

We decreased the water level with the dyke relocation and land use change in R1 compared to the original and current versions. The difference is 5-15 cm near to the pilot site. The R2 version did not cause further reduction in the water level. The aim was to increase the ecological status while the flood risk is not rising.

		HQ5	**HQ10**	**HQ100**
Q_{max} [m^3/s]	out CS	1929	2273	2904
	out R1	1927	2275	2905
	out R2	1937	2275	2906
Delta Q_{max} [m^3/s]	R1-CS	-2	2	1
	R2-CS	8	2	2
Delta t [h]	R1-CS	8	4	15
	R2-CS	7	0	6
Change in flooded area [%]	R1-CS	6.2	5.0	6.2
	R2-CS	6.1	4.4	6.1
Change in volume [%]	R1-CS	4.5	5.0	5.0
	R2-CS	3.9	4.4	5.0
Average water depth [m]	CS	3.70	5.20	5.97
	R1	3.63	5.14	5.90
	R2	3.61	5.12	5.90
Average flow velocity [m/s]	CS	0.150	0.200	0.220
	R1	0.140	0.180	0.210
	R2	0.150	0.190	0.220

Table 2: Results of the 2D simulations

Locally the effect is visible in a decreased water depth upstream of the dike relocation up to 0.5 m up to the upper model boundary. Downstream of the dike relocation there is no change in the water depth. Looking at the velocity, the flow speed in the Tisza riverbed is decreased, but this reduction is just visible for ca. 7 km of the river length.

However, it can be stated that the increased ecosystem services in the R2 scenario do not negatively affect the flood risk. This version is considered to be the most optimal from both flood protection and ecological point of view.

V. Detailed evaluation of the chosen scenario

5.1 Hydrodynamic modelling

During the pilot study, different measures could be taken into account in determining geometry (e.g. dyke) and land use (forest areas, grassland). The main challenge was to calibrate the model sufficiently.

The river gained more space with the dike relocation. This can be seen in the water depths formed near the new floodplain area. Examining the HQ100 flood wave, a 5-10 cm water level decreasing occurs with this implementation. Figure 7 show the water depth with scenario R2

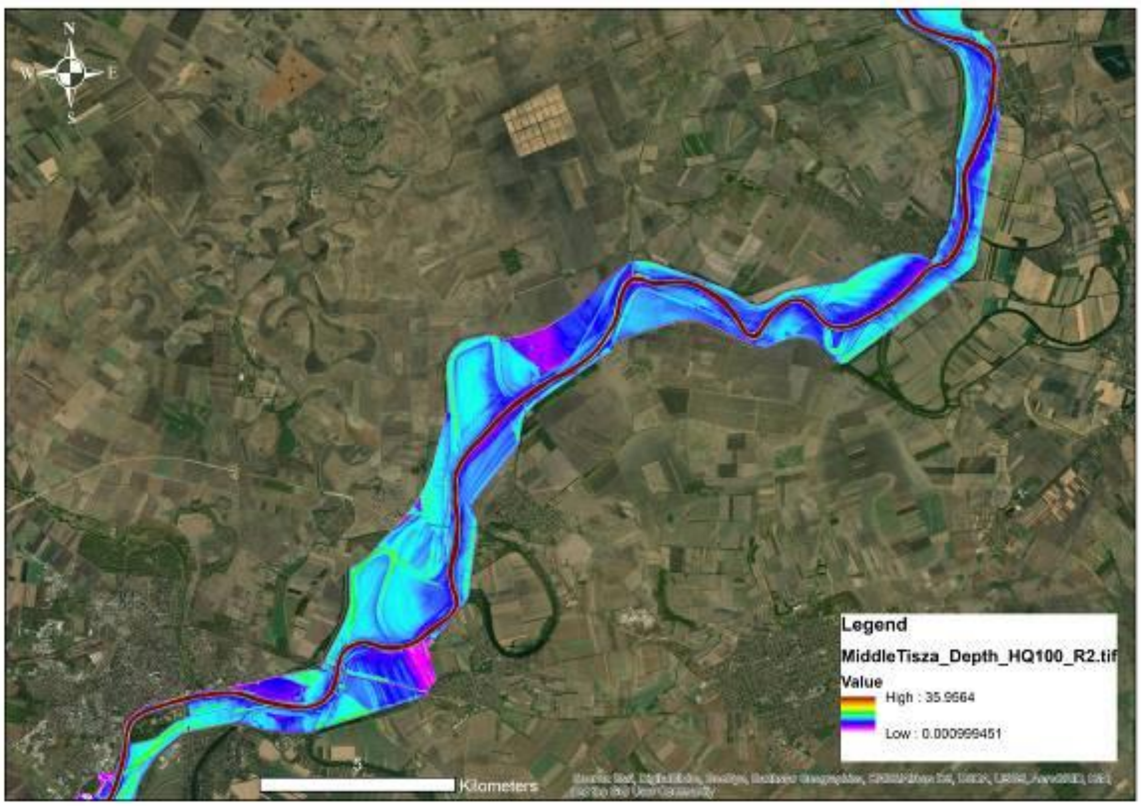
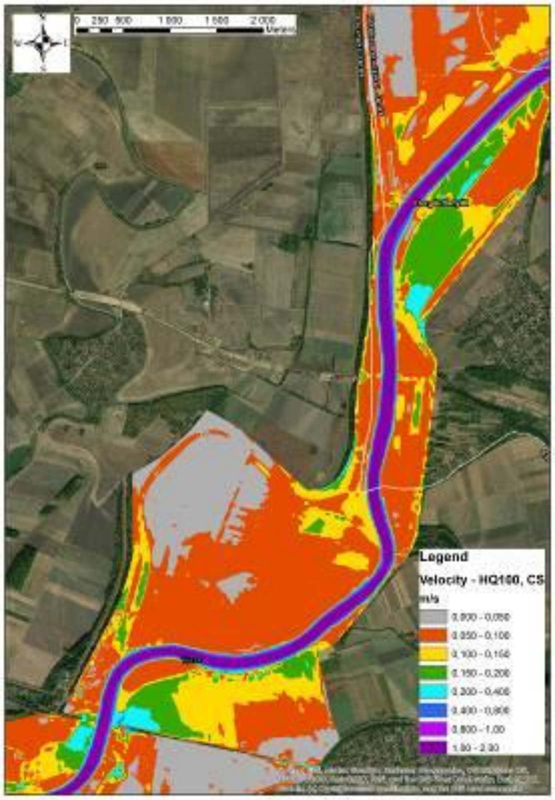


Figure 7: Water depth with R2 scenario

The dike relocation also created a new situation in the flow conditions. The floodplain can transfer more water, and higher velocity also can be formed compared to the current state (Figure 8). An oxbow lake is also reconnected with this version, which helps to improve the conveyance capacity in the floodplain. An important topic is the management of the invasive species to maintain the adequate flow conditions along the river.


Legend
Velocity - HQ100, CS
m/s
0.000 - 0.050
0.050 - 0.100
0.100 - 0.150
0.150 - 0.200
0.200 - 0.400
0.400 - 0.800
0.800 - 1.00
1.00 - 2.00

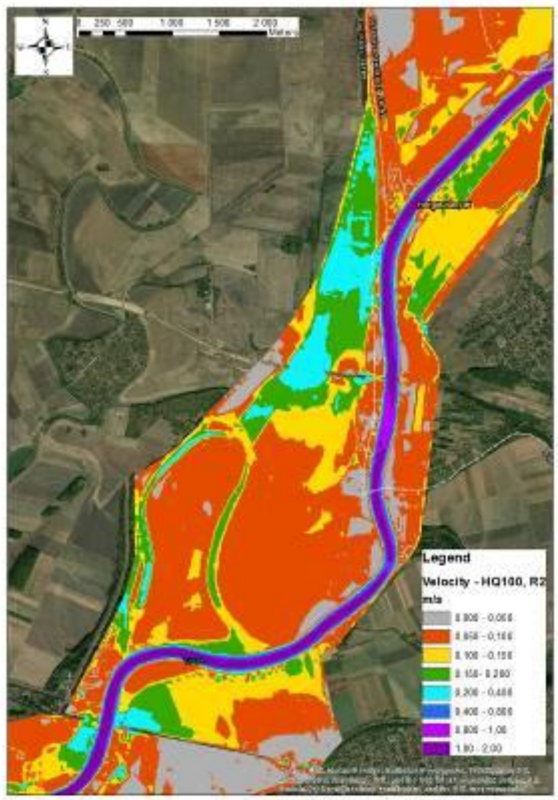


Figure 8: Velocity with CS (left) and R2 (right) scenarios

The initially specified purposes of restoration were partly met: the conveyance capacity and the floodplain area were increased and show the significant effect in flood volume storage. However, the decrease of the flood hazard with the two restoration scenarios only can be considered as a local effect. The impact of ecological measurements should be determined by other tools (e.g. cost-benefit analysis).

5.2 Potential vegetation modelling

Potential vegetation modelling predictions were carried out and best realistic solutions for future landuse were investigated a floodplain area along River Tisza to find the possibly most optimal solutions, which meet flood and drought management requirements, and consider ecology and local economy aspects.

The pilot area in the Danube floodplain project was investigated. Fokorúpusza site is in Middle-Tisza and location is prepared for floodplain restoration. On Fokorúpuszta pilot site there were already ongoing measures during the potential vegetation modelling. Dyke relocation (floodplain extension) is a fixed measure on both areas, and on the extended floodplains there are still more options for modification of landuse and introduce new vegetation.

Based on results of these investigations, conclusions were summarized and recommendations are given for planning of future floodplain restorations.

5.2.1 Predictions of the potential vegetation

Potential vegetation predictions obtained for this pilot area demonstrate that habitat suitability trends can greatly differ for floodplains even along the same river and relatively close locations. Fokorúpuszta demonstrates the expected trends, i.e. the areas newly added to the floodplain by shifting the dams farther from the river will be more suitable for wetlands.

Modelling can be further optimised with a feedback mechanism between hydrological and vegetation models. Iterating the two steps – described in detail in the study – until reaching no further change in either the water regime or the potential natural vegetation would mean that a stable prediction has been reached showing the expected water regime together with the vegetation that can live under it. Such a prediction loop could also be automatised and become a decision support tool in planning river regulation modifications.

In conclusion, it was recognised that outcomes of river regulation modifications can be highly variable depending on local conditions (e.g. terrain, river dynamics, existing vegetation). Therefore, preparatory modelling appears to be essential to assess the possible changes and whether the goals can be met. Such predictions are also key to communicating the potential consequences and benefits of river regulations to the stakeholders and to the public.

Investigating of deployable landuse types started with an overview of former land use types and land use history, then ecological frames of farming and land use were reviewed with regard on the predictable results of the proposed water management interventions. Finally, farming and land usage methods at the project areas in frames of their natural conditions were introduced.

After the realization of the water management measures, complete conversion of previous land usage, farming and utilization methods is expected on both project areas.

5.2.2 Options of land use conversion and new vegetation forms

Such farming and management methods should be applied that can handle problems occurring due to sudden floods and along them appearing invasive plants. To achieve defined objectives, the operation of drainage and water retention systems could be effective tools for handling these problems.

In the past pasturing livestock farming was a prevalent farming method on the floodplain. Short floods fertilized forests, orchards, fields, grazing lands and grasslands. Periodically flooded grasslands and meadows with higher grass yields were ideal for livestock farming. The most effective method of repressing invasive bush and tree species – that are unfavourable from flood protection perspectives and are causing huge problems – is pasturing or regular mowing on areas that are not used as forests or croplands. On active floodplains exposed to more floods or their parts deemed to be appropriate, extensive, organic or bio-farming could also be possible.

5.2.3 Conclusions

As a final step hypothetical reality of potential land use was ranked, expectable conflicts between various stakeholders were analysed. Farming forms were rated according to the criteria / aspects of four sectors: the natural conditions, water management requirements, economic factors and nature protection principles.

According to these results, cultivation of meadows – pasture or mowing – is the most idealistic land use, which both consider the criteria mentioned above.

Natural forestry or fruit growing could also be good solutions – these, combined with predictions from the potential vegetation and hydrological modelling can give a good pattern for restored floodplains.

Besides, solutions for the prevention of further drying floodplains should also be investigated, and water retention measures on floodplains could be inevitable. Relevant conditions for more varied utilization could be: meadows or wooded pastures on deeper areas; soft and hardwood forests on higher locations or along the new dykes.

5.3 Cost-benefit analysis and financial sustainability of the project (REKK)

The results of the complex, extended CBA based analysis of the Fokorúpuszta dyke relocation project show that implementing the intervention would be a beneficial public investment both from financial and natural point of view. Based on the analysis one can assume that no stakeholder group would be left behind in terms of bearing the cost of others' benefit without having compensation.

While the biggest share from the benefits is associated with flood risk reduction, the calculations show that the proper, ecosystem service benefit oriented management of the transformed territory also has a key role to ensure the positive balance of the investment. From this point of view the proper management agreements with the angler associations about the operation of fish spawning area for rejuvenating and supplementing the native fish population has high importance.

Although CO2 sequestration represent a smaller benefit element it is worth noting that this benefit comes from a relatively small area (20 hectares), that is only 6% of the transformed territory. Because it is a forest patch with defense function that protect the dyke, our calculation expected a constant forest cover management approach. Our results also illustrate that constant cover forests can be considered as a viable land use alternative for publicly acquired land for flood protection.

It is also worth acknowledging that these “fringe” benefits are responsible for 50% of the positive balance of the investment. Especially the creation of forests with carbon storage purpose in mind is a financial surplus generating efficient additional service implementation, if land is already available for public reconsideration of use optimalization.

Like in the case of the above mentioned additional ecosystem service provisions, it can be decisive to reach agreement on the terms of a development, but it requires site specific information and stakeholder bargains to reach in order to include them in a real ex-ante decision support calculation in a credible way, otherwise it represents only a theoretical potential and not a realised benefit.

The applied methodology helped to structure the intervention as a bundle of development elements whose economic and natural benefits exceeded costs. Importantly, the analysis also shows that evaluating the cost and benefit components separately will highlight items where additional considerations, issues can be raised for further improving the balance. The excel based support tool had a good helping hand in that element.

Economic analysis with a positive balance is only a part of the necessary approval of a flood risk mitigation intervention. That is the reason why the methodology we tried to follow and test at the same time, introduced a decision flow approach with a (1) sustainability check, (2) extended CBA and (3) stakeholder negative-impact neutralization. So far aspect (2) and (3) were assessed. The sustainability check of the intervention takes two steps, from one part showed that the decisive conditions of the environmental quality that dispatch through the land use patterns of the area don’t deteriorate due to the intervention (actually improves). The criteria/condition list itself were judged appropriate and practically useable for the purpose by both partners who collaborated with Rekk in the case study elaboration (Kötivizig, WWF). The second step monitors the change of the functional capacity of the area, how it provides ecosystem services. Did the asset (on which the actual bundle of ecosystem services are based on) change? In the methodology we laid down a theoretical framework that connected this measurement of ecosystem service asset base to the inter-seasonal water budget allocation efficiency of the analyzed territory. Based on the available data we can state that the intervention improved this capacity of the area. Meanwhile we couldn’t prepare the dataset what we consider the suitable one for such a judgement. This element needs further development in simulation capacity to improve the integrated use of discharge, infiltration and transpiration models whose resolution can cope with the land use changes considered along the analyzed intervention.

In our judgment the pilot site calculations proved the usefulness and the practical applicability of the methodology that follows a decision flow approach the extended CBA analysis is a part of. The sustainability analysis phase was conducted on a simpler dataset than what the methodology deemed suitable in order to grasp the most important dynamics of ecosystem service asset change. We are convinced that the right way ahead in this aspect is the improvement of the information supply, not the change of the methodology. The post CBA element of the decision flow, the structuring of the stakeholder group impact also proved a useful method to make the results understandable.

We created a spreadsheet tool to assist in the calculation of the balance of all costs and benefits (CBA Tisza pilot.xlsm). All the benefit and cost items described in the previous chapters are entered into this spreadsheet, indicating also the year in which given items occur. Non-monetised benefits are also entered in order to have everything in one structure, and stakeholders who bear the cost or enjoy the benefit also need to be supplied to help the structured discussion of distribution impacts and compensation mechanisms.

Within the tool the present value is calculated for all monetised costs and benefits through the application of a real discount rate (discount rate in excess of the rate of inflation) supplied by the user. For this exercise we used a 2% discount rate and made sensitivity analysis with 1% and 3% values as well.

The detailed results of the analysis using 2% real discount rate and a 50 year time horizon (discounting all costs and benefits that register during the next 50 years) are in 0. There is a net monetised overall benefit of about HUF 1.16 billion. In case of a 1% real discount rate net benefits would increase to HUF 2.71 billion, while a 3% discount rate would reduce them to HUF 0.02 billion, still a positive result. Obviously, results are highly sensitive to the level of the real discount rate. A low interest rate will result in a higher present value for costs and benefits farther in the future, and since most of the costs are up-front investment type costs while most benefits take place in the future, lower interest rates will improve the cost benefit balance substantially.

In case of public investments on long life-cycle infrastructure the 1%-3% interval of discount values could be considered as an acceptable range. In this range of discount rates the time horizon becomes crucial, if it is too long, it implies an unjustified bet on unchanging circumstances, while setting it too short keeps important segments of the impacts out of the analysis. Dyke developments are a long term public investment, it is safe to assume that at least a 50 year period of operation should be expected.

Costs and benefits of dyke relocation, 2% real discount rate

Stakeholder	**Description**	**Present value (million HUF)**
State (flood)	**Total Investment costs**	**-5,453**
Society (flood)	**Flood risk reduction**	**6,026**
Society	**Carbon sequestration**	**274**
Local population	**Non-monetised benefits**	

Farmers	**Land purchase is part of the total investment costs**	
Anglers	**Fish spwaning area**	**311**
All stakeholders together	***Net monetised benefit (+) or cost (-)***	***1,157***

A number of non-monetised items could further modify these results, but it is unlikely that they would represent such a high level of cost that would turn the current positive expectations around, especially since non-monetised benefits substantially outnumber non-monetised costs.

The main cost type is the up-front investment cost (altogether HUF 5.3 billion) paid by the state[1], while the main benefit is reduced flood risk (HUF 6 billion) enjoyed by and spread through society. From a different perspective this is also a state benefit, since it reduces other types of flood defense costs of the state. From the perspective of the state, the relocation of the dyke is a good investment, already justified by flood risk reduction alone.

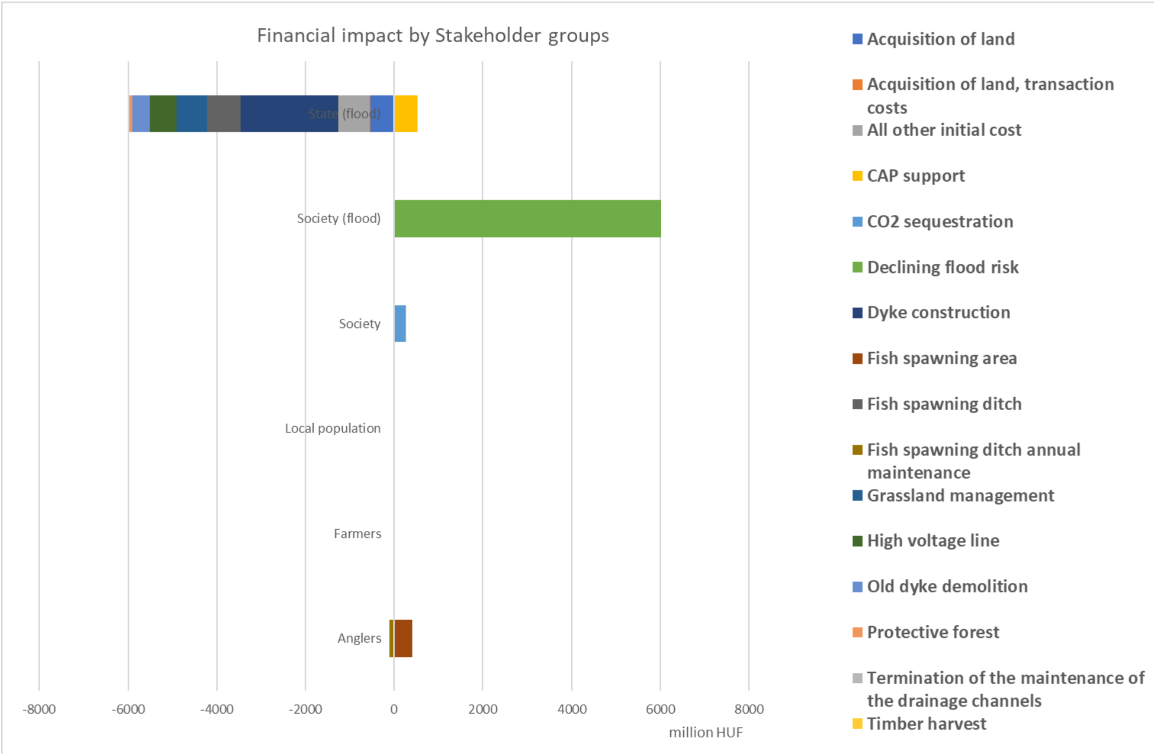
Looking at other stakeholders, society (in its numerous manifestations) will reap a wide variety of benefits, only part of which was possible to monetise, to some extent balanced by one type of cost, due to ending crop production. We can safely assume that for society as a whole, the project is advantageous.

Part of the local population can benefit from enhanced opportunities for hunting, beekeeping, fishing and other activities, all in all, the changes are positive for them.

Anglers, through their associations, – if in charge of taking care of the spawning grounds – will face a new annual expenditure, but in exchange they can substantially reduce their fish stock replenishment expenditures, overall enjoying a sizeable financial benefit.

Financial impact by stakeholder groups

[1] By state cost we mean the central budget and KÖTIVIZIG together



5.4 Risk evaluation of the chosen scenario and risk management strategy

We consider any event that endangers or hinders the successful implementation of the project to be a risk. Risk can occur at any stage of the project and can stem from a number of factors. In connection with the planned project, the possibility of technical, legal, social, economic, environmental, natural, climatic, institutional and financial-sustainability risks also arises. Of course, not all risks are of equal weight; the risk classification depends on the extent of the expected effect and the probability of the occurrence of the risk if the risk occurs. Based on both the expected impact and the probability of occurrence, each risk was classified on a three-point scale, as follows:

In case of risk, the expected impact is:

1-Non-significant risk

2-More significant risk

3-Very significant risk

Probability of occurrence of a risk:

1-Low probability risk

2-Medium probability risk

3- High probability risk

Based on the above scoring, the risk rating is given by the product of the scores given for the probability of occurrence and the degree of impact. According to them, the risk rating is as follows:

Risks scored 1-2 points - Less significant risks

These risks are usually not an immediate response or treatment, but a constant attention and response during the project. they require prior preparation and avoidance. Treatment here is mostly about measures to prevent this from happening.

Risks scored 3-4 points - Major risks

Dealing with the risks listed here already requires prior preparation.

Risks scored 6 points - Most significant risks

In case of their treatment or occurrence, immediate response and prior preparation for their occurrence is essential. Preparation of a detailed risk management strategy and action plan is part of the preparation.

Risk assessment and management

Risks	**expected impact**	**Probability of occurrence**	**Risk score**	**Risk management strategy**	**Responsible**	**Deadline**
Preparation phase						

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
Social and economic risks						
Resistance of affected landowners, residents, municipalities, or green organizations	2	1	2	Forums, public hearings, project brochures, press releases, involvement of relevant landowners in planning and preparation	Project manager, PR organization	continuously
Environmental, natural, climatic risks						
Modification of design conditions with increasing frequency / value of floods, increasing probability of other climatic conditions	3	2	6	Careful planning; taking into account other experiences	Technical-water management expert	continuously
Technical risks						
Information is published on the basis of which the areas affected by development and their immediate surroundings	3	1	3	**financial provisioning**	Project manager, Technical-environmental expert	During project preparation

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
are declared to be protected areas from the point of view of heritage protection.						
Legal risks (also in the implementation and operational phase)						
Non-compliance with applicable laws, standards, regulations	3	1	3	Continuous monitoring of legislation, contact	Technical-environmental and legal expert	continuously
Modify legislation, standards, regulations	3	1	3	Continuous monitoring of legislation, contact	Technical-environmental expert, legal expert	continuously
Risks to financial sustainability (also in the implementation phase)						
Improper resource allocation	3	2	6	Reserve formation, cost reallocation	Project manager, financial expert	continuously
Underestimation of necessary costs	3	2	6	Reserve formation, cost reallocation	Technical-environmental and financial expert	continuously
Institutional risks (also in the implementation phase)						

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
Conflicts within the Project Consortium	3	1	3	Consultations, discussions, constant contact	Project owner's representative, project manager	continuously
The operation of the project management organization is inadequate	3	2	6	Consultations, discussions, constant contact	Project owner's representative, project manager	continuously
Conflicts arising from certain different ownership / management relationships of the flood protection system (municipality, state, private, water company, etc.)	3	1	3	Consultations, discussions, constant contact	Project owner's representative, project manager	continuously
Implementation phase						
Social and economic risks						
Resistance and dissatisfaction of the affected landowners, the population, local	2	1	2	Forums, public hearings, project brochures, press releases	Project manager, head of PR organization	continuously

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
governments or green organizations						
Environmental, natural, climatic risks						
Disturbance of protected areas / species, natural values, damage during construction	3	1	3	Careful planning, Selecting the right contractor, Transferring risk, proper scheduling of works	Project manager, technical-environmental expert, public procurement expert, contractor	During preparation, during the preparation of the public procurement notice, continuously
Technical risks						
Preparation of inappropriate documentation	3	1	3	Selection of a suitable designer (Contractor), Continuous consultations, preliminary assessment of official needs	Project Manager, Technical-Environmental Expert, Public Procurement Expert	continuously
Prolongation of the adoption and issuance of plans and permits by the Authority	3	2	6	Ongoing consultations, (temporal) provisioning, preliminary assessment of official needs	Technical-environmental expert	continuously

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
Due to unfavorable weather and elemental disasters, the implementation of the project is delayed	3	1	3	Temporary reserve formation, appropriate work schedule	Technical-environmental expert, Contractor	During project preparation, continuously
Procurement of necessary materials, tools, machines, vehicles is difficult (inadequate quality, excessive price increase)	3	2	6	**financial provisioning**	Technical-environmental expert, Contractor	During project preparation, continuously
Insufficiency and non-compliance of material extraction sites	3	1	3	**financial provisioning**	Technical-environmental expert, financial expert, Contractor	When preparing a project or making plans
Inadequate construction	3	1	3	Risk transfer, continuous monitoring of works, immediate accountability	Technical-environmental expert, technical inspector	continuously

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
Construction delays, delays / omissions by suppliers, failure of machinery, poor work organization, labor shortages, bankruptcy of the contractor, etc. due to	3	2	6	Provisioning, risk transfer, preparation of internal control plan and quality assurance plan	Technical Expert, Contractor	During project preparation, continuously
Operational phase						
Social and economic risks						
Dissatisfaction of affected landowners, residents, municipalities or green organizations	2	1	2	Forums, public hearings, project brochures, press releases	Project owner's representative	continuously
Environmental, natural, climatic risks						
Extreme weather conditions, water management situations, higher (than planned) flood levels	3	2	6	Proper, careful, prudent long-term planning	Technical-water management expert	Pro-ject during preparation, immediately in case of occurrence

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
Technical risks						
Occurrence of construction problems	3	1	3	Risk transfer to constractor	Project owner's representative	Immediately upon occurrence
The structures failure, damage	2	1	2	Control, monitoring, immediate intervention	Project owner's representative	continuously, immediately upon occurrence
Failure to perform the necessary maintenance and operation activities or to perform them to an inadequate standard	3	1	3	Control, monitoring, immediate intervention	Project owner's representative	continuously
Risks to financial sustainability						
The maintenance of the elements of the system and the financial background of the operation of the system are not guaranteed	3	2	6	Arranging the financing of the water sector: the implementation of the territorial water management concept - in order to	Project owner's representative	continuously

Risks	expected impact	Probability of occurrence	Risk score	Risk management strategy	Responsible	Deadline
				facilitate this, continuous negotiations, contacts, enforcement of interests		
Institutional risks						
Institutional transformation / reorganization at the institution that responsible for the operation	2	2	4	Consultations, discussions, continuous contact	Project owner's representative	continuously
Conflicts arising from the relations of some different owners / operators / cultivators of the flood protection system (municipality, state, private person, water management, etc.)	3	1	3	Consultations, discussions, continuous contact	Project owner's representative	continuously

5.5 Implementation of the project and timeline

In the project development phase, the preparation of the Feasibility Study and the public procurement documentation for the Implementation, as well as the preparation of the PR activity and the real estate purchase will take place. In the first 15 months of the project implementation phase, the founding documents, the licensee's plans are prepared, the licenses are obtained, and the real estate is purchased. Site preparation can start in August 2020, and then we have calculated 22 months for the actual construction.

Milestones

sn.	Planned date of achievement of the milestone	Name of milestone
1.	2020.01.01.	Carrying out project preparation
2.	2020.08.01	Commencement of construction work
3.	2021.06.30.	50% progress in construction work
4.	2022.05.30.	Completion of construction work

5.6 Communication and publicity

Communication about the project lasts from the beginning to the end of the project, following the most important steps of implementation, the expected milestones. The project can be divided into three phases in terms of communication. In the preparatory phase from the conclusion of the grant contract to the physical start, the aim is to plan the applicable communication tools and timetable, as well as to inform the population, the target groups concerned, increase acceptance and involve the landowners concerned. In the physical implementation phase, the aim is to provide continuous information on the project results, to make the individual milestones known to the public and stakeholders. In the phase from the physical completion of the project to the financial closure, ie in the post-implementation phase, the aim is to present the results of the completed investment and their positive effects. Examined from the point of view of professional goals, the first and most important task of communication is to present the project, to acquaint it with the target groups, to accept it, and to communicate clearly the benefits of its implementation for the stakeholders. The aim is also to answer and clarify the possible questions, doubts and objections of the stakeholders. It is important to provide accurate, professional, credible information, to deliver positive messages, to deal with possible conflict situations, to increase public confidence, and to support the positive perception of the beneficiary. The communication target group of the project can be considered directly the population of the affected settlements, as well as the tourists and holiday owners visiting here, as well as those who do not live in the project area but have a job in the area (ie regularly staying here), farmers, entrepreneurs and businesses. However, it is also very important that the professional (disaster protection, water management, environmental protection) state and non-governmental organizations, as well as the decision-making bodies are properly informed.

Monitoring requirements

KÖTIVIZIG will be the manager of the section of the Tisza River affected by the project, and at the same time the provider of maintenance and operation tasks after the implementation of the project. In the case of floodplain reconstruction interventions, the tasks related to the maintenance and repetitive management of the area in order to maintain the appropriate condition come to the fore. The created assets and new flood protection embankments will become state property.

After the completion of the constructions, an important aspect is the continuous monitoring of the area from the point of view of flood protection, nature protection, ecology and socio-economic aspects. Land use change may require the study of the formed flora and fauna with the involvement of the affected organizations (eg nature conservation, forestry, hunting company). In addition, the maintenance and operation of the fish spawning area and the related infrastructure in cooperation with the fishing association and nature conservation is an important aspect.

VI. Appendixes

VII. Literature

2007/60/EC Directive of the European Parliament and of the Council on the assessment and management of flood risks

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4.2. Slovenia

Feasibility study Kostanjevica na Krki

REPORT IS BASED ON TRANSLATION OF PROJECT:

Investitor:	**Direkcija RS za vode,** **Hajdrihova 28c,** **1000 Ljubljana**
Projekt:	**Načrtovanje ukrepov in izdelava projektne** **dokumentacije za namen zmanjšanja poplavne** **ogroženosti območja pomembnega vpliva poplav** **Kostanjevica na Krki ter za strokovno podporo pri** **izvajanju delovnega WP4 Interreg DTP projekta** **Danube Floodplain**
Del projekta:	**ŠTUDIJA IZVEDLJIVOSTI**
Vrsta proj. dok.:	**študija**
Sklop (faza):	**4. mejnik** [redacted]

Izdelovalec: **SL CONSULT d.o.o.**

Dimičeva 9, 1000 Ljubljana

Odgovorni predstavnik podjetja: Mirjan Poljak, direktor

Vodja projekta : Anica Smrekar, univ. dipl.ekon.

Številka dela projekta: 16/19

Datum: V Ljubljani, december 2019

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FIGURES

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5

Introduction

This feasibility study was finished in December 2019 by client SL CONSULT, d.o.o., and according to Slovenian by-law act Decree on the uniform methodology for the preparation and treatment of investment documentation in the field of public finance (Official journal of RS, No. 60/06, 54/10 and 27/16). The study was reported in P4 to the 1st level control and in eMS. Here follows an extensive study summary with comments.

The main objective of the feasibility study is to provide the bases for planning measures to reduce the flood risk of the Kostanjevica na Krki pilot area with the simultaneous protection or restoration of the floodplains. In addition, the goal is to assist in the implementation of the Danube Floodplain project and preparation of flood maps for a wider area.

The pilot area that is the subject of this documentation is the area of Kostanjevica na Krki together with Krakovski gozd (Krakovski forest) and Šentjernejsko polje (Šentjernejsko field). Due to the objectives of flood risk reduction, we have prepared three scenarios as part of the documentation.

As part of the study, we made a mathematical hydraulic model of the Krka River from Gorenje Gomila to Podbočje for the existing situation and all three scenarios. The results of hydraulic models for all three scenarios were evaluated with hydrological and hydraulic parameters according to the FEM method in the Kostanjevica na Krki pilot area.

For each scenario, a conceptual design of measures was made and a rough inventory of construction works was given.

Data on calculated flood water depths and cost of measures are used for a cost-benefit analysis made for all three scenarios. The KRPAN application was used for the estimation of expected annual flood water damages.

From the results of evaluation according to the FEM method and the results of calculations shown in the annexes, the following conclusions can be made (from the point of view of hydraulic and hydrological parameters):

- None of the considered scenarios has a significant impact on the regime of flood water runoff in the area of the APSFR (area of potentially significant flood risk) Kostanjevica na Krki. Despite the perceptible reduction of the peak flow through the APSFR area (by 2.11 - 3.69 % at the return period Q100), this has a minor effect on the calculated levels themselves. With all different combinations of measures, the calculated level in the APSFR area at Q100 does not change by more than 1cm.

Measures to activate floodplains have little effect on reducing flows on APSFR Kostanjevica na Krki. However, since the western area of the Krakovski forest has an outflow downstream from Kostanjevica (Sajevec stream), additional activation with corridors K3 and K4 also results in a rise in the peak at the lower boundary condition at Gauging station Podbočje. This means that this area acts not only as a flood retention basin but to some extent also as a flood-control reservoir.

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- The riverbed deepening measure (K1) has no measurable impact on the expected flood water levels.

- Due to the very small impact of scenarios 1 and 3 on the Kostanjevica APSFR area itself, the first preliminary damage calculations show even higher damages for the planned situation. We estimate that these two scenarios slightly improve the situation in the APSFR area, but increase the flooding in the area where the flood waters run through the corridors, and the calculated damages are higher in that area.

The floodplains of the Krakovski forest along the Krka river in the area observed are already activated in the existing state, even during frequent floods. According to the results of the modelling, the additional activation of floodplains does not bring significant improvements in the hydraulic-hydrological parameters in the area of the APSFR Kostanjevica na Krki.

- A measure that could ensure the protection of the area and of the facilities within the APSFR Kostanjevica, is the construction of prefabricated walls (those that are installed only for the duration of the floods) and / or permanent embankments that would surround the endangered settlement. In this way, the intrusion of flood water into the area of settlement would be prevented, and the surroundings would still be flooded in the same way as in the existing condition.

- As measures in the riverbed itself and the measures for the activation of floodplains discussed in this documentation do not bring significant improvements to the hydraulic and hydrological parameters, the question arises as to the appropriateness of further consideration of these measures. If the increase of the inflow to floodplains in very frequent floods (Q2-Q5 and more often) is useful from other aspects, in our opinion it makes sense to consider the corridor K3. However, that should be implemented in quite reduced extent of the measure itself, as it has no significant effects from the flood risk point of view.

Based on the prepared cost-benefit analysis for each individual scenario, we can summarize:

- The total investment value of individual scenarios is the highest in the case of scenario 2, around EUR 9.8 million €.

- Financial indicators are negative in all three scenarios, as the project as such does not generate direct revenues.

- Based on the economic analysis, we can conclude that the positive economic net asset value is only in scenario 2, which takes into account, among other measures, also protective measures within Kostanjevica itself. There occur the greatest effects, especially in terms of benefits due to the flood risk reduction.

- In the case of scenarios 1 and 3, the risk of flooding even increases and additional costs are incurred.

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Figure 1: Comparison of financial and economic indicators in the context of cost-benefit analysis in each scenario

	SCENARIO 1	SCENARIO 2	SCENARI4 3
Total investment value including VAT	2.849.302,22	9.833.948,41	4.715.148,90
Annual additional and maintenance operating costs	22.929,14	84.237,83	34.914,89
Financial indicators:			
Financial net present values	- 2.931.066,76	- 10.559.776,92	- 4.791.521,46
Financial internal return rate	- 2.931.066,76	-0,23	-0,19
Economic indicators:			
Average annual benefits from lower average annual claims	-57.000	551.000	-45.000
Average annual benefits from biodiversity conservation and adequate protection of Natura 2000 protected areas	48.402	58.899	49.568
Net present value	-2.492.214	1.466.468	-3.768.257
Economic return rate	/	6,32%	/

Benefit-cost ratio (B / C ratio)	-0,06	1,17	0,02

1 PRESENT STATUS

1.1 Geographical description of the area

The Krka river has its source in the western Suha krajina area in picturesque karst spring Pod jama, a few meters lower from Krška cave. There the water from the wider karst hinterland comes to the surface, the largest part from 5 km distant sinks at the southeastern end of Radensko field. Just 500 m downstream, the Poltarica stream is joining from the west, which also flows from a karst spring on the south side of the village Gradiček. Another 500 m further on the Višnjica stream, the only non-karst tributary in the entire upper course is joining from the east.

Initially it runs 28 km southeast along a wide valley formed along the Žužemberk joint, which has a very unusual cross section - the river flows most of the way through a narrow, 10–25 m deep valley with steep slopes. The river bottom is carved into the solid old rock base of the older valley. There remained a 1-2 km wide bottom from the valley on both sides of the river, on which many villages and their fields found plenty of space. On the way through Suha krajina area, the river Krka increases imperceptibly, as water from the karst underground flows into it from both sides. There are many tiny springs that only get stronger during prolonged rains, and some are just mighty, like e.g. stream Globočec, a right tributary near Zagradec, from which a large part of Suha krajina area is supplied with drinking water. Tominčev well on the right bank of the river Krka below Podgozd is one of Slovenian most abundant karst springs - at high water it reaches a flow of up to 10 m^3 / s.

A special feature of this part of the valley are the tufa cascades - Krka river is the only major river in Slovenia that deposits tufa. The most numerous and most beautiful are between Zagradec and

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Žužemberk, and then between Dvor and Gornji Kot. Tufa is made of calcium carbonate ($CaCO_3$). It is deposited on mosses and other aquatic plants, that's why it is very perforated, light and relatively soft, and was once also used as a building stone. Numerous mills and sawmills once operated along the tufa cascades, but today all but one are abandoned.

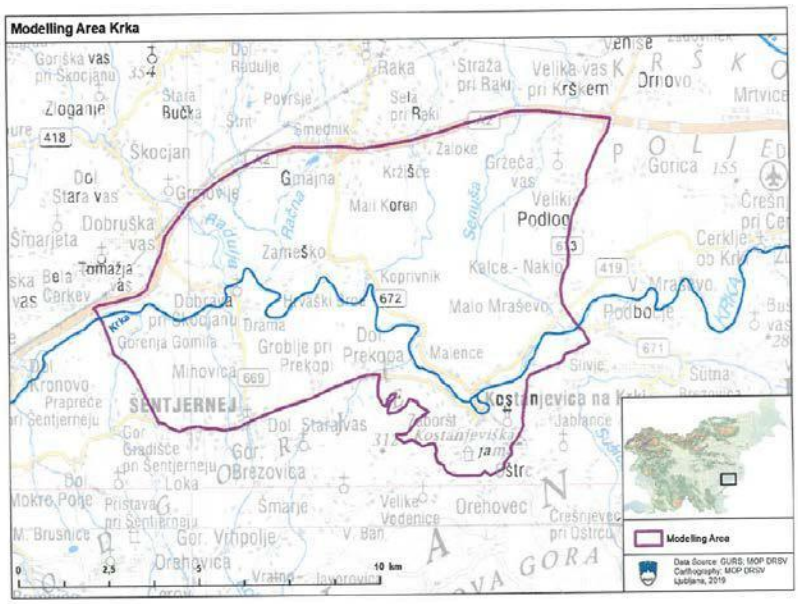
Downstream Dvor, the character of the Krka valley changes completely. The wide valley turns into a narrow, about 5 km long gorge between the steep slopes of the Ajdovska plateau on the north and Kočevski Rog region on the south. At the lower end of the gorge are the remains of the castle of the same name, and soon after it the river makes a distinct turn and heads towards the northeast. Streams Radeščica and Sušica join it from the right, and the valley widens into a small Straška basin - this is one of the youngest collapse valley in Slovenia, as according to geologists it sank only in the Pleistocene. The Prečna stream flows into it from the left, and from the right it gets some smaller tributaries from the karst foothills of Gorjanci mountain.

A little further on, the river Krka eroded the rock solid base and flows in two beautiful turns through Novo Mesto town, where the old part of the city is squeezed to the inner side of the river Krka meander. It also continues to run along a narrow valley 20-30 m beneath the slightly undulating and slightly karstic terraces, all the way to Otočec, where Otočec castle stands on one of the tufa islands. A little lower, at Dolenji Kronov, the Krka turns into a slow lowland river. Along it is an ever-widening floodplain, which on the right side barely noticeably rises into a huge Šentjernej fan. Several streams from Gorjanci flow from the right side into Krka, which winds further towards the east and at Kostanjevica na Krki town and again approaches the foothills of Gorjanci hill. On the left it is accompanied by the extensive Krakovski forest, the largest lowland forest in Slovenia.

In the Krško-Brežiško field, in the last ice age the river Sava filled an extensive gravel fan, which pushed the river Krka again right at the foothills of the Gorjanci hill.

The pilot area, which is the subject of this study, is the area of Kostanjevica na Krki together with Krakovski forest and Šentjernejsko field and represents one part of the entire Krka river basin.

Figure 2: Modelling and pilot area



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1.2 Climatic characteristics

Slovenia lies at the junction of the Alps, the Pannonian plain, the Dinaric massif and the Mediterranean basin. Due to this diversity, the climate is also very variable. The Krka river basin, which is part of Sava river basin region, is mainly influenced by the sub-Pannonian or Continental climate. Due to its open position to the east, milder sub-Pannonian climatic characteristics are gaining ground in the Brežice-Krško basin. Hot summers are typical, which are among the warmest in Slovenia and not too cold winters. Frequent thermal inversions and fogs are related to the annual average relative humidity, which reaches 80%. For this part of Posavje basin the frequent rains and storms, which cause excessive rising of water in watercourses are characteristic. In recent years there has been a very common occurrence of hailstone. Recently, longer and longer periods of drought which is causing damage, especially on agricultural land is noticed. There are also dangerous phenomena of hoarfrost and frost in agriculture.

1.3 Soil

The area of Kostanjevica na Krki is located in the southeastern part of Slovenia, more precisely it is located in the southern part of the Krško basin, which is a Quaternary tectonic sink basin formed above the Neogene syncline. A newer theory about the formation of the Krško basin says that it is a Quaternary syncline, which was formed by compression tectonics, what was later confirmed by seismic reflection measurements in the area between the Inner and Outer Dinarides. The immediate vicinity of Kostanjevica na Krki consists of alluvial river sediments of Holocene age, consisting of clays, sand and small pebbles. Here predominates gray to red clay with an admixture of sand and gravel, which is of finer granulation and is properly rounded. This type of gravel is called the Krško gravel. It differs from the Sava in terms of pebble diameter and roundness. In the Krakovski forest and its surroundings, it is also possible to observe the fossil river bed of the Krka river and its terraces, which were formed when the Krka changed its flows.

The biggest question is the exact dividing line between the Sava and Krka rivers in terms of fossil flows. The Krka flowed into the Sava several times at different locations, and roughly speaking, the fossil flow of the Krka River in the SW-NE direction, and the fossil flow of the Sava River in the NW-SE.

1.4 Nature

There are two NATURE2000 areas in the project area:

- Krakovski forest (Krakovski gozd), Area ID: SI3000051, name of the group SAC
- Krakovski forest – Šentjernejsko field (Krakovski gozd - Šentjernejsko polje), area ID: SI5000012, name of the group SPA

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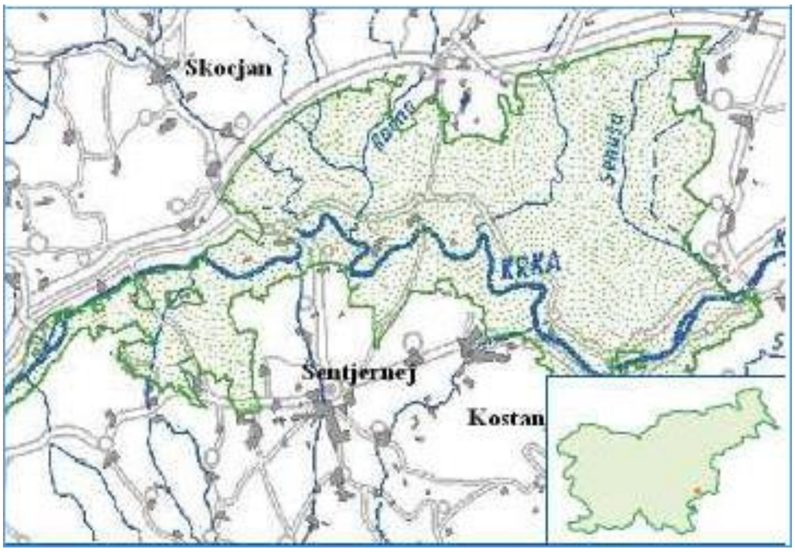
Figure 3: The area of Krakovski forest and Šenjernejsko field



The Krakovski forest is the largest lowland floodplain forest covered with oak and hornbeam in Slovenia at the transitional area of continental and Pannonian climate. It covers an area of 2,400 ha between the Sava rivers in the north and Krka in the south. In the heart of the forest is 42 ha of preserved secondary primeval forest, which has been protected as nature reserve. In that primeval forest there are oaks, up to 40 m in size and more than 250 years old. In addition to oak there also grows hornbeam and black alder in heavily soaked soil.

The Krakovski forest provides shelter for many species of animals and plants and is a wetland of national importance. 122 bird species have found their place here, many of them are very rare in Slovenia (e.g. black stork and white -tailed eagle). One of the most famous wetlands in the area is Trstenik, which is an important bird area in Europe, a spawning ground for fish and frogs. The most beautiful example of this is a frog (*Rana arvalis*) that acquires a distinctive blue color during spawning. The Krakovski forest is also home to the protected plants such as marsh tulip (*Fritillaria meleagris)*.

1.5 Cultural heritage

Units of immovable cultural heritage are entered in the Register of Immovable Cultural Heritage (RKD) kept by the Ministry of Culture. Areas of immovable cultural heritage are subject to different legal regimes according to their status (cultural monument, registered cultural heritage) and type (building, settlement, garden architecture, memorial heritage, cultural landscape). All units are entered in the Register of Immovable Cultural Heritage at the Ministry of Culture with a registration number (EŠD).

The following cultural heritage of the area observed is recorded:

- 16525 Malo Mraševo – Archaeological site Gomilke-Grubelce
- 16535 Slinovce – Building site Hrastina
- 17420 Slinovce - Homestead Slinovce 3
- 5574 Sajevce – Mound cemetery

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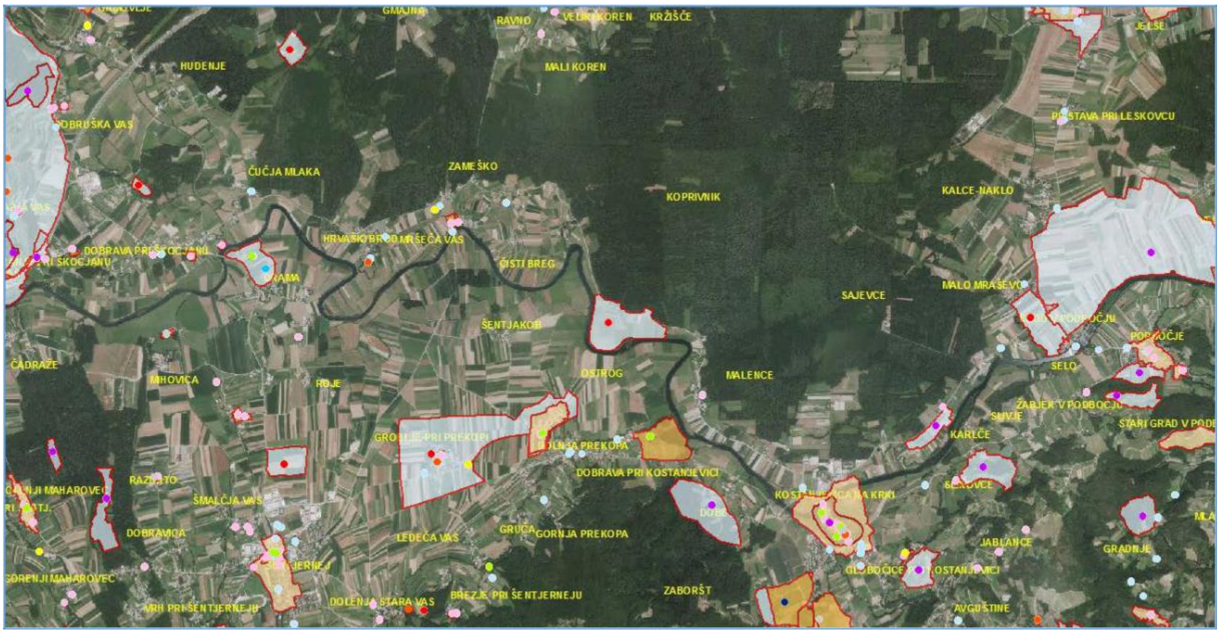
- 262 Kostanjevica na Krki – Old town centre
- 25834 Dobrava pri Kostanjevici – Manor with park
- 19613 Mršeča vas - Homestead Mršeča vas 2
- 19612 Mršeča vas - Homestead Mršeča vas 4
- 8744 Mršeča vas - Wooden bridge over the river Krka
- 8697 Zameško - House Zameško 1
- 27397 Zameško - Šjorov drying-frame
- 16523 Koprivnik pri Kostanjevici na Krki – Archaeological site Cizelj
- 30031 Hrvaški Brod - Manor Gutenwerd
- 2434 Čadraže – Church of St. Urh
- 19632 Čadraže - Pavlinov drying-frame
- 2434 Čadraže – Church of St. Urh
- 8706 Mihovica – House of the Jordan family with its collection
- 19599 Drama - House Drama 22
- 2504 Drama - Church of St. Nikolaj
- 8614 Drama - The area of the medieval town of Gutenwerth
- 19017 Dobrava pri Škocjanu - Homestead Dobrava pri Škocjanu 38
- 19015 Dobrava pri Škocjanu - Homestead Dobrava pri Škocjanu 26

- 18425 Dobrava pri Škocjanu - Drying-frame on homestead Dobrava 22

- 29621 Dobrava pri Škocjanu - Drying-frame on homestead Dobrava pri Škocjanu 21

Figure 4: The locations of the cultural heritage sites and objects



Reference: http://giskd6s.situla.org/giskd/

The town center of Kostanjevica lies on a river island, which is a specialty among Slovenian cities. Due to its ambient exceptionality, Kostanjevica na Krki gained monument protection status.

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Main features:

- **Parish Church of St. Jakoba** is the oldest preserved building in the city, first mentioned in documents in 1220.

- **Wooden oak bridges** - due to the nearby Krakow Forest, wooden oak bridges are typical for this area; the most interesting is the Tertiary Bridge, designed by the architect Jože Plečnik.

- **Ministerial Palace of the Spanheims** (Lamut Art Salon) from the end of the 15th century;

Since 1958, an art exhibition place for occasional exhibitions of the Božidar Jakac Gallery has been arranged in the eastern wing, and since 2017 it has also housed the Tourist Information Center (TIC).

- **Iva's house (Ivina hiša)** is the largest burgher house on the island - built in 1878, renovated into beautiful tourist apartments under the name Vila Castanea.

- **The Church of St. Nicholas** was first mentioned in sources in 1581, and its interesting features are beautiful frescoes painted by the local Jože Gorjup.

- **Jože Gorjup Elementary School**, built in 1906, has the largest Central European mosaic on the west side, "The Battle of the Krško Field", and it houses many works of art by Gorjup's Gallery.

1.6 Administrative division of the area

The area of consideration takes place in the following administrative units:

- Municipality of Kostanjevica na Krki: settlements Dobrava pri Kostanjevici, Karlče, Koprivnik,

Kostanjevica na Krki, Malence, Sajevce

- Municipality of Krško: settlements Brod in Podbočje, Malo Mraševo, Selo

- Municipality of Šentjernej: settlements Čadraže, Čisti Breg, Drama, Gorenja Gomila, Hrvaški Brod, Šentjakob, Zameško

- Municipality of Škocjan: settlements Čučja Mlaka, Dobrava pri Škocjanu

1.7 Population

The area observed is administratively located in the area of four municipalities, the Municipality of Kostanjevica na Krki, Krško, Škocjan and Šentjernej. At the beginning of 2019, there were a total of 38,861 inhabitants in the area of all municipalities, of which 1,725 lived in the area of matter. In the last 10 years, it can be observed that the number of inhabitants is increasing, with an average annual growth rate of 0.12% or in the area of the settlements of matter in the amount of 0.31%.

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Figure 5: Number of inhabitants in the area of the municipalities of Krško, Kostanjevica na Krki, Škocjan and Šentjernej and settlements that are the subject of the consideration for the period 2008-2019

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average growth (2008-2019)
Municipality of Krško	25.933	25.600	25.795	25.867	25.886	26.050	25.893	25.835	25.884	25.853	25.833	25.996	0,02%
Brod v Podbočju	104	101	97	98	99	100	100	101	104	105	113	115	0,92%
Malo Mraševo	115	109	109	111	108	108	114	115	125	123	125	129	1,05%
Selo	13	13	13	13	12	13	11	12	10	10	10	10	-2,36%
Municipality of Kostanjevica na Krki	2.467	2.413	2.421	2.404	2.413	2.416	2.399	2.455	2.419	2.425	2.437	2.450	-0,06%
Dobrava pri Kostanjevici	47	40	40	40	34	30	27	25	25	25	24	24	-5,93%
Karlče	10	10	9	9	12	11	10	9	10	10	9	9	-0,95%
Koprivnik	13	13	14	12	11	11	12	12	10	9	10	10	-2,36%

Kostanjevica na Krki	712	701	705	695	703	711	704	720	717	707	720	729	0,21%
Malence	64	60	56	58	62	63	60	67	67	67	63	64	0,00%
Sajevce	26	23	22	20	20	21	22	21	20	21	21	21	-1,92%
Municipality of Šentjernej	6.745	6.694	6.727	6.779	6.882	6.908	6.946	6.990	6.993	7.094	7.062	7.125	0,50%
Čadraže	79	80	78	76	81	81	84	87	92	89	86	85	0,67%
Čisti Breg	27	25	24	25	24	22	23	25	21	22	18	20	-2,69%
Drama	81	84	83	95	95	94	94	94	93	97	96	98	1,75%
Gorenja Gomila	75	78	81	86	88	87	84	93	97	101	102	102	2,83%
Hrvaški Brod	75	66	71	67	72	72	71	73	70	70	71	67	-1,02%
Šentjakob	36	35	34	34	34	35	36	35	35	30	30	27	-2,58%
Zameško	100	98	98	99	100	100	96	99	96	99	98	99	-0,09%
Municipality of Škocjan	3.212	3.177	3.273	3.212	3.193	3.224	3.221	3.224	3.236	3.267	3.261	3.290	0,22%
Čučja Mlaka	22	19	19	21	19	23	23	22	23	23	23	23	0,40%

Dobrava pri Škocjanu	184	184	209	197	196	202	203	214	215	217	220	222	1,72%
Municipalities - together	38.357	37.884	38.216	38.262	38.374	38.598	38.459	38.504	38.532	38.639	38.593	38.861	0,12%
Settlements in the area observed	1.668	1.630	1.653	1.645	1.662	1.676	1.660	1.709	1.705	1.702	1.714	1.725	0,31%

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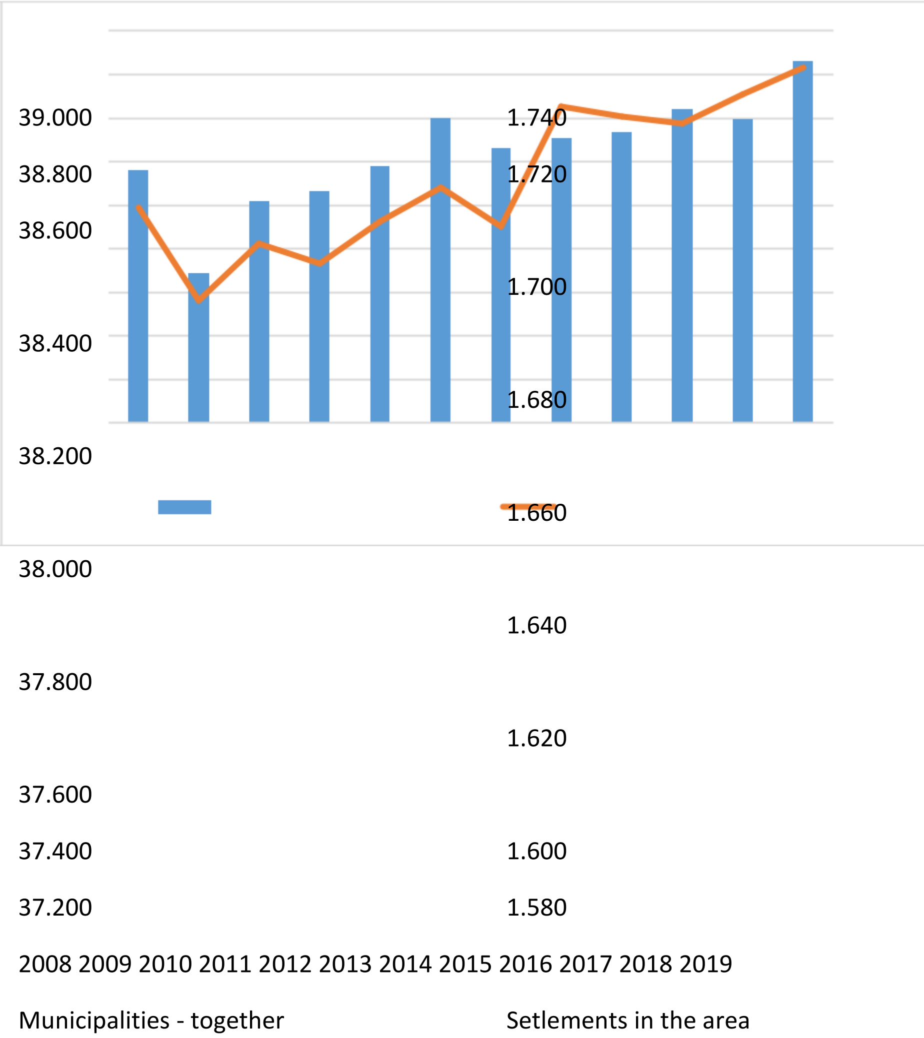
Figure 6: Number of inhabitants in the area of the municipalities of Krško, Kostanjevica na Krki, Škocjan and Šentjernej and settlements for the period 2008-2019



Reference: SURS

1.8 Economy

Kostanjevica na Krki is a newly formed municipality located in the south of the region. It is known mainly for its cultural and natural heritage. The town lies on the island of the river Krka and is one of the oldest and at the same time the smallest Slovenian town. It was first mentioned in 1220 as the seat of the parish. It received its city rights in 1252. The city structure with two streets has been preserved until today, when the place was declared a cultural monument. Due to frequent floods, the town became known as "Dolenjska Venice". On Venice is also associated with a number of cultural monuments and art collections that visitors can see: the Božidar Jakac Gallery and Forma Viva. Other tourist attractions offered by Kostanjevica na Krki include the Karst cave, the Krakovski forest, boating on the Krka river, fishing, hunting, cycling and a good restaurant offer.

The municipality of Krško is the largest municipality in the Posavje region. In the past, it has developed due to the manufacturing industry and energy, but in recent years it has undergone radical changes in the economy. The Krško Nuclear power plant and the Brestanica thermal power plant operate in the Municipality of Krško, and the construction of the Krško Hydroelectric power plant is planned as part of the construction of a chain of hydroelectric power plants on the lower Sava river. In addition, the municipality has a rich tradition of metal processing, papermaking, viticulture and fruit growing. The heritage of the past is also rich: finds from the Stone age in Ajdovska cave, from the Iron age in Libna above Krško, remains of the Roman town and river port of Neviodunum near Drnovo, medieval castles and churches - Rajhenburg nad Brestanico castle is the first medieval castle in Slovenia.

In the **Municipality of Šentjernej**, agrarian and viticultural activity predominates. After the collapse of the larger industrial plant Iskra, more and more unemployed people found employment in crafts. There are quite a few successful entrepreneurs and craftsmen, good inns, well-stocked shops, and top winegrowers and cellars - producers of the best Dolenjska wine. On the slopes of Gorjanci, high-altitude game hunting is possible. Fishing is most widespread on the Krka river and its tributaries.

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The municipality of Škocjan was founded in 1994, when it (as the first of several municipalities in time) separated from the hitherto territorially largest Slovenian municipality Novo mesto.

In the year 2017, there were 178 companies in the municipality of Kostanjevica na Krki, which generated 68 million € in revenue, there were 1.991 companies in the municipality of Krško, which generated 3.488 million € in revenue, and 459 companies in the municipality of Šentjernej with 156 million € in revenue, and in the municipality of Škocjan there were 190 companies, which together generated 40 million €in revenue.

Figure 7: Number of companies, number of working persons, revenue (in 1000 €), and number of persons working in companies in specific municipality for the year 2017

	No. of companies	No. of working persons	Revenue [1000 EUR]	No. of parsons/company in municipality
SLOVENIA	**195.756**	**881.920**	**108.840.205**	**4,5**
Kostanjevica na Krki	178	803	68.054	4,5
Krško	1.991	9.027	3.488.168	4,5
Šentjernej	459	1.933	156.903	4,2
Škocjan	190	471	40.953	2,5

Reference: SURS

Agriculture (vegetable and fruit plantations along the Krka river) and the development of tourism (Kostanjevica na Krki) play an important economic role for the area in question. In recent years, there has been an increase in tourist arrivals and overnight stays, which in the year 2018 tripled compared to the year 2014.

Figure 8: Number of tourists and overnight stays of tourists by municipalities for the period 2014-2018

	2014		2015		2016		2017		2018	
	Arrivals of tourists	Overnight stays of tourists	Arrivals of tourists	Overnight stays of tourists	Arrivals of tourists	Overnight stays of tourists	Arrivals of tourists	Overnight stays of tourists	Arrivals of tourists	Overnight stays of tourists
together	625	1.079	775	1.710	1.248	2.477	1.287	2.577	1.928	3.551

Kostanjevica na Krki	domestic	271	336	267	402	411	682	440	700	607	1.032
	foreign	354	743	508	1.308	837	1.795	847	1.877	1.321	2.519
	together	3.743	11.359	3.613	10.184	3.252	11.195	4.065	11.130	8.216	24.392
Krško	domestic	1.723	4.924	1.164	2.520	1.229	3.821	1.458	3.548	3.136	7.608
	foreign	2.020	6.435	2.449	7.664	2.023	7.374	2.607	7.582	5.079	16.784
	together	840	1.875	919	1.997	952	2.024	955	2.129	543	1.636
Šentjernej	domestic	565	1.288	623	1.356	644	1.364	643	1.406	253	924
	foreign	275	587	296	641	308	660	312	723	290	712
	together	890	1.606	782	1.311	975	1.803	925	1.463	2.424	9.235
Škocjan	domestic	217	413	156	326	226	388	216	346	307	2.620
	foreign	673	1.193	626	985	749	1.415	709	1.117	2.117	6.615

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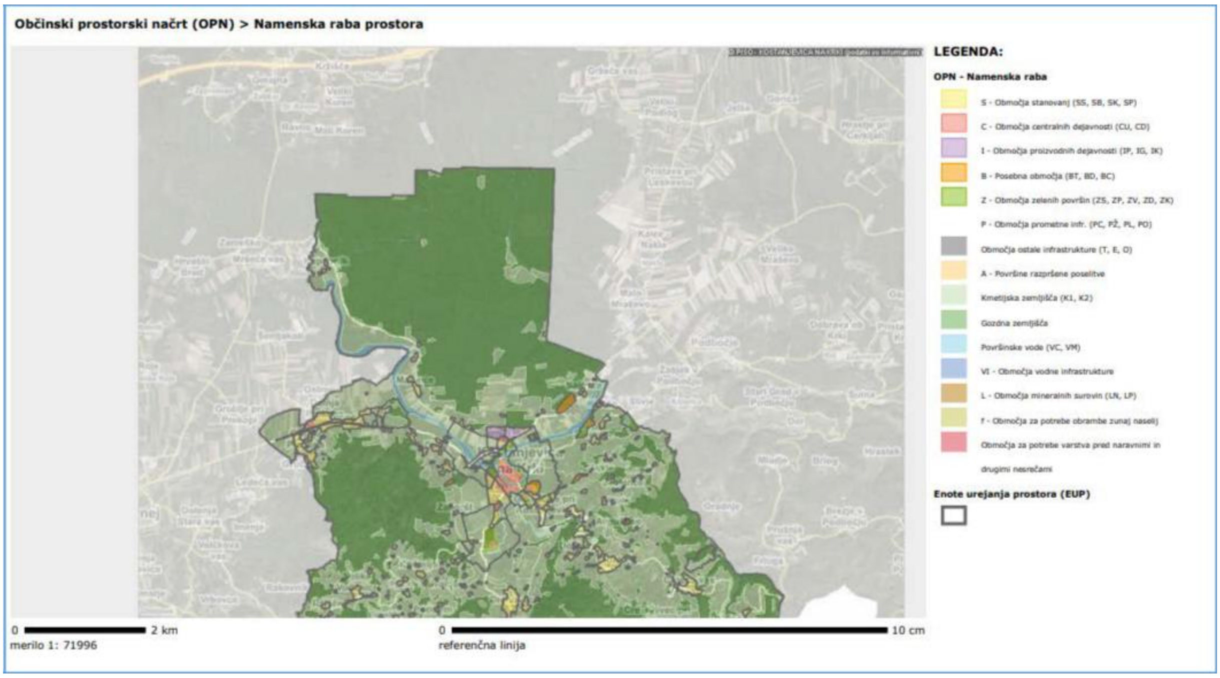
1.9 Land use

In the project area, most of the land use in the municipalities is intended for forest areas (Krakow Forest area), followed by areas of agricultural land. In the area of Kostanjevica, the land along the left bank of the Krka is intended for production activities. the area of the old town is defined as the area of central activities.

In the following, we are describning the land use characteristics on the basis of municipal spatial plans.

Figure 9: Municipal spatial plan (OPN) – the land use in the Municipality of Kostanjevica na Krki



Glossary of the figures 9 - 12:

Občinski prostorski načrt - Municipal spatial plan

Območja stanovanj - Residential areas

Območja centralnih dejavnosti - Areas of central activity

Območja proizvodnih dejavnosti - Areas of production activities

Posebna območja - Special areas

Območja zelenih površin - Green areas

Območja prometne infrastrukture - Transport infrastructure areas

Območja ostale infrastrukture - Other infrastructure areas

Površine razpršene poselitve - Dispersed settlement areas

Kmetijske površine - Agricultural land

Gozdna zemljišča – Forest land

Površinske vode - Surface waters

Območja vodne infrastrukture - Water infrastructure areas Območja mineralnih surovin - Mineral resource areas

Območja za potrebe obrambe zunaj naselij - Areas for defense purposes outside settlements Območja za potrebe varstva pred naravnimi in drugimi nesrečami - Areas for protection against natural and other disasters

Enote urejanja protora - Spatial planning units

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Figure 10: Municipal spatial plan (OPN) – the land use in the Municipality of Krško

Figure 11: Municipal spatial plan (OPN) – the land use in the Municipality of Šentjernej

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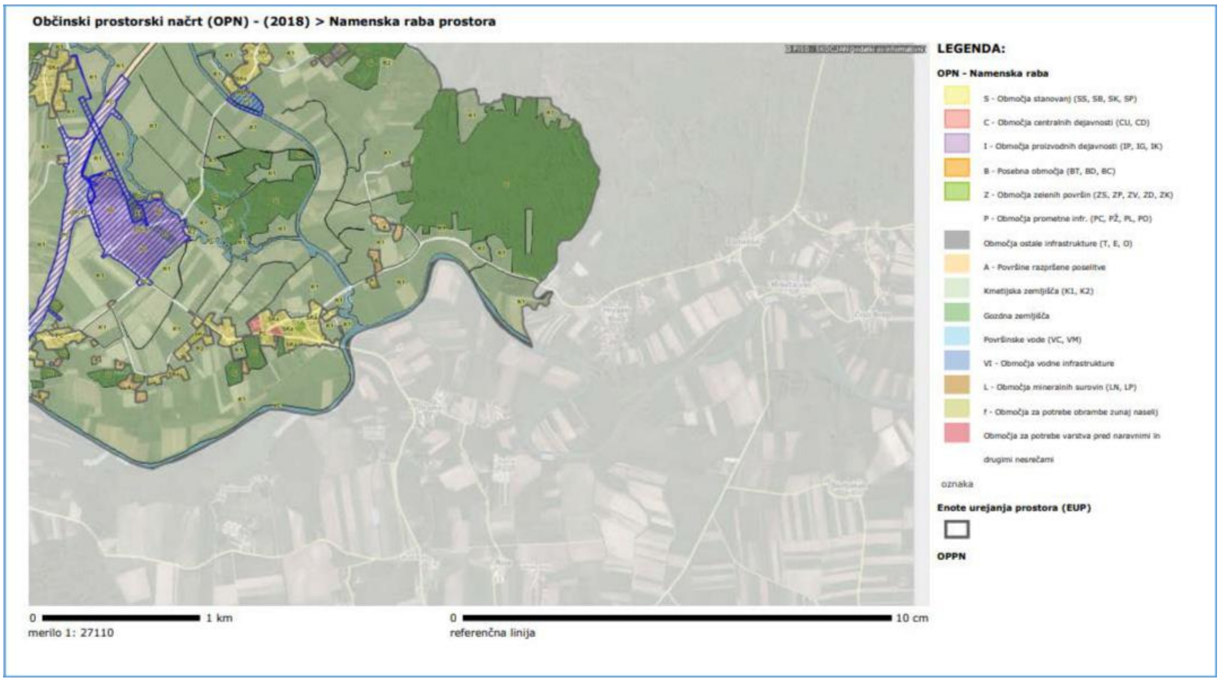
Figure 12: Municipal spatial plan (OPN) – the land use in the Municipality of Škocjan



1.10 Threat assessment

From the aspect of nature conservation, the most important species of birds are in the Šentjernejsko field depend on preservation of the traditional cultural landscape of the area. Their important feeding grounds are extensive orchards, pastures and meadows. Their abandonment and the introduction of intensive farming reduce the chances of survival of the endangered birds. Intensive drying has been observed in the Krakovski forest since

1980. Possible causes for this phenomenon can be found in irrigation interventions in the vicinity of the forest, which supposed to lower the groundwater level. The problem is also the illegal felling of old trees, which takes place in the protected central part of the forest.

2 ANALYSIS OF THE NEEDS AND OBJECTIVES

2.1 Legislation framework

The project takes into account social, economic and environmental factors of the area, which are in line with the relevant background documents and information of the financial perspective 2014-2020 and the Normative framework for the implementation of European cohesion policy.

The legislation framework and its system of in the implementation of European cohesion policy follows the regulation of the European Union (Parliament, Council), delegated and implementing regulations of the European Union (Parliament, Council, Commission).

Beside that the legislation of the Slovenian legal order was followed (the directives, regulations and agreements of Nature Conservation Act, Environmental Protection Act, Water Act, etc.).

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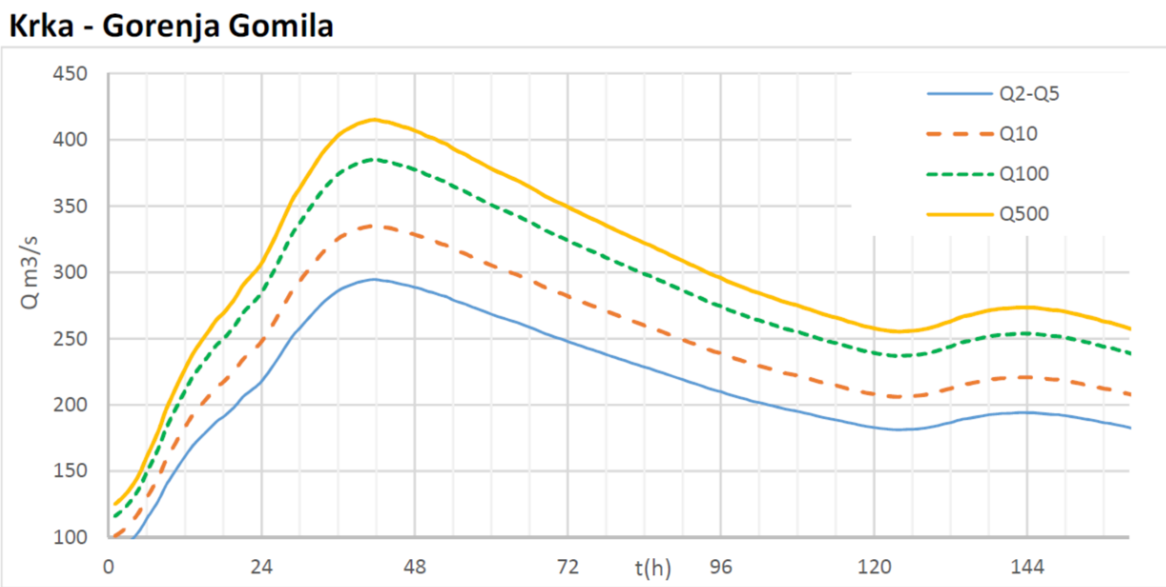
2.2 Hydrological analysis

In accordance with the project task, hydrological data on the characteristic flows and waves needed for hydraulic analyses were summarized after the last hydrological study, which dealt with Krško (*Hidrološka študija Krke, HEK Doroteja Starec s.p., 2/2017-DS, november 2018*).

Hydraulic analyses were performed for the return periods Q10, Q100 and Q500 (return periods as prescribed by the regulations for the production of flood hazard maps), and due to the requirements of the project task also for the return periods Q2-Q5. There are no data on the return periods Q2 and Q5 in the above mentioned hydrological study, so we obtained them directly from the author of the study. For the peak of the return period Q2-Q5, we used the arithmetic mean between the peaks for Q2 and Q5, and the waveform is the same as the dimensionless wave prepared as part of the above mentioned hydrological study. In the conceptual design of the hydraulic model and its calibration, we used the findings and results from the documentation *Hidrološko hidravlični elaborat za OPVP Kostanjevica na Krki, iSprojekt d.o.o., 7-S/17, januar 2018* (*Hydrological and hydraulic study for APSFR Kostanjevica na Krki, iSprojekt d.o.o., 7-S/17, January 2018).*

As the upper boundary condition (input hydrogram), we used in all calculation cases high-water waves with return periods Q2-Q5, Q10, Q100 and Q500 for hydrological section Krka to Gornja Gomila from above mentioned hydrological study. In all cases, we used a so-called composite wave (double-peak wave), which is given as the most representative in this study.

The input hydrographs of Krka used for all return periods are summarized in the figure below. *Figure 13: The upper boundary conditions used*



	obstoječe stanje OS (=PS1=PS2.2=PS3)			
	Q2-Q5	Q10	Q100	Q500
	Q[m3/s]	Q[m3/s]	Q[m3/s]	Q[m3/s]
maxQ	294.50	335.00	385.00	415.00

The inflows of tributaries of the Krka river in the considered area were taken into account with respect to certain flow peaks for various hydrological cross-sections of the Krka determined in the hydrological study. Part of the inflows was added directly to the Krka riverbed as a longitudinally

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distributed inflow (Distributed source) in the area between two hydrological sections for the section from Gorenje Gomila to Radulja and the section from Radulja to Podbočje.

In addition we added the Radulja inflow to the Krka as a point source (the difference between the hydrographs of Krka to Radulja and Krka below Radulja). In important depression areas on the left bank (outflow section of Račna and Sajovec east and west of the Smednik-Zameško road), we added springs in the 2D model to the model, with which we modeled the filling of floodplains with water from the tributaries of the Krka and not only directly from the Krka riverbed. The shape of all hydrographs used was identical to the shape of the hydrograph of the upper boundary condition (Krka Gorenja Gomila, composite wave from the hydrological study). In the process of calibrating the model, we iteratively increased the lateral inflows into the model so long that we achieved a good match of the peak of the output hydrogram from the hydraulic model at water level gauging station Podbočje with a specific hydrogram at water level gauging station Podbočje from the hydrological study.

For the model calibration (water level), we used data on measured surface heights in the Kostanjevica na Krki area during the 2010 flood event (source: iSprojekt 2018) and data from water level gauging station Podbočje (source: ARSO).

Figure 14: Data used for model calibration from flood event 2010

Točka	Opis	X (G.K)	Y (G.K)	measure	calculation	difference
t1	Gauging station Podbočje	535754	80110	150.83	150.83	0
t2	Kostanjevica – otok	532887	78130	152.08	151.99	-11cm
t3	Kostanjevica – pri lesenem mostu, levi breg Krke, severna struga	532828	78372	151.93	152.03	+10cm

According to previously prepared documentation (iSprojekt 2018), the flood of tributaries in the area of Kostanjevica (Obrh and Studena) is not relevant. Also, given the ratio of the size of watercourses (Krka / tributaries) and the morphology of the terrain (flat, lowland, large floodplains), we can conclude that the Krka flood is relevant everywhere, except at the very edge of the flood reach. The same conclusion follows from the comparison of the calculated flood of the Krka and the maps made in the past, which are shown on the Water Atlas application (in the area of the Radulja estuary).

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3 HYDRAULIC MODEL OF THE KRKA FROM GORENJA GOMILA TO PODBOČJE

3.1 General - concept

For the purposes of this task all hydraulic calculations were made with the mathematical software MIKE FLOOD v. 2012 which enables simultaneous calculation of one-dimensional flow in the riverbed (1D model) and two-dimensional calculation of floodplains (2D model). Both models exchange data on water depth and speed with each other in each time sequence. This way we can more accurately determine the reach of flood waters and the depth of floods, as the program as a result gives us the depth of water in each individual cell of the calculation area. Due to the size of the modeling area in the 2D model, we used a relatively large computational cell measuring 15x15 m.

Figure 15: Area considered, 1D model scheme

In the 1D model, we modeled the basic river bed of the Krka river in the entire area, cross-sections were determined by a combination of LIDAR image data and bathymetric measurements. We did not have data about tributary riverbeds. We introduced 1D model of riverbeds of larger tributaries on the left bank of Krka river into the model, but only in the places where they cross the road, so that we can better model the passage of Krka water (and also its larger tributaries) through the road embankments. This way, we entered six culverts in road embankments (listed in the direction from west to east) into the model:

- culvert (bridge) on the Radulja stream
- culvert (bridge) on the Račna stream
- doble culvert under the road Smednik-Zameško
- culvert on the Sajovec stream
- culvert on the Lokavec stream
- culvert on the Sajevec stream

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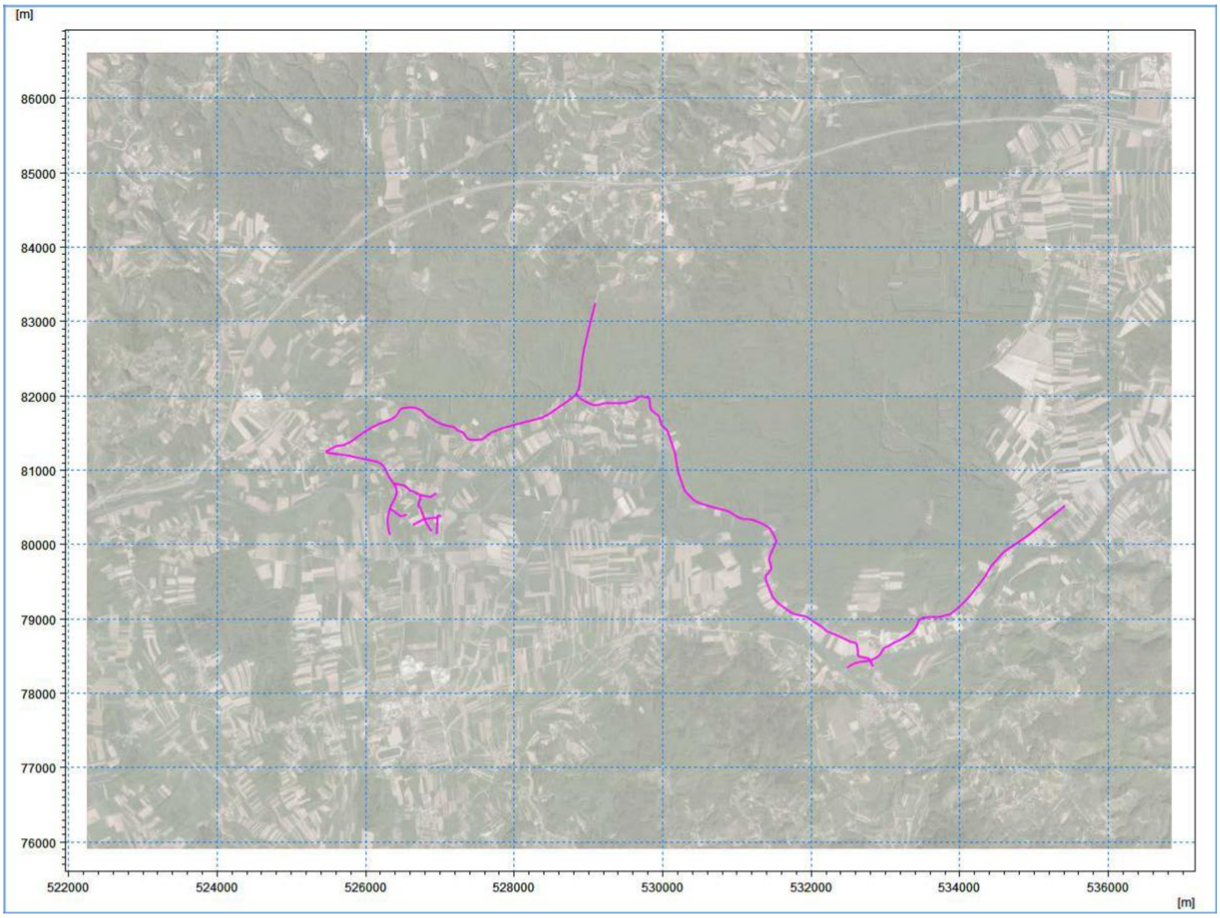
Since geodetic data on culverts were not available, the used dimensions of the openings are a rather rough estimation made only on the basis of LIDAR data.

A 15x15m model cell was used for the preparation of 2D model bathymetry. Because this cell is too large to capture road embankments (which are narrower than 15 m), we (for hydraulics) entered important road embankments into bathymetry directly from the LIDAR image as a high of model cell.

Figure 16: Routes of embankments on which we corrected the bathymetry of the 2D model



The inflows of tributaries of the Krka river were taken into account with respect to certain flow peaks for different hydrological cross sections of the Krka river determined in the hydrological study. Part of the inflows was added directly to the Krka riverbed as longitudinally distributed (Distributed source) in the area between two hydrological sections for the section from Gorenje Gomila to Radulja and the section from Radulja to Podbočje. In addition, we added the Radulja inflow at the Radulja estuary to the Krka as a point source (the difference between the hydrographs of Krka to Radulja and Krka below Radulja). In important depression areas on the left bank (outflow section of Račna and Sajovec east and west of the Smednik-Zameško road) we added to the model the springs in the 2D model, with which we modeled the filling of floodplains with water from the tributaries of the Krka and not only directly from the Krka riverbed.

The shape of all hydrographs used was the same as the shape of the hydrograph of the upper boundary condition (Krka Gorenja Gomila, composite wave from the hydrology study).

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In the process of calibration of the model, we iteratively increased the side inflows into the model for so long that we achieved a good match of the tip of the output hydrogram at gauging station Podbočje with that from the hydrology study.

All lateral inflows are taken into account only by complementary waves. All calculated results thus represent the Krka flood event. According to previously prepared of flood risk maps, the flood of tributaries in the area of Kostanjevica (Obrh and Studena) is not competent. According the ratio of the size of watercourses (Krka / tributaries) and the morphology of the terrain (flat, hollow terrain), we can conclude that the Krka fiver flood is competent everywhere, except at the very edge of the flood reach. The same conclusion follows from the comparison of the calculated Krka river flood and maps produced in the past (iKRPN layer on ATLAS VODA ("Water Atlas" application) in the area of the Radulja estuary.

3.2 Boundary conditions

Lower boundary conditions

For the lower boundary condition, we used the Q-H curve at the outflow from the model, which was calibrated according to the data from water level gauging station Podbočje. The lower boundary condition was calibrated according to the data for the high-water event 2010, when, according to official data, the maximum flow on the gauging station was 468.2 m^3/s (20.09.2010, 02:00-06:00), and the maximum level is 150.83 m above sea level.

Upper boundary conditions

In all models we used as the upper boundary condition high-water waves with return periods Q2-Q5, Q10, Q100 in Q500 for the hydrological cross section of Krka river to Gorenje Gomila from the hydrological study of Krka. In all cases, we used so-called composite wave.

3.3 Determination of roughness coefficients - model calibration

The model was calibrated according to two different parameters, firstly the matching of the output hydrogram (variation of side inflows into the model) and then also matching the calculated levels with the measured ones (variation of roughness coefficients of the Krka main riverbed and floodplains).

In order to approach the output hydrogram from the Gauging station Podbočje, we had to increase the side inflows into the model by a factor of 2.5 with respect to the difference between the tips of the hydrograms at the GS Podbočje and GS Gorenje Gomila.

By calibration determinated roughness coefficients of the Krka main riverbed (1D model) are ng=0,050-0,065, and on the places of wooden bridges ng=0,080.

At floodplains (2D model), the roughness coefficient was determined as follows:

- ng=0,050 meadow, sparsely inhabited
- ng=0,100 forest
- ng=0,080 densely inhabited

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For the model calibration, we used data on measured points in the Kostanjevica area during the 2010 flood event and data from the GS Podbočje.

Figure 17: Calibration of the model on flood event 2010

Location - spot	Description	X (G.K)	Y (G.K)	mesurement	count	D
t1	GS Podbočje	535754	80110	150.83	150.83	0
t2	Kostanjevica – otok	532887	78130	152.08	151.99	-9 cm
t3	Kostanjevica – at the wooden bridge, left bank of the Krka, northern riverbed	532828	78372	151.93	152.03	+10 cm

In all cases, the calculations showed a much smaller difference between the maximum level at points t2 and t3 than was measured (the calculated difference is 4cm and the measured one is 15cm). Similar results are also in the previously performed hydraulic study. Therefore, the model was calibrated between the measured points t2 and t3.

3.4 Calculation examples

Discharge peak of GS Podbočje for the return period Q100 is practically equal to the maximum flow of the flood event 2010 (Qmax(Q100)=470m^3/s, Qmax(2010)=468m^3/s) the calculation example for calibration of the model represents at the same time the calculation of Q100 existing state.

We performed calculations for four return periods (Q2-Q5, Q10, Q100, Q500) and four different scenarios: current state, scenario 1 (code PS1), scenario 2 (code PS2) and scenario 3 (code PS3), this means 16 (4x4) final calculation cases. We performed significantly much more of the calculations, as the calibration process required an iterative model adjustment process. We also had to add measure K5 to scenario 2 due to the failure to achieve a significant improvement of flood risk situation in the APSFR Kostanjevica na Krki, which was not foreseen in the original calculations.

The calculation time for an individual calculation case is approx. 44h for entire wave above the flow of 150m^3/s at Q100 (wave duration 15 days). In individual calculation cases, due to time savings, the calculations were stopped after a certain time after the peak wave has passed (when the water in the entire area observed has already receded) therefore, in some places the hydrographs in the appendices end earlier.

4 FLOOD HAZARD MAPS

Based on the results of hydraulic models, we drew a map of flood hazard map for the area in accordance with the methodology set out in the by-law act Rules on methodology to define flood risk areas and erosion areas connected to floods and classification of plots into risk classes (Official journal of RS, No. 60/07).

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The rules stipulate that the following contents are drawn on the flood risk map:

- flood range at return period Q10

- for the case of the return period Q100 of the area where

o the depth of the flood water is less than 0.5 m,

o the depth of flood water is between 0.5 and 1.5 m, o the water depth is greater than 1.5m.

For the purpose of determining the residual hazard class, we also plotted the flood range with a return period of Q500. According to the regulations, in addition to depths, flood velocities must be taken into account when determining areas at a return period of Q100, so that wherever the water velocity exceeds 1 m/s, the product of depth and velocity is taken into account instead of depth. In this case, the floods appear in a very flat area in the lower reaches of the Krka river. Flood flow velocities exceed 1 m/s only in particular small areas where water overflows embankments or roads, flood velocities in flood areas otherwise range between 20 in 40 cm/s. The display of maximum speeds is shown in the hydraulic analyses as an example of the existing condition. Based on this presentation, we can conclude that the velocities (or the product of velocity and depth) are not relevant for plotting a flood hazard map in the study area, and this applies to all calculation cases.

For the relevant flood water depth to determine the flood risk areas, we considered the envelope of the calculated depths in all cells of the 2D model, i.e. the maximum value for each individual cell of the calculation model (namely, the highest depths do not necessarily occur in all cells of the computational model in the same time step). In this way, we obtained the necessary data for the production of depth areas according to the criteria from the previous mentioned Rules. The validity area was determined in such a way that the produced maps are representative for the calculation of flood damages in the considered area. All lateral inflows are taken into account only by complementary waves. All calculated results thus represent the Krka river floods. According to previously prepared documentation, the floods of tributaries in the area of Kostanjevica na Krki (streams Obrh and Studena) are not competent. Given the ratio of the size of watercourses (Krka and tributaries) and the morphology of the terrain (flat, hollow world), we can conclude that the Krka river floods are competent everywhere, except at the very edge of the flood reach. The same conclusion follows from the comparison of the calculated Krka river floods and maps produced in the past in the area of the stream Radulja estuary.

At the lower edge of the model, we excluded the area of the lower course of the stream Senuša from the area of validity of maps (and the area of flood damage calculation), as we did not have a dimensions of culvert on the stream Senuša on the Kostanjevica Cerklje ob Krki road in the model. This culvert has no effect on the situation in Kostanjevica na Krki, and the flood reach north of the road calculated in the model is not representative of this part.

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Figure 18: The existing state of the depth curve envelope for Q2- Q5

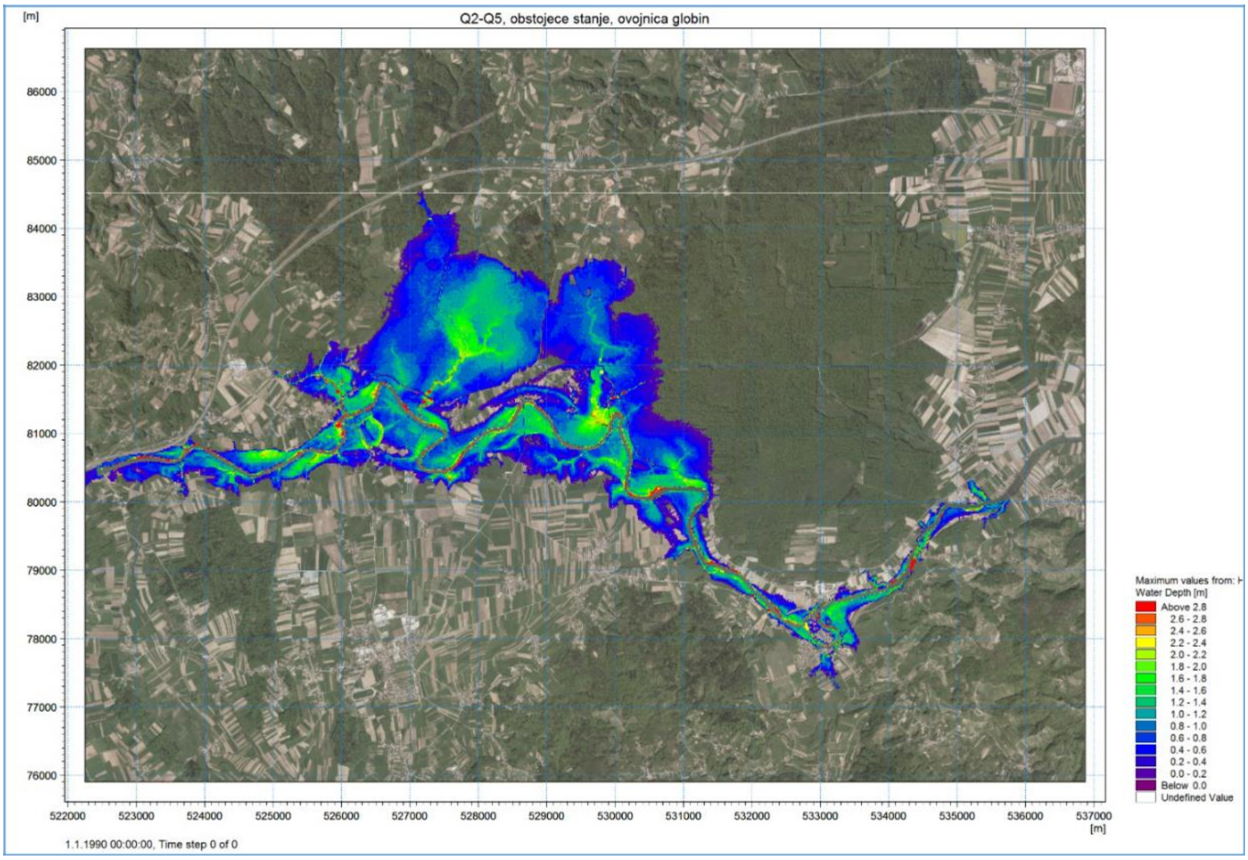

Figure 19: The existing state of the depth curve envelope for Q10

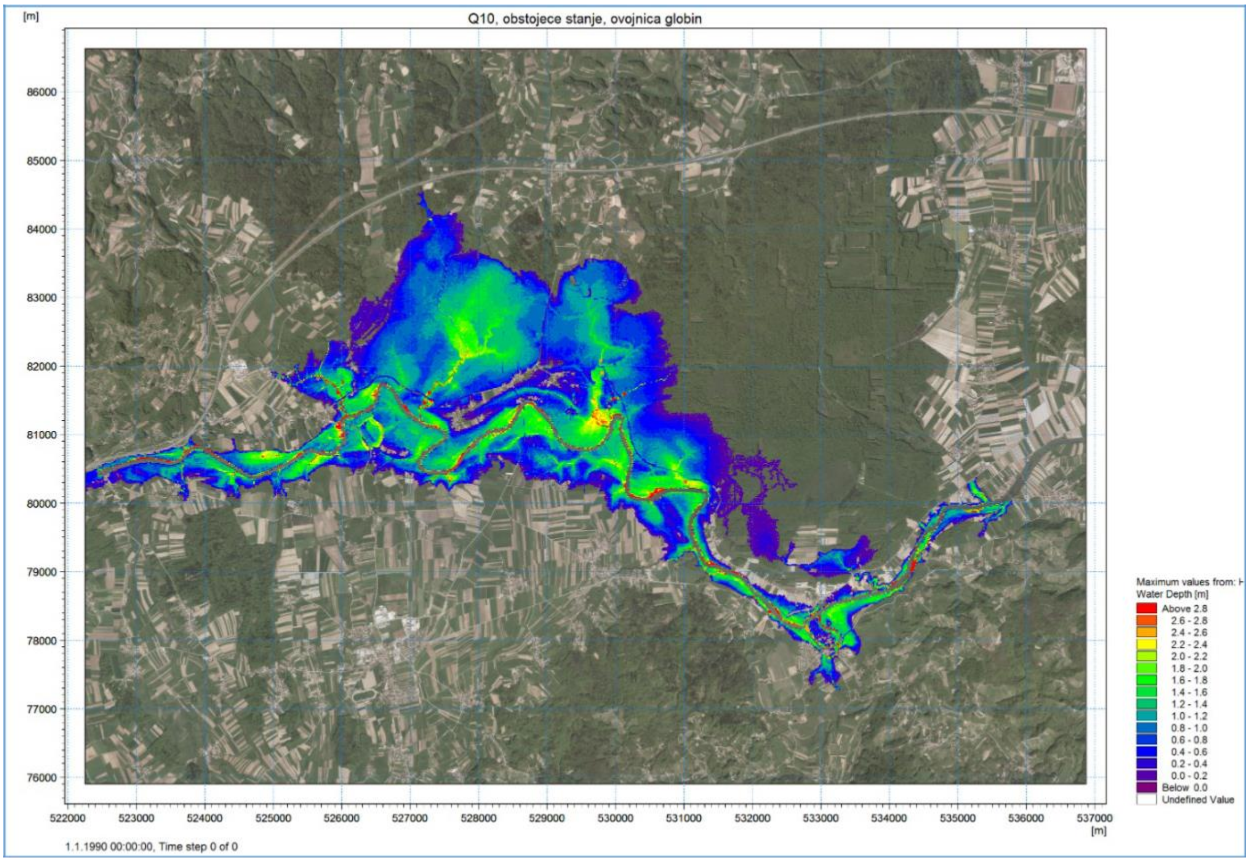

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Figure 20: The existing state of the depth curve envelope for Q100

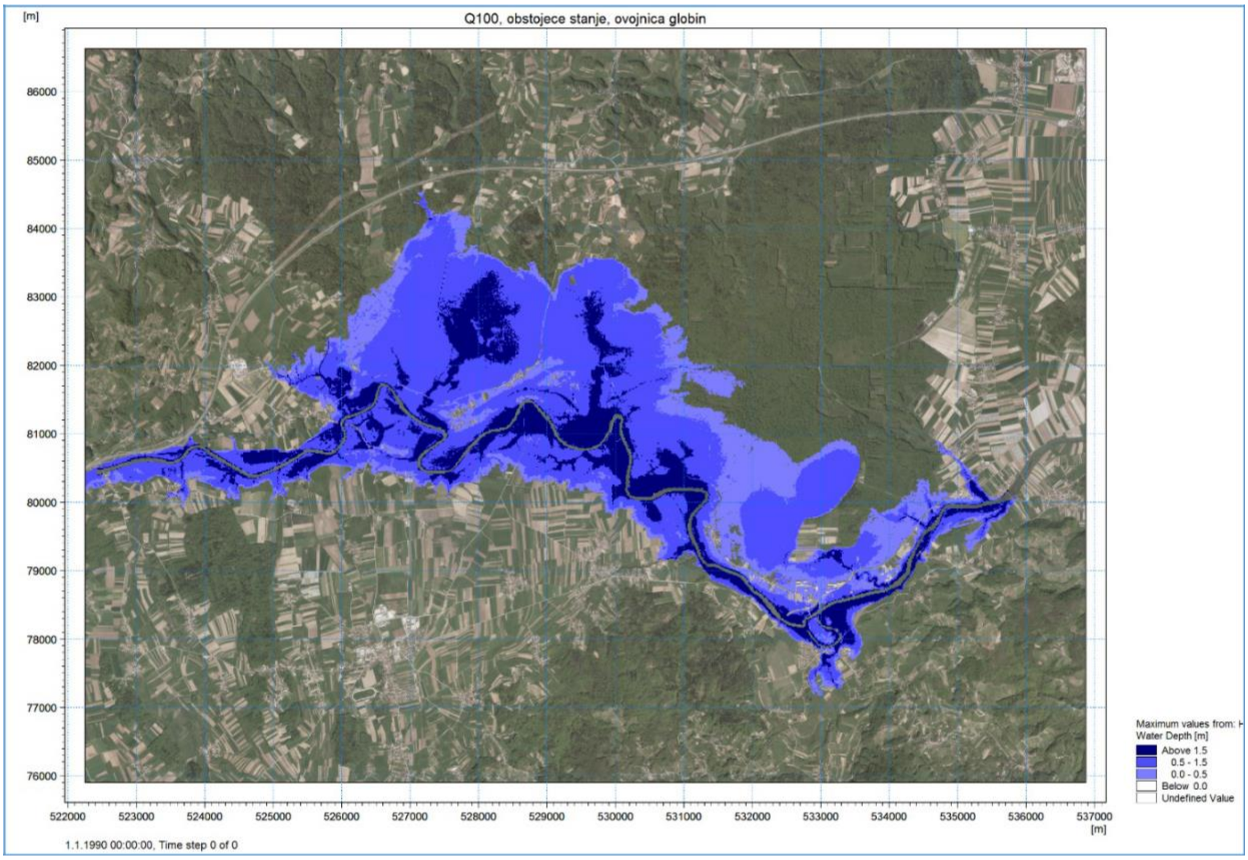

Figure 21: The existing state of the depth curve envelope for Q500

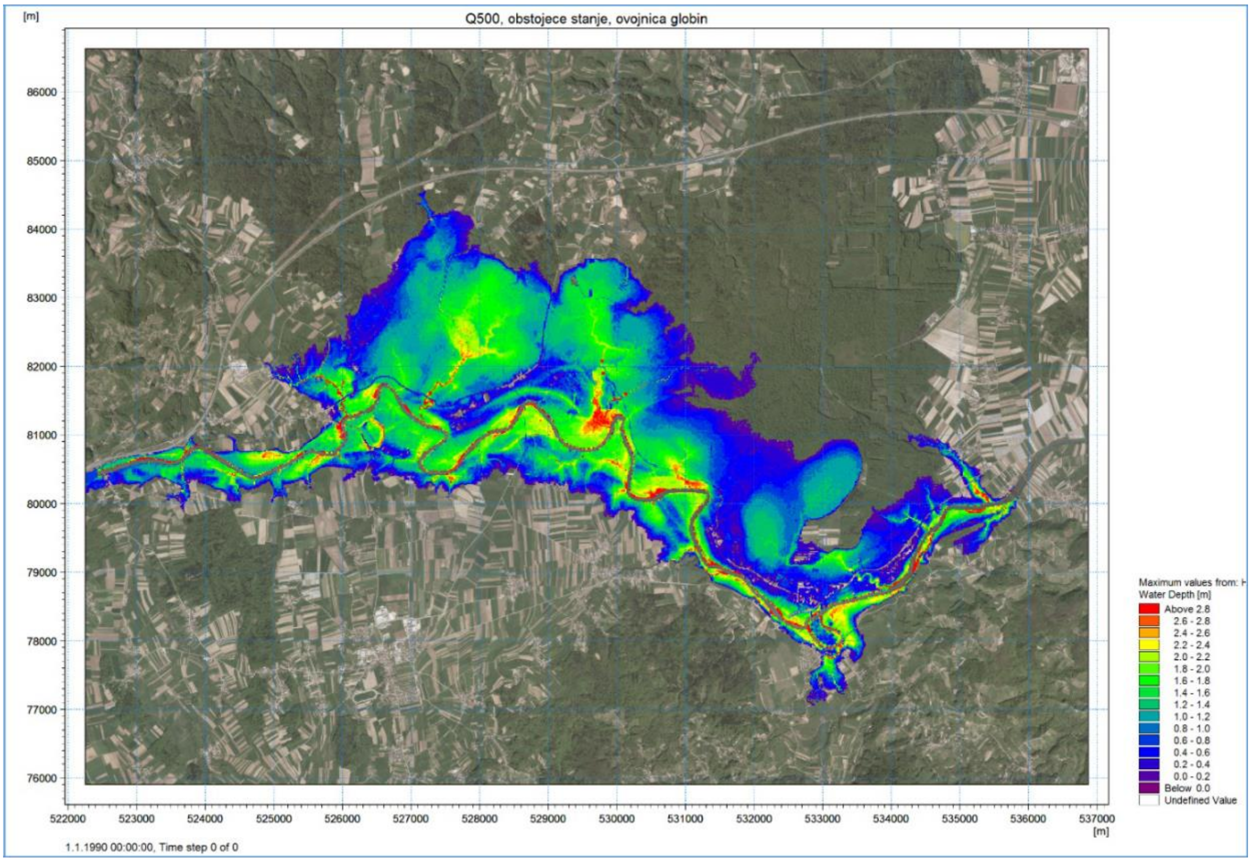

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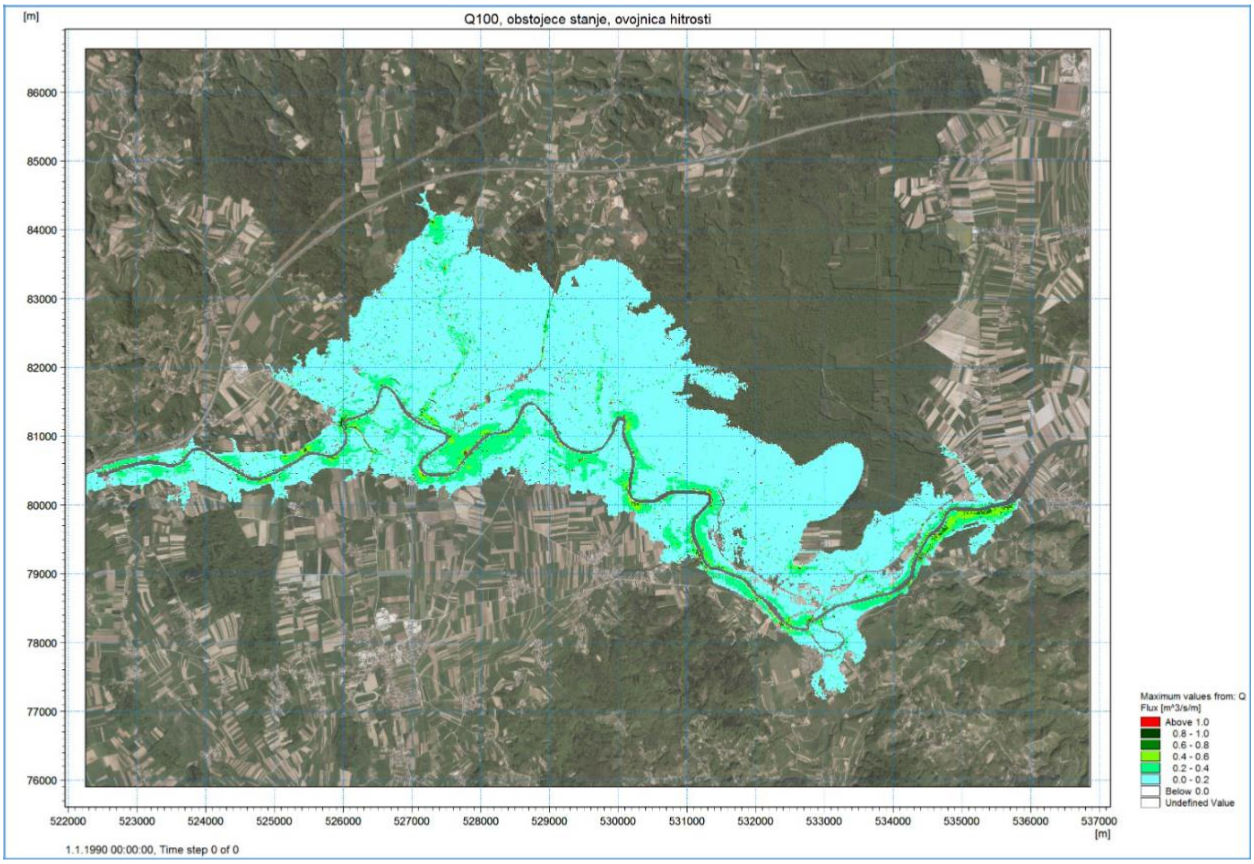
Figure 22: The existing state of the velocities envelope for Q100



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5 FLOOD RISK ANALYSIS

Flood risk is a combination of flood hazard (reach, depth, frequency of floods) and vulnerability of area or individual elements in the area. According to the valid Slovenian legislation, this means the overlap of flood hazard with classes of vulnerability.

Rules on the methodology for determining areas endangered by floods and related erosion of inland waters and the sea, and on the method of classifying land into risk classes (Official journal of RS, No. 60/2007) defines, that the elements of threat are mainly people, the environment, economic and non-economic activities and cultural heritage. The vulnerability of risk elements means their exposure and susceptibility to flood damage and associated erosion and depends on physical, social and economic elements and processes (e.g. spatial positions, structural resistances, time exposures).

5.1 Methodology for flood damage calculating

The KRPAN computer application was used as a basis for determining the benefits of flood risk reduction. It was developed for the purpose of assessing the benefits of construction and non-construction measures to reduce flood risk. It is designed to enable the calculation of flood damage estimates in any area of the Republic of Slovenia. In case of availability of flood reach data for events with return periods of flows T = 10, 100 and 500 years, it allows the calculation of expected annual damages. The calculation of expected damages is also based also on data on flood water depths for a return period of 100 years.

The input data that were included in the KRPAN application were prepared in the same way as they were prepared in the test case that we received together with the KRPAN program and the instructions for its use.

The data are prepared as follows:

1. four layers are prepared for each calculation case:

a. OV - area of validity of maps or area of damage calculation

b. X1 – flood zone Q10

c. C1 - flood zone Q100

d. D1- flood zone Q500

2. All layers are in .shp vector format (polygon shape), all data are in EPSG 3912 coordinate system (Gauss-Krueger). All .shp files must also have the appropriate .prj file, otherwise KRPAN does not work.

3. Layers have water depth H as the only attribute in .dbf files. The latter also applies to the area of validity (although this attribute is not relevant for this layer) otherwise KRPAN does not work.

4. Layers X1 and D1 have the value -99.99 for the H attribute everywhere.

5. 5. Layer C1 has three classes of attribute H, individual areas are grouped into their polygon (or class) according to the following criteria:

a. Depth value between 0 and 0.5m – attribute value H=0.5

b. Depth value between 0.5 in 1.5m – attribute value H=1

c. Depth value more than 1.5m – attribute value H=1.5

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Aarea of validity of maps taken into account in the damage calculations is the same as shown in the plotted flood hazard maps.

The following shows the flood zones for the return periods of 10, 100 and 500, which were taken into account in the context of average annual damages.

5.2 Baseline scenario

Based on the input data, the average annual damage for the existing situation was estimated at 2,092,000 EUR. The calculation of damage for Q10, Q100 and Q500 and the average annual damage are shown below.

Figure 23: Estimated flood damage for the subject area - baseline scenario

Calculation area:			**Kostanjevica na Krki: current status**	
Estimated number of at-risk:	**309**	**540**	**675**	
ENDANGERED	Damage_Q010(€)	Damage_Q100(€)	Damage Q500(€)	**AAD(€)**
CULTURAL HERITAGE - Archaeological heritage	174.387	219.982	262.632	19.677
CULTURAL HERITAGE – Memorial heritage	55.594	94.398	94.398	7.505
CULTURAL HERITAGE – Settlement heritage	21.294	23.804	24.196	2.221
CULTURAL HERITAGE – Profane architectural heritage	123.793	188.293	215.236	15.658
CULTURAL HERITAGE – Sacral architectural heritage	45.288	65.791	65.792	5.525
CULTURAL HERITAGE – Sacral profane architectural heritage	0	374	991	22
CULTURAL HERITAGE – Garden-architectural heritage	0	0	0	0
CULTURAL HERITAGE – Cultural landscape	0	0	0	0

CULTURAL HERITAGE – Historical landscape	0	0	0	0
CULTURAL HERITAGE – Other	0	0	0	0
INFRASTRUCTURE – State roads	241.676	298.274	328.987	26.807
INFRASTRUCTURE – Local roads	111.464	152.985	162.947	13.164
INFRASTRUCTURE – Forest roads	11.348	12.487	13.157	1.175
INFRASTRUCTURE – Electricity underground network	74.700	88.205	94.826	8.063
INFRASTRUCTURE – Water network	134.016	180.354	192.796	15.639
INFRASTRUCTURE – Sewerage network	64.156	105.081	110.229	8.477
AGRICULTURE – Field	284.925	364.052	395.539	32.242
AGRICULTURE – Field - crops	203.739	260.329	282.840	23.056
AGRICULTURE – Meadow	107.274	122.473	127.835	11.340
AGRICULTURE – Field - meadow	331.769	378.821	395.360	35.073
AGRICULTURE – Forest	123.269	172.391	181.476	14.720
BUILDING AREAS – Cleaning and decontamination	308.868	494.632	568.124	40.409
BUILDING AREAS – Personal vehicles	470.136	752.903	864.760	61.507
BUILDINGS- Construction, agricultural equipment and machinery	1.065.490	2.404.092	2.043.038	173.920
BUILDINGS – Construction – residential building	3.729.653	8.538.206	8.992.190	622.175
BUILDINGS – Residental building equipment	2.194.638	4.986.679	5.291.274	364.271
BUILDINGS – Construction – industrial and commercial	46.706	213.098	619.990	15.024
BUILDINGS – Construction – other and auxiliary	784.208	1.598.540	1.845.822	121.001
ENVIRONMENT – Aestetic value, bioeiversity	1.831.993	2.329.520	2.456.276	206.411
TRAFFIC – Personal cars	196.431	342.967	429.384	27.362
APARTMENTS – Residents, alternative temporary residence	185.402	323.712	405.282	25.826
INDUSTRIAL AND BUSINESS ENTITIES	8.400	11.200	22.400	1.016

- Equipment, machinery and supplies – mycro company				
INDUSTRIAL AND BUSINESS ENTITIES - Equipment, machinery and supplies – small company	0	8.000	16.000	456
INDUSTRIAL AND BUSINESS ENTITIES	0	0	20.600	82

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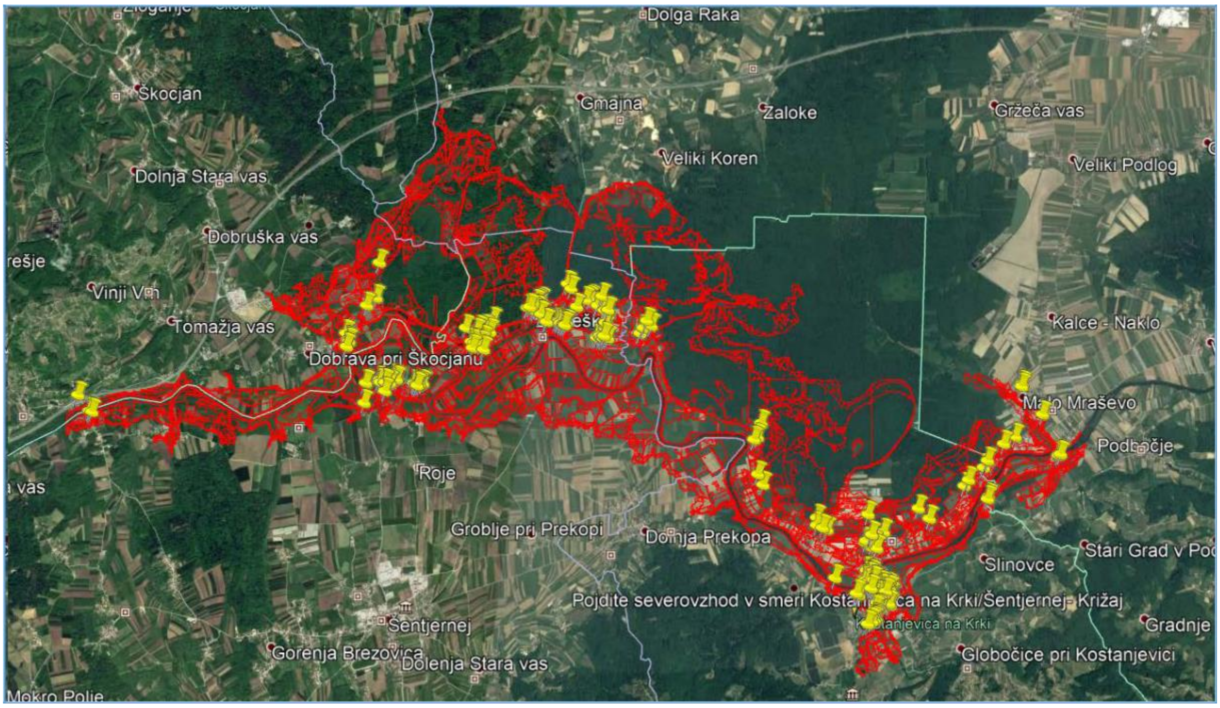
Calculation area:			**Kostanjevica na Krki: current status**	
Estimated number of at-risk:	**309**	**540**	**675**	
- Equipment, machinery and supplies – medium company				
INDUSTRIAL AND BUSINESS ENTITIES - Equipment, machinery and supplies – big company	0	0	46.000	184
INDUSTRIAL AND BUSINESS ENTITIES - Loss of revenue – mycro company	2.100	2.800	5.600	254
INDUSTRIAL AND BUSINESS ENTITIES - Loss of revenue – small company	0	5.600	11.200	319
INDUSTRIAL AND BUSINESS ENTITIES - Loss of revenue – medium company	0	0	31.400	126
INDUSTRIAL AND BUSINESS ENTITIES - Loss of revenue – big company	0	0	174.000	696
WATER - Watercourses	0	0	0	0
SUM (€)	12.932.717	24.740.043	26.792.577	1.901.403
Unforeseen damages 10% (€)	1.293.272	2.474.004	2.679.258	190.140
TOTAL EXPECTED ANNUAL DAMAGE (rounded to 000 €)	14.226.000	27.214.000	29.472.000	**2.092.000**

Figure 24: Display of damage assessment from the KRPAN application using the Google Earth application - baseline scenario



The presentation of the estimated damage due to reference flood events at the project level shows that the largest part of the damage potential is in the group of residential buildings and residential equipment. That represents 47% of the total average annual damage. The estimated damage to residential buildings represents from EUR 3 to 8.9 million depending on the flood event, while the estimated damage to residential buildings ranges from EUR 2 to 5 million depending on the flood event. A higher percentage of average annual damage is represented by the environment - aesthetic value and biodiversity, which is assessed in terms of damage in the area caused by the flood (cleaning costs…).

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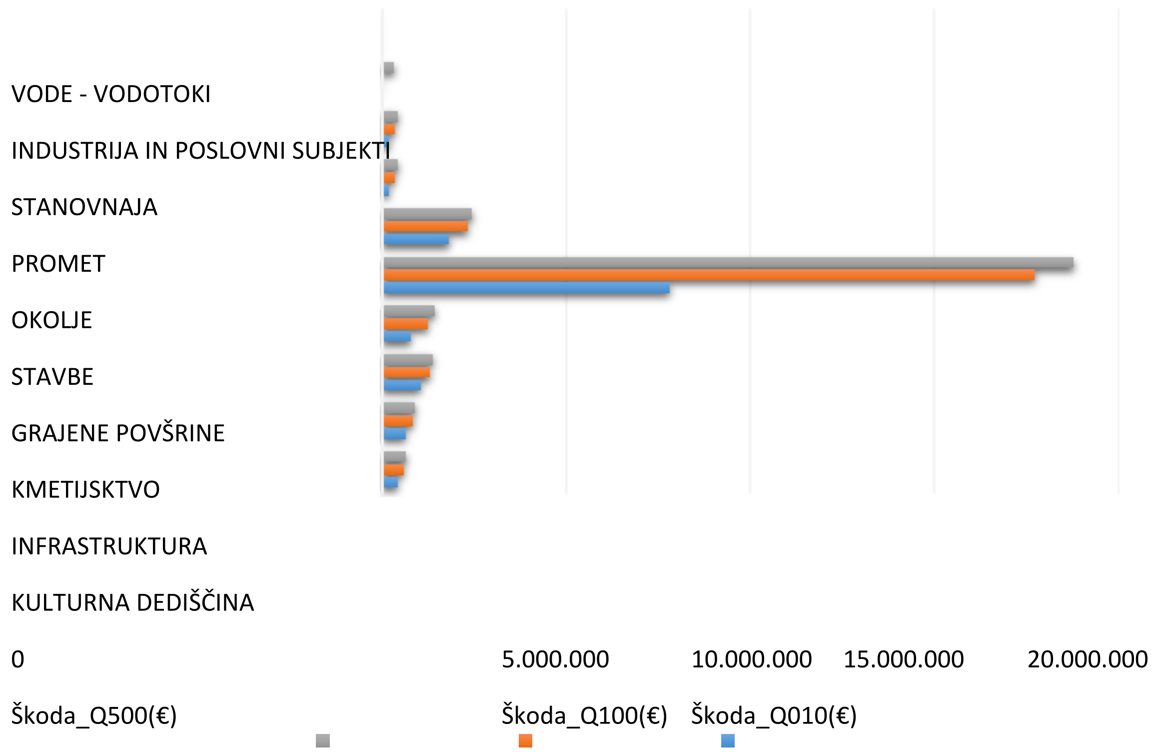
Figure 25: Estimated damage in flood events with a return period of 10, 100 and 500 years - baseline scenario



Glossary for figures 25 and 26:

VODE – VODOTOKI - Water - Watercourses;

INDUSTRIJA IN POSLOVNI SUBJEKTI - industry and businesses; STANOVANJA - Apartments;

KULTURNA DEDIŠČINA - Cultural heritage;

INFRASTRUKTURA - Infrastructure;

KMETIJSTVO - Agriculture;

GRAJENE POVRŠINE - Building area,

STAVBE - Buildings;

OKOLJE - Environment;

PROMET - Traffic;

Škoda - Damage

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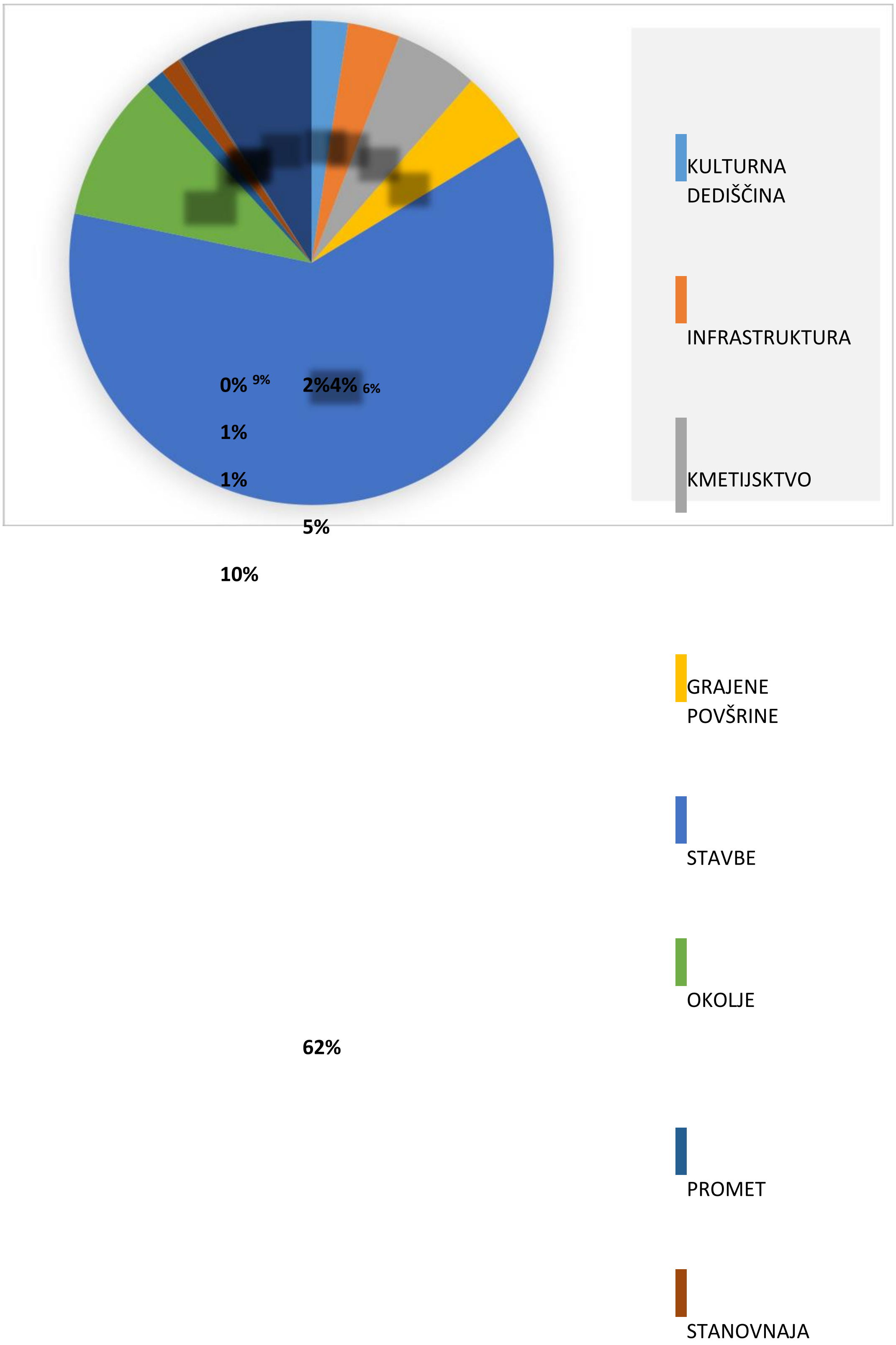
Figure 26: Distribution of estimated damage shares in flood events with a return period of 10, 100 and 500 years - baseline scenario



6 ANALYSIS OF ALTERNATIVE SOLUTIONS

The pilot area that is the subject of this documentation is the area of Kostanjevica na Krki together with Krakovski gozd (Krakovski forest) and Šentjernejsko polje (Šentjernejsko field). In accordance with the provisions of the ToR (Terms of Reference), all scenarios must provide the restoration or activation of the wider area of Krakovski forest and/or Šentjernejsko field as natural retention areas and must not provide the measures limited only to interventions in the Krka riverbed.

After performing hydraulic analyses for the existing condition, which included calibration of the model and then calculation for all five considered return periods, based on the analysis of the results of calculations (flood reach for different return periods, water level differences between individual floodplains) and analyses of the natural conditions of area observed from the point of view of the flood water runoff regime, we first prepare a set of potential measures. All measures can be divided into three types:

- floodplain activation measures (flood water corridors),

- measures to increase the conductivity of the riverbed passing Kostanjevica na Krki (measures in and along the Krka riverbed), and

- flood prevention measures in settlement areas (flood embankments / walls).

6.1 Flood water corridors - activation of floodplains (measures K2, K3, K4)

Firstly, we identified a potential area that could enable basic requirements of the ToR i.e. restoration or activation of the wider area of the Krakovski forest and / or Šentjernejsko field.

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There are no major areas of such on the right bank of the Krka (Šentjernejsko field area). The terrain on the right bank for the most part rises steeply and evenly into the hinterland to the south. Smaller individual depressed areas do not have a large retention potential.

On the left bank of the Krka (Krakovski forest area) we verify three larger areas with retention potential (in the direction from west to east):

1. The area of the stream Račna outflow section west of the Smednik-Zameško road.

2. The area of the stream Sajovec outflow section east of the Smednik-Zameško road.

3. The area between Malenci and Sajevec north of Kostanjevica na Krki.

The first area is part of the stream Račna (Loščček) basin, whose catchment areas extend to the hills north of the Dolenjska highway. The Smednik-Zameško road runs between the first two areas, which mostly runs along a small embankment.

The third area has no inflow of water from the hinterland, as no riverbed leads into it. Otherwise, the watercourse flows along the lowest points of the terrain (named Sajevec on Topographic map 1:5000, which should not be confused with the Sajovec watercourse east of the Smednik-Zameško road), which, however, begins in the middle of the area itself (geographical name Trstenik on Digital topographic map 1:50 000). The surface inflow of flood waters into this area comes partly from the western area described above, at higher return periods, also by overflowing the Zameško-Kostanjevica road on the section past the third area.

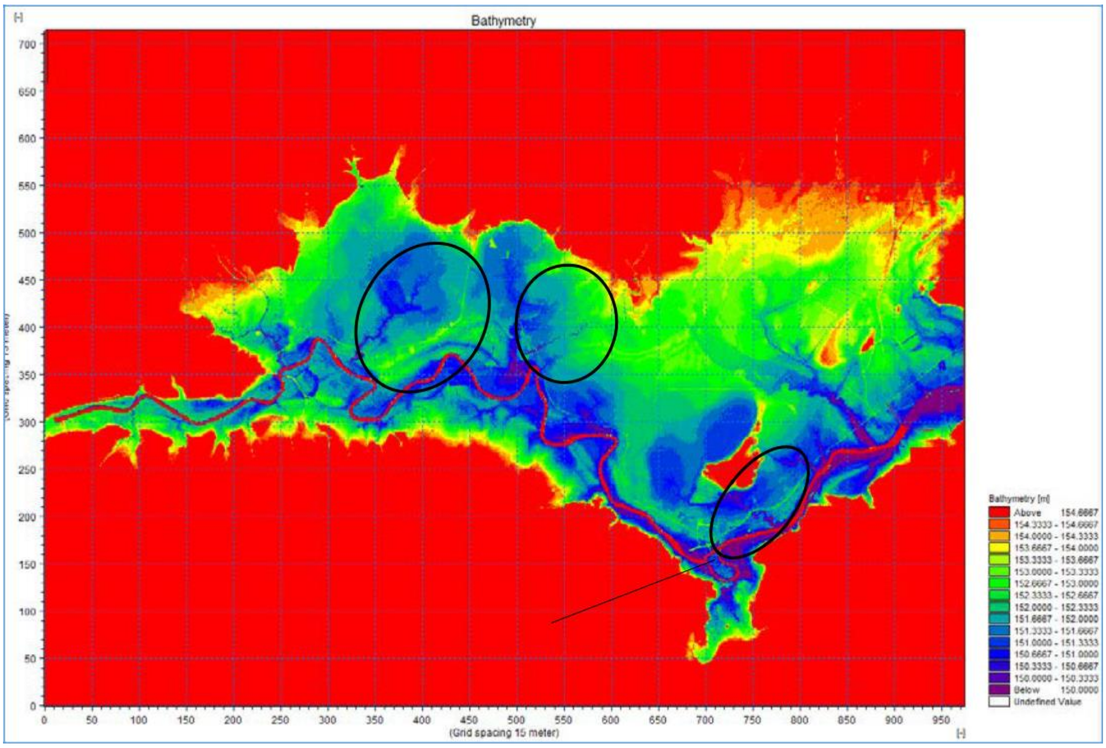

Figure 27: Bathymetry (3D model) of the terrain with elevation display

Kostanjevica na Krki

** Three depressed, hollow areas with high volume potential for flood waters are marked*

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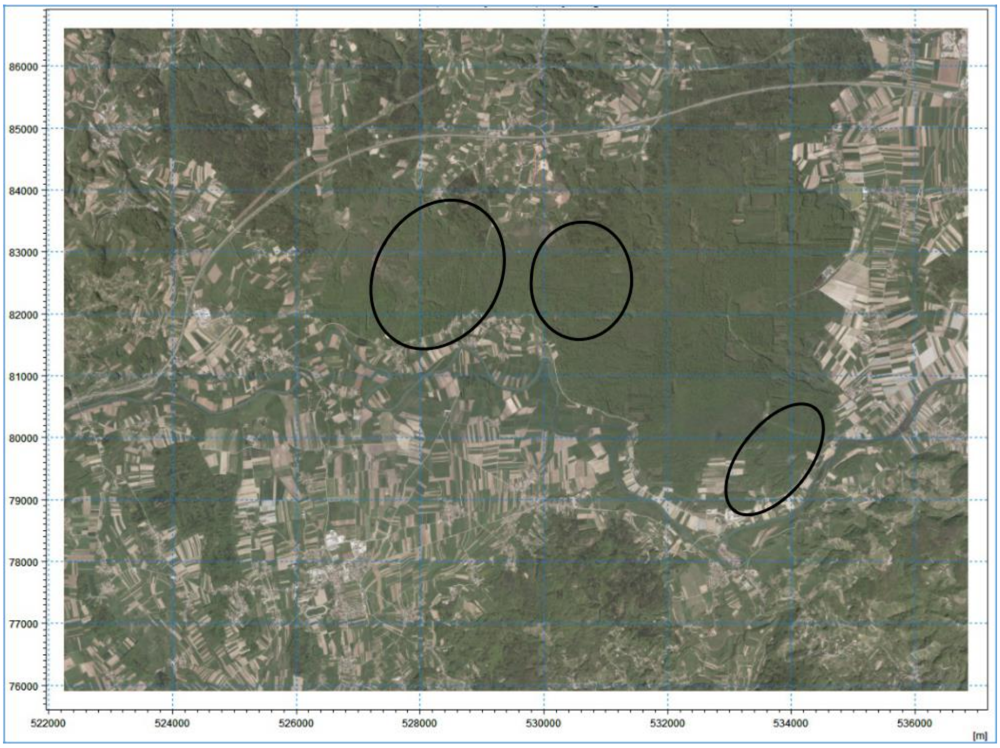
Figure 28: Aerial photography of modelling area



Kostanjevica na Krki

* *Three depressed, hollow areas with high volume potential for flood waters are marked*

Hydraulic calculations for the existing condition have shown that all three areas are already activated during floods in the case of the existing condition. The first two areas are largely activated already in the return period Q2-Q5, while the inflow of flood waters to the third (eastern) area has not yet occurred. But at the Q10 return period, very large parts of all three areas were flooded.

The comparison between the Q2-Q5 flood is shown in the figure below (in yellow - the area flooded at Q100, but not at Q2-Q5. In the first two areas there is very little difference between the floodwater reach of Q2-Q5 and Q100.).

Based on the results for the existing situation, we envisaged three corridors, through which could be additionally activated existing floodplains. In determining the areas, we took into account the morphology of the terrain in floodplains and lowlands directly along the Krka riverbed (beginning and end of the corridor at existing heights of the terrain) and the suitability of the site itself in terms of existing land use. Corridors are implemented as a small deepening of the terrain (dry riverbed). With them we connect areas with lower terrain heights or flood areas (measure K2), or between the floodplain directly along the Krka riverbed and the floodplain (measures K3 and K4).

In this part of the documentation is presented the basic concept of the measures taken into account in the hydraulic calculations. Further on identification (definition) and technical description of the project the measures are discussed in more detail - by individual measures and scenarios.

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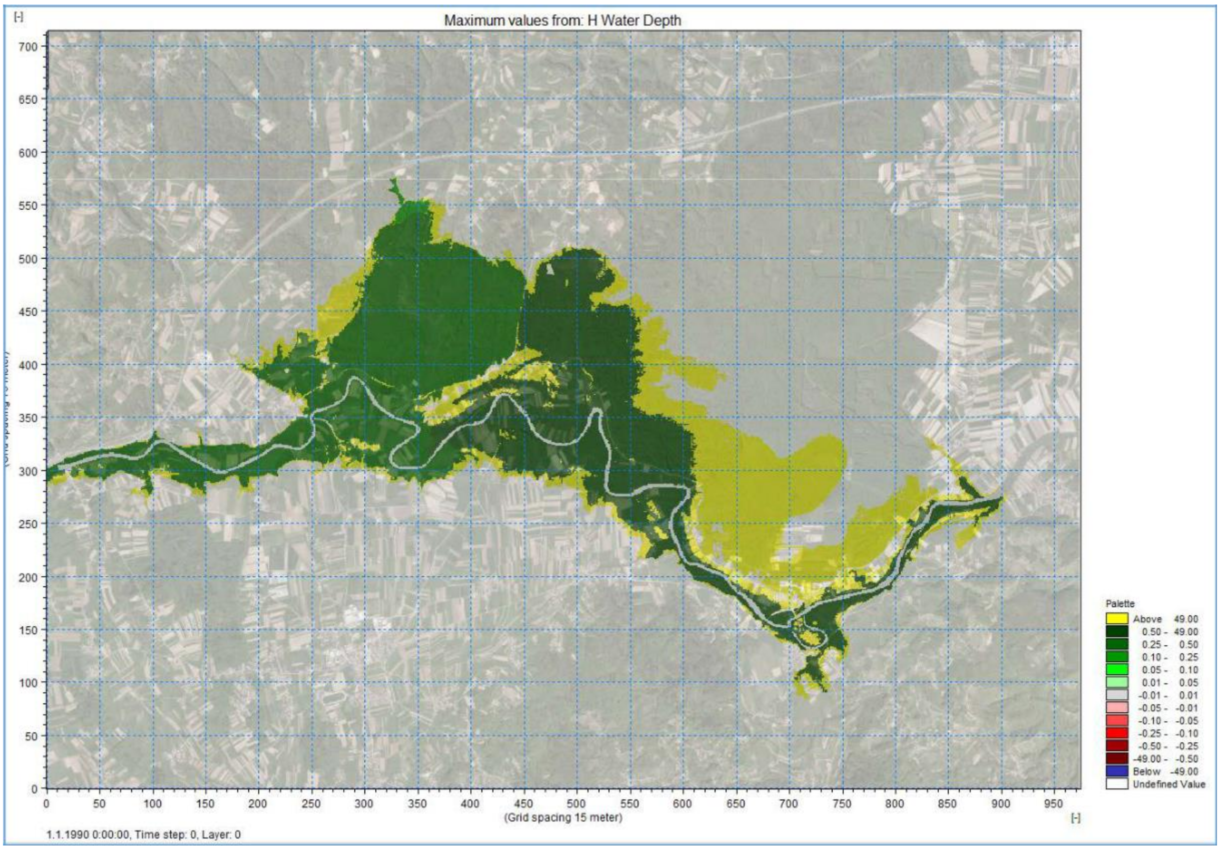
Figure 29: Water level difference envelope, existing condition, the difference Q2-Q5/Q100, yellow is dry for Q2-Q5 and flooded for Q100



6.2 Measure K2

Measure K2 is a corridor with which we connect both large floodplains, located east and west of the Smednik-Zameško road. The surfaces are already connected in their existing state by two smaller culverts. We envisaged a corridor at the northern edge of both surfaces, at the point where we connected the existing heights of the terrain at an altitude of 151,35 m.

6.3 Measure K3

Measure K3 is a corridor connecting the floodplain along the Krka riverbed and the western depression area of the Krakovski forest. The corridor is planned at the highest point from which we can connect the flood plain and the depression area.

6.4 Measure K4

As with measure K3, measure K4 is a corridor connecting the floodplain directly along the Krka riverbed and the western depression area of the Krakovski forest, only that it is located further more to the west and it is closer to Kostanjevica itself.

6.5 Measures in the Krka riverbed - increase in conductivity by Kostanjevica (measure K1)

From the available data on the Krka riverbed (bathymetric measurements, LIDAR, archive data), we found out that in the area of Kostanjevica na Krki itself, the northern riverbed is much shallower than the southern one. Thus, the height of the bottom of the riverbed in cross section upstream from the bridge on the north riverbed by 2 m higher than of the riverbed bottom in the cross section above the bifurcation, and approx. 3,2 m higher than the heights of the bottom below the confluence of both branches around Kostanjevica.

The rise of the riverbed bottom heights in the direction of flow is also noticeable in the southern branch, which runs around Kostanjevica (the highest height is in the area just above the Studena stream estuary), but on the southern branch the rise is much less pronounced.

The bifurcation of the riverbed above Kostanjevica is hydraulically rather unfavorably shaped, as the basic riverbed "crashes" into the island on which Kostanjevica is located. Measure K1 was designed to increase the conductivity of the northern bed past Kostanjevica and to improve the hydraulically unfavorable bifurcation.

6.6 Flood embankments and flood protection walls (measure K5)

A measure that could ensure the protection of the area of facilities within the APSFR Kostanjevica na Krki is the construction of prefabricated movable walls (those that are installed only for the duration of the flood risk), and/or permanent embankments to surround endangered objects. In this way, the intrusion of water into the area of the facilities would be prevented, and the surroundings would still be flooded in the same way as in the existing condition.

As the duration of floods in this area is relatively long (several days), it is necessary to envisage solutions for the drainage of rain water, for the time when the prefabricated walls are in operation (pumping stations, two-way barriers on the existing rain sewage system, etc.).

6.7 Design of scenarios

In accordance with the ToR, it was necessary to prepare three different scenarios of measures to reduce the risk of floods. Based on the set of measures described above, the individual measures were combined into scenarios 1, 2 and 3. In the first phases, we performed calculations only with floodplain activation measures (K2, K3 and K4) and measures in the riverbed itself (K1). As these scenarios did not bring a significant improvement in the situation in the area of APSFR Kostanjevica na Krki, we subsequently added measure K5 to scenario 2, which represents the protection of the Kostanjevica na Krki area itself with (prefabricated) walls and embankments.

The analysis thus considered three scenarios of measures:

Scenario 1: Scenario 1 represents a combination of measures K1 and K3. It is therefore a combination of one corridor for the activation of floodplains and measures in the Krka riverbed itself to increase the conductivity of the riverbed and consequently reduce water levels in the Kostanjevica na Krki area.

The following measures are envisaged under this scenario:

o K1- deepening of the Krka riverbed and inundation in the bifurcation area o K3 - corridor 45 m wide and 650 m long

Scenario 2: Scenario 2 represents a combination of all three measures K2, K3, K4, and measure K5. In this scenario, measures in the Krka riverbed itself are not envisaged. The following measures are envisaged under this scenario:

o K2 - corridor 30 m wide and 950 m long o K3 - corridor 45 m wide and 650 m long

o K4 - corridor width 60 m and o K4 - corridor width 60 m and length 280 m length 280 m

o K5 - flood protection prefabricated walls and embankments in the area of APSFR Kostanjevica na Krki

Scenario 3: Scenario 3 represents a combination of all three corridors K2, K3 and K4 and measure K1 in the Krka riverbed.

The following measures are envisaged under this scenario:

o K1- deepening of the Krka riverbed and inundation in the bifurcation area o K2 - corridor 30 m wide and 950 m long

o K3 - corridor 45 m wide and 650 m long

o K4 - corridor 60 m wide and 280 m long

6.8 Evaluation of hydraulic - hydrological effects of mitigation measures according to the FEM method

In accordance with the project task, the hydraulic and hydrological effects of the planned measures were evaluated in the area of APSFR Kostanjevica na Krki according to the principles of the FEM method (Floodplain Evaluation Matrix method, FEM, Habersack et al. in Nat Hazards, 2013).

In the evaluation, we took into account three parameters: maximum flow, time of occurrence of maximum flow and depth of flood waters in the area of OPVP Kostanjevica.

The first two quantities (maximum flow and time of its occurrence) were evaluated in the hydrological section of the APSFR Kostanjevica na Krki, the section in the area of the new road bridge just upstream from Kostanjevica na Krki was taken into consideration. The calculated differences from the existing state (dQ) and the peak offset (dT) are summarized below in the table.

Evaluation of flood water depths was performed on a grid of cells from the model (15x15 m). In the entire area of the APSFR Kostanjevica na Krki, we calculated the difference in depths (depth envelopes) of flood waters and then calculated[their average value,] so we performed the calculation:

$$h* = \max(h\quad) - \max(h\qquad)$$

The expression in square brackets is calculated for each cell of the model within the area of the APSFR Kostanjevica na Krki. The average of the differences was calculated only for cells where the difference in depth is not equal to zero, and when calculating the differences in depth, we also considered cells with a depth equal to zero. The evaluation results are shown in the table below.

*Figure 30: FEM parameter dh**

average depth on APSFR [m]	**Q2-Q5**	**Q10**	**Q100**	**Q500**
CURRENT STATE – OS	1.075809	1.158422	1.397912	1.524473
SCENARIO 1 - PS1	1.075145	1.164856	1.399643	1.525093
dh*	**0.0188**	**0.0135**	**0.0042**	**0.0015**
SCENARIO 2 - PS2.2	1.190247	1.371523	1.697788	1.834917
dh*	**0.2023**	**0.2638**	**0.3652**	**0.4183**
SCENARIO 3 - PS3	1.079031	1.159963	1.400814	1.526769
dh*	**0.0096**	**0.0240**	**0.0010**	**-0.0013**

Figure 31: FEM parameters dQ in dT

	Q2-Q5	**Q10**	**Q100**	**Q500**
SCENARIO 1- PS1				
dQ [m3/s]	1.57	6.64	9.10	10.67
dQ [%]	0.49	1.79	2.11	2.36
dT [h]	-1h	0h	-1h	-2h
SCENARIO 2- PS2.2				
dQ [m3/s]	1.18	11.19	11.88	22.98

dQ [%]	0.37	3.02	2.75	5.09
dT [h]	-1h	0h	-1h	-1h
SCENARIO 3- PS3				
dQ [m3/s]	0.16	9.64	15.90	17.06
dQ [%]	0.05	2.60	3.69	3.78
dT [h]	-1h	0h	0h	0h

40

Figure 32: Scenario 1 - Difference of surface envelopes, Q2-Q5

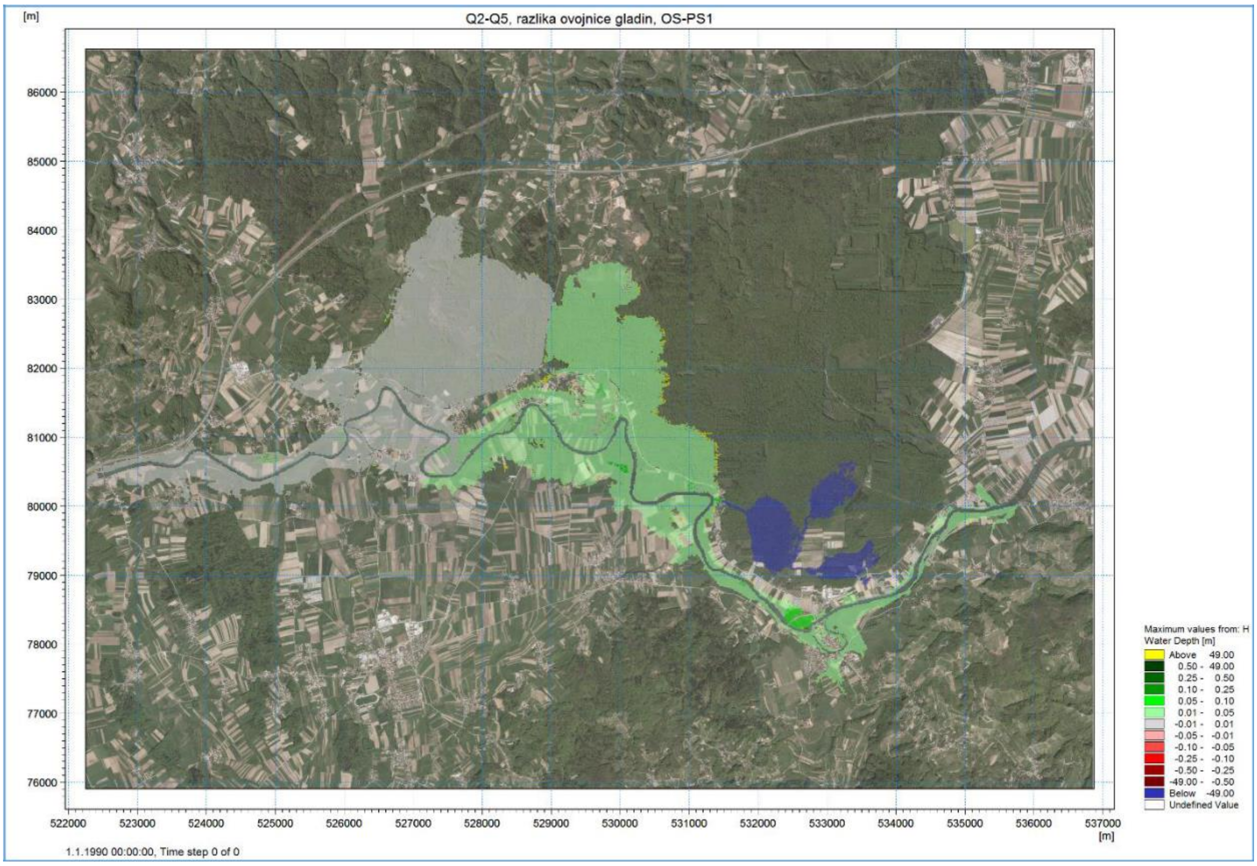


Figure 33: Scenario 2 - Difference of surface envelopes, Q100 – whole area

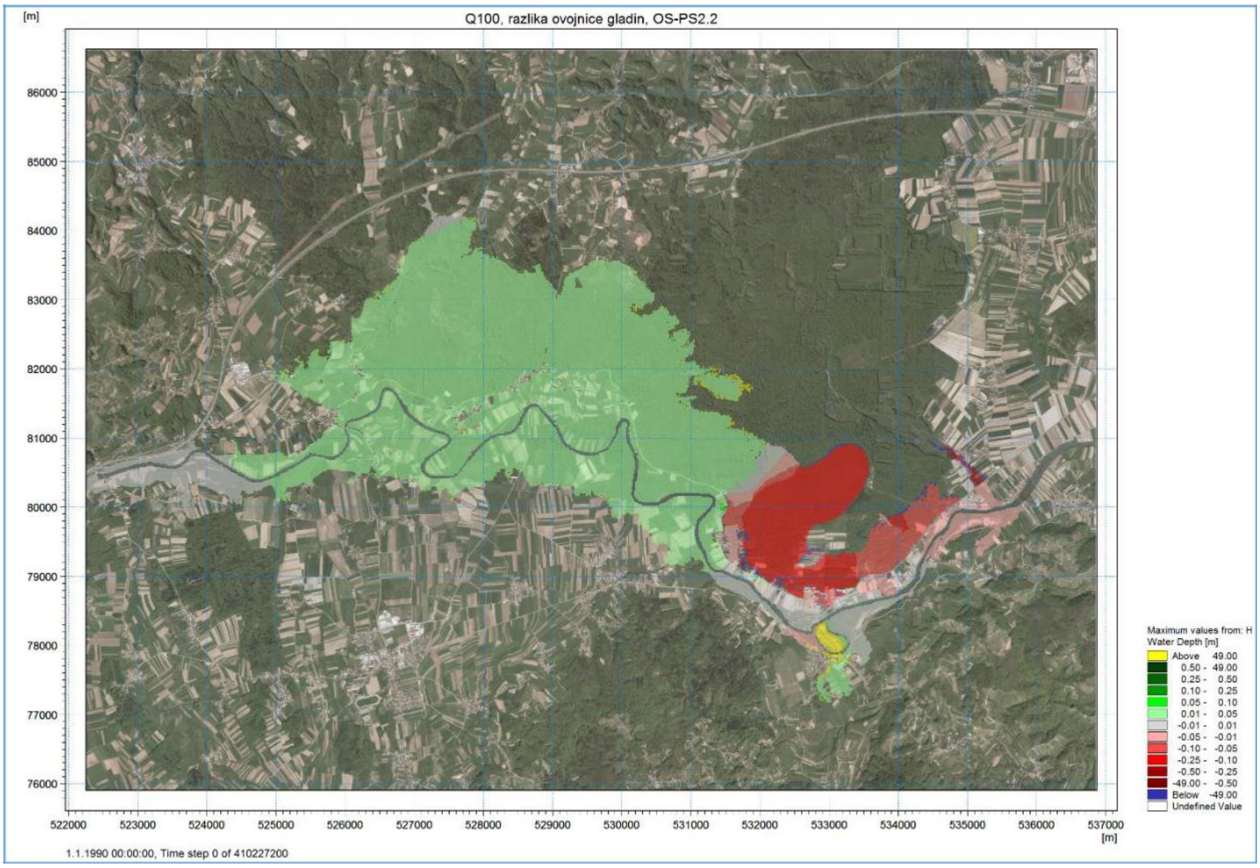


Figure 34: Scenario 2 - Difference of surface envelopes, Q100 – Kostanjevica na Krki area

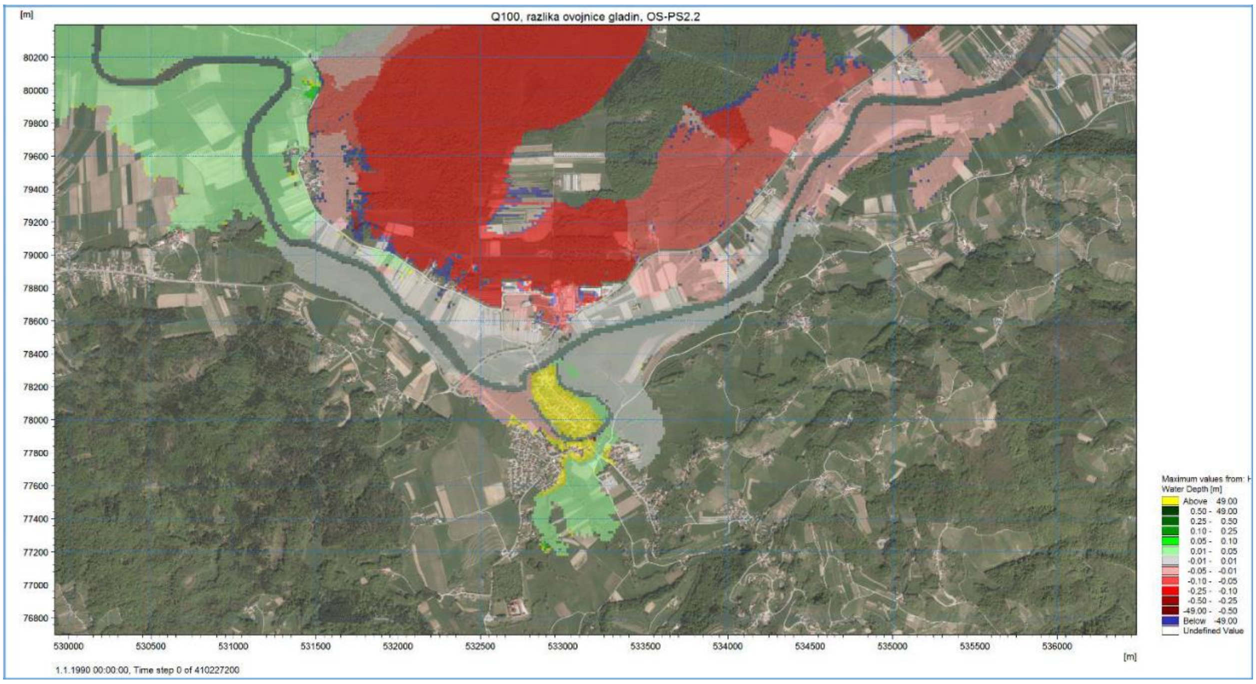


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Figure 35: Scenario 3 - Difference of surface envelopes, Q100 – Kostanjevica na Krki area

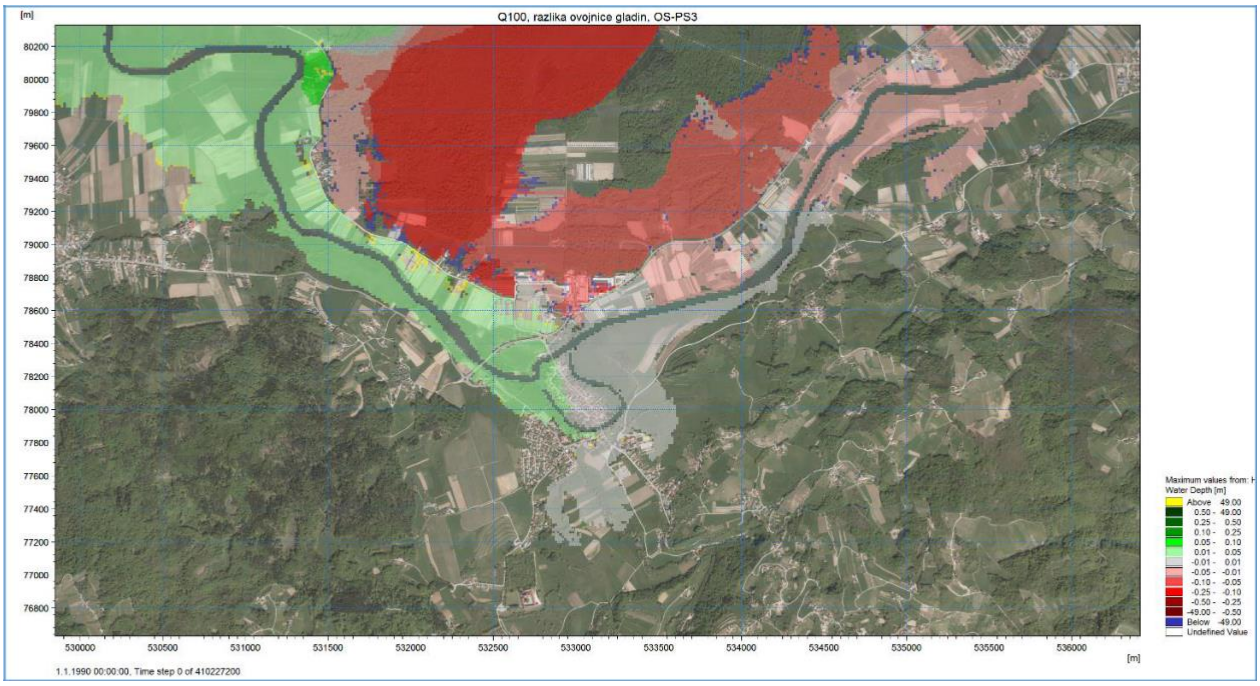

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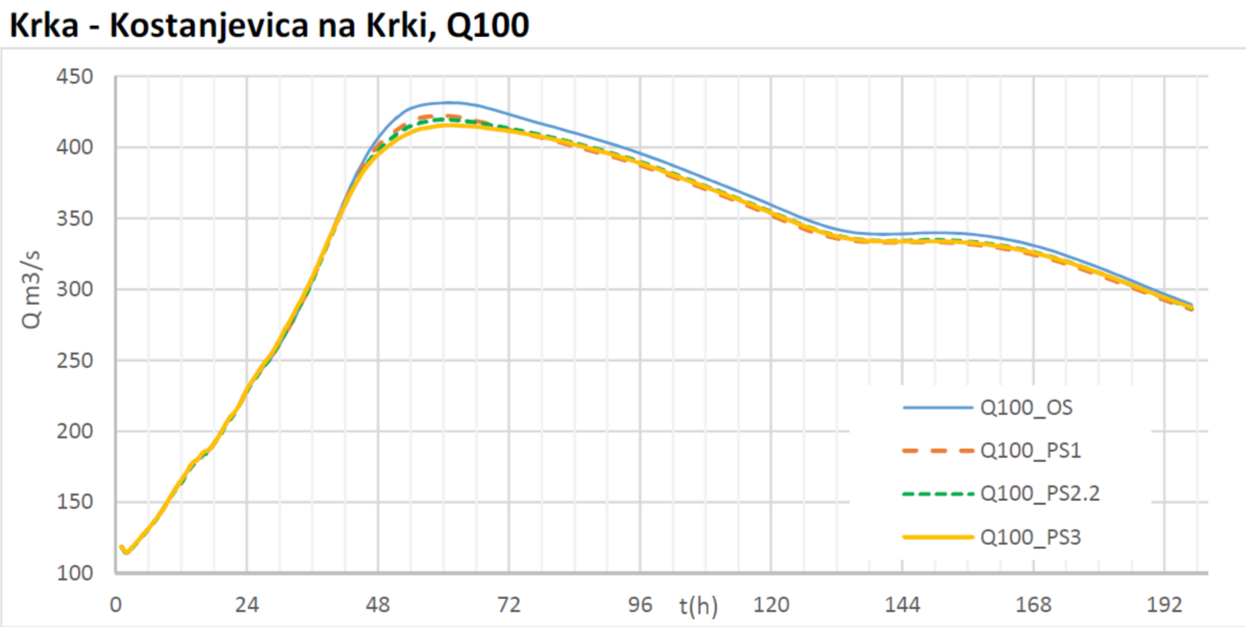
Figure 36: Histogram - Kostanjevica na Krki, Q100 for current state, scenario 1, scenario 2 and scenario 3



	obstoječe	scenarij 1 - PS1	scenarij 2 - PS2.2	scenarij 3 - PS3
	Q100_OS	Q100_PS1	Q100_PS2.2	Q100_PS3
	Q[m3/s]	Q[m3/s]	Q[m3/s]	Q[m3/s]
dQ	-	9.10	11.88	15.90
dT	-	-1h	-1h	0h
maxQ	431.40	422.30	419.53	415.50

From the results of the evaluation according to the FEM method and the results of the calculations shown, the following conclusions can be drawn (from the point of view of hydraulic hydrological parameters):

- None of the considered scenarios has a significant impact on the regime of flood water runoff in the area of the APSFR Kostanjevica na Krki. Despite the perceptible reduction of the peak flow through the APSFR area (2.11-3.69% at return period Q100), this has a minor impact on the calculated water levels themselves. With all different combinations of measures, the calculated level in the APSFR area at Q100 does not change by more than 1cm.

- Measures for floodplains activation have a small impact on reducing flows past APSFR Kostanjevica na Krki. However, since the western area of the Krakovski forest has an outflow downstream from APSFR Kostanjevica na Krki (Sajevec stream), additional activation with corridors K3 and K4 results in an increase in the peak on the lower boundary condition at GS

Podbočje. This means that this area acts not only as a retention area but to some extent also as a flow balancing reservoir.

- The riverbed deepening measure (K1) has no measurable impact on the expected flood waters.

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- Due to the very small impact of scenarios 1 and 3 on the area of the APSFR Kostanjevica na Krki, the first preliminary calculations of damages show even higher damages for the planned situation.

- The floodplains of the Krakovski forest along the Krka river in the considered area are already activated in the existing state, even during frequent flood events. Additional activation of floodplains (by diversion of Krka flood waters in the direction of the riverbed from the riverbed) according to the results of calculations does not bring significant improvements of hydraulic and hydrological parameters in the area of APSFR Kostanjevica na Krki.

- A measure that could ensure the protection of the area of facilities within the APSFR Kostanjevica na Krki is the construction of prefabricated movable walls (those that are installed only for the duration of the flood risk), and/or permanent embankments to surround endangered objects. In this way, the intrusion of water into the area of the facilities would be prevented, and the surroundings would still be flooded in the same way as in the existing condition.

- Since both the measures in the riverbed itself and the measures for the activation of floodplains discussed in this documentation do not bring significant improvements to the hydraulic and hydrological parameters, the question arises as to the appropriateness of further consideration of these measures. If the extent of inflow to floodplains in very frequent floods (Q2-Q5 and more frequent) is useful from other aspects, in our opinion it makes sense to continue to consider corridor K3, but in significantly reduced extent, as it has no significant effects from the point of view of flood risk reduction.

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7 PRESENTATION OF INDIVIDUAL SCENARIOS WITH REGARD TO THE PROPOSED MEASURES

The analysis thus addressed three scenarios, which were hydraulically verified and subsequently taken into account in the cost-benefit analysis:

Figure 37: Set of measures under scenario 1

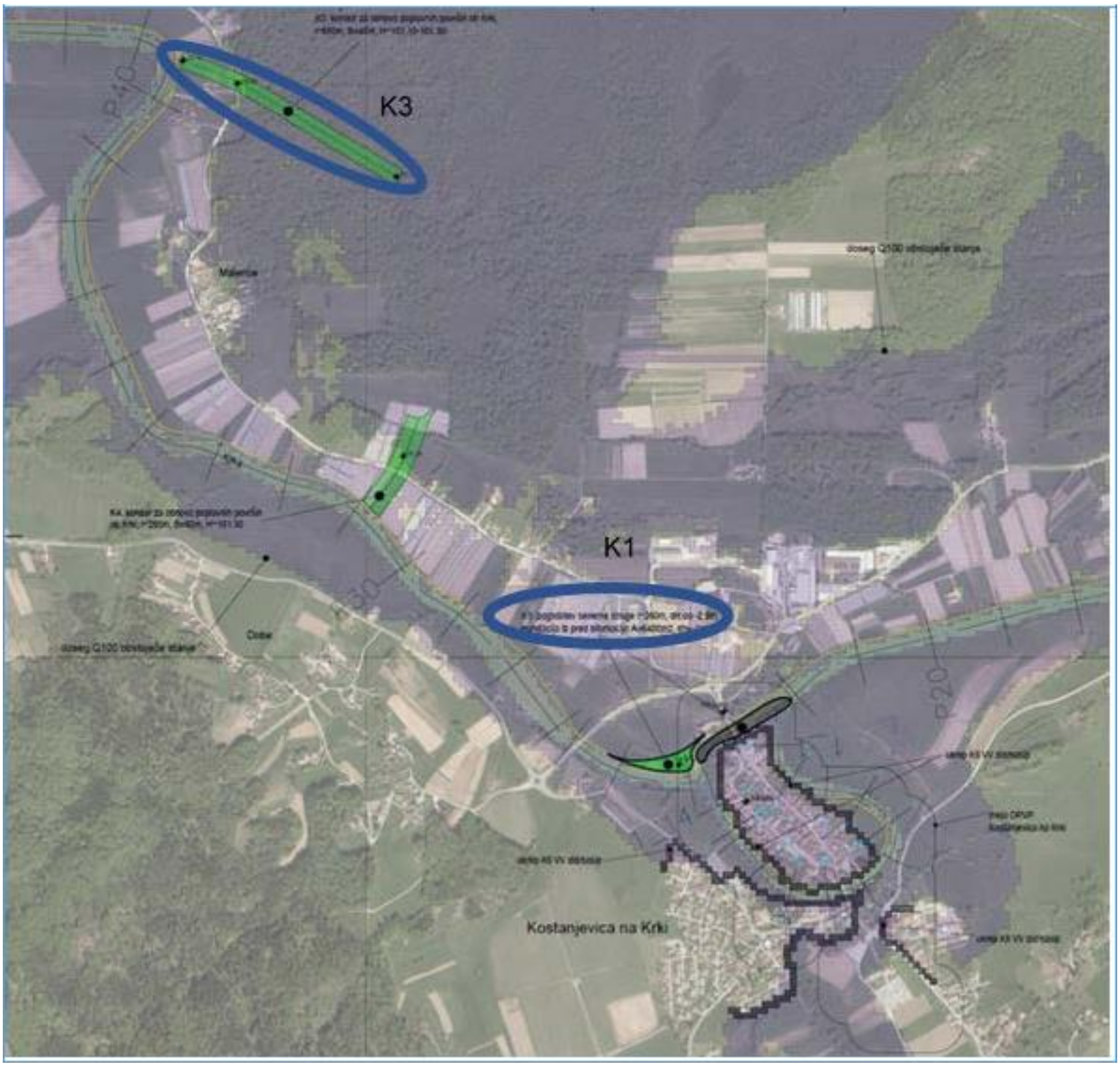

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Figure 38: Set of measures under scenario 2

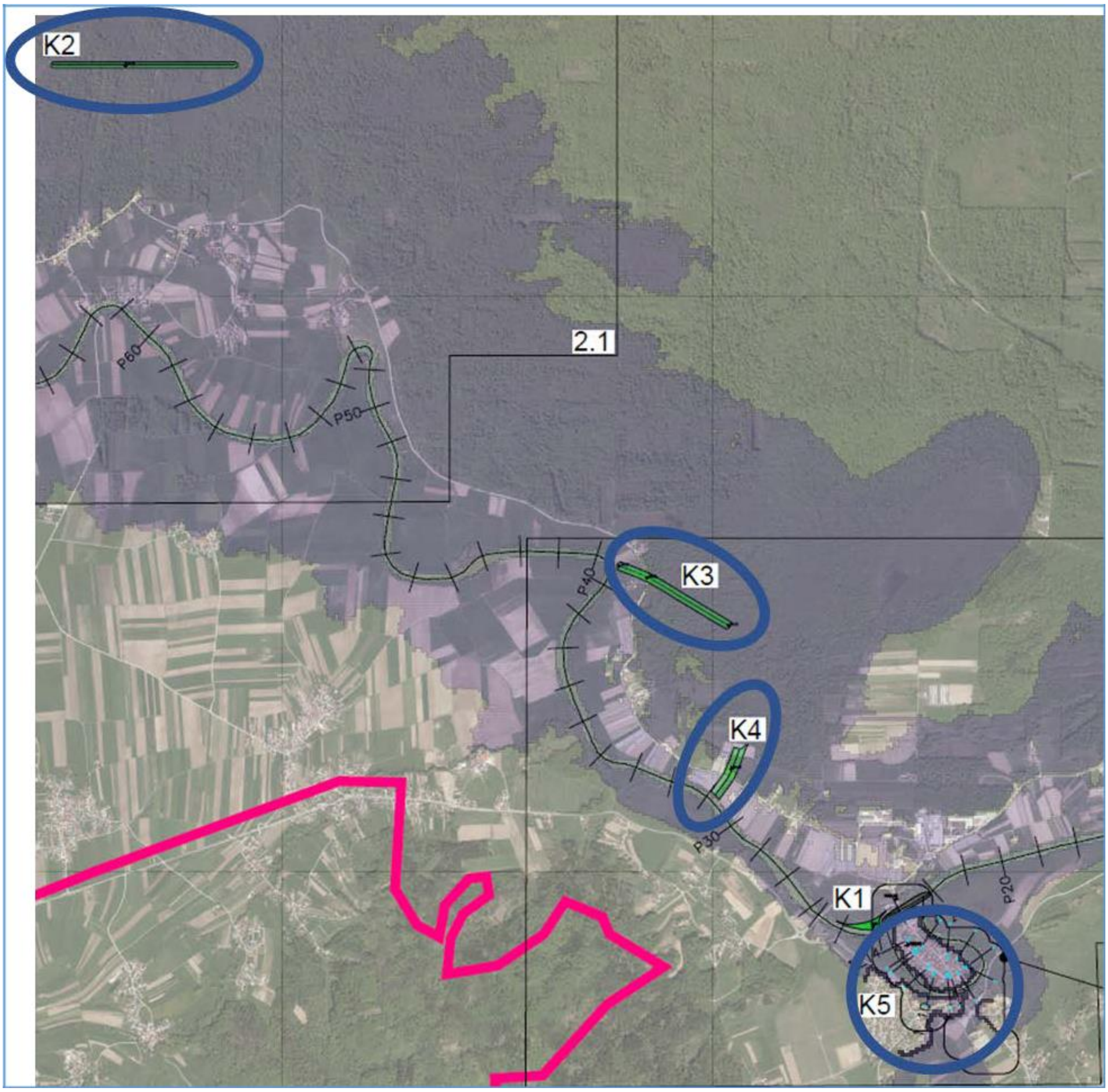

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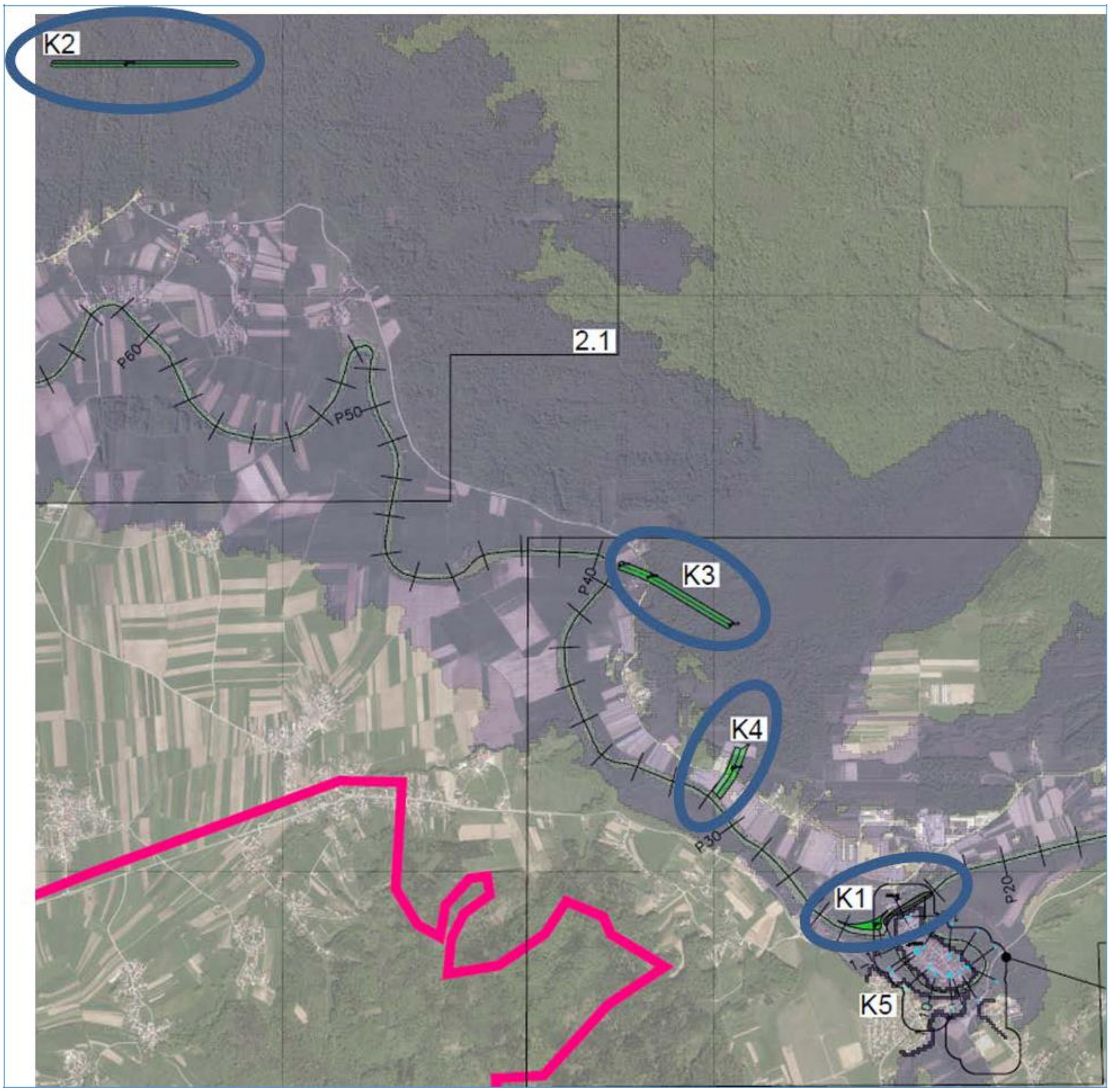
Figure 39: Set of measures under scenario 3



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8 COST AND BENEFIT ANALYSIS FOR INDIVIDUAL SCENARIOS

8.1 Financial analysis - methodology

In accordance with EU Regulation 1303/2013, and in accordance with Article 101, it is necessary to provide the information necessary for the approval of the project also in terms of cost-benefit analysis, including economic and financial analysis and risk assessment. Financial analysis should be included in the Cost-benefit analysis (CBA), where it is necessary to calculate the financial indicators of the project. The financial analysis requires:

- Assessing the profitability of the project / investment.
- Assessing the profitability of the project from the perspective of the owner, and some key stakeholders.
- Checking the financial sustainability of the project, which is a key condition of feasibility for each project typology.
- Describing cash flows that support the calculation of socio-economic costs and benefits.

The financial model for the CBA is made in accordance with „Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020“ (EC DG Regio, 2014) and a common bilaterally harmonized methodology for the economic assessment of flood damage in transboundary river basins. Accordingly, the methodology to be used to make the financial analysis of the project is the discounted net flow method. The financial analysis is made on the basis of the following assumptions:

- The project was studied in terms of discounted cash flows, using the incremental method (without project and with project).
- Only actual cash income and expenses are taken into account, while depreciation, provisions for future costs and contingencies and other accounting items that do not represent actual cash expenses are not taken into account. Cash flows are determined for each year in which they are / will be incurred.
- The financial analysis is made from the perspective of the project owner.

- In accordance with the European Commission's recommendation for the 2014-2020 programming period, a 4% financial discount rate is used to calculate the present value of future cash flows. The discount rate reflects the opportunity cost of capital.

- The cash flow of the project is shown for the entire reference period (economic period of the project), including the preparation time and the operating period; the reference period of the project is 50 years.

- Costs are shown in constant prices.

- All prices are in euros.

- Prices include value added tax (22% VAT) because it is not refundable.

- Financial analysis is made for all three scenarios.

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8.2 Economic analysis - methodology

As provided for in Article 101 (1) (e) of Regulation (EU) No 1303/2013, economic analysis must be included in the Cost-Benefit Analysis. Economic analysis is an analysis performed using economic values and reflecting the social opportunity costs of goods and services.

The essence of economic analysis is that project inputs need to be estimated on the basis of their opportunity costs, and the return in terms of consumer willingness to pay. Opportunity costs do not necessarily correspond to observed financial costs, nor is payment readiness always correctly reflected by observed market prices, which may be distorted or even non-existent. Economic analysis is made from the point of view of the whole society. Cash flows from financial analyses are considered as the starting point for economic analyzes.

The essence of the economic analysis is to ensure that the project has positive net benefits for society and is consequently eligible for co-financing by EU funds. It is therefore necessary that:

- the benefits outweigh the costs of the project,

- the present value of the economic benefits exceeds the net present value of the costs.

The fulfillment of the conditions is seen with the help of the following calculated economic performance indicators:

- **Economic net present value (ENSV)** is the main reference indicator for project evaluation. It is defined as the difference between discounted total social benefits and costs.

- For a project to be economically viable, the economic net present value of the project should be positive (ENSV> 0), which proves that the project will be beneficial to society in a given region or country because its benefits outweigh the costs and the project should therefore be implemented.

- **The economic rate of return (ESD)** is the internal rate of return calculated using economic values and reflects the socio-economic profitability of the project.

- The economic rate of return should be higher than the social discount rate (ESD> SDS) to justify EU support for the project.

- **Benefit-cost ratio, utility ratio (K/S)** is defined as the net present value of the project benefits divided by the net present value of the project costs. The benefit-cost ratio should be greater than one (K / S> 1) to justify EU support for the project.

The goal of cost-benefit analysis is to determine the economic value of the project by determining the additional benefits that will result from the implementation of the project. The project has several indirect economic, social and environmental impacts. Investments can only be properly assessed by considering these impacts, and these impacts are most often linked to development.

8.3 Assumptions of economic analysis - methodology

The economic analysis was based on financial analysis and used the standard discounted cash flow methodology. The main assumptions of the model are:

- All assumptions from the financial analysis (except the discount rate) were taken into account.

- A 5.0 % social discount rate was taken into account for the economic analysis.

- Financial costs are transformed into economic ones by conversion factors. A factor of 1 was taken into account for the standard conversion factor.

The following adjustments were needed in determining the economic indicators:

- **Tax adjustments:** indirect taxes (VAT), subsidies and net transfers (eg social security payments) were deducted in the economic analysis.

- **External corrections (external effects):** some effects of the project may affect other non-compensating businesses. These effects can be positive or negative. As there are no monetary compensations for externalities, these are also not included in the analysis and need to be assessed and evaluated.

- **Market of accounting fictitious (corrected) prices:** in addition to tax distortions and externalities, other factors may contribute to the deviation of prices from a competitive market (i.e. efficient) equilibrium (monopolistic arrangements, trade arrangements, labor arrangements, incomplete information, etc.). In all these cases, the observed market (i.e. financial) prices are misleading and should be replaced by accounting (fictitious) prices, which reflect the opportunity cost of inputs and the willingness of consumers to pay in the event of a return. Accounting prices are calculated using conversion factors for financial prices.

To avoid double counting, only direct effects are considered in the economic analysis. After adjusting market prices and valuing external influences, all costs and benefits of economic analysis can be discounted at an economic discount rate of 5% (a lower discount rate would be more acceptable for such type of projects). The use of that discount rate is recommended by the EC for the 2014-2020 programming period for projects in the member states.

8.4 Economic residual value

The economic residual value was calculated using the same methodology as the financial residual value.

As the basis for the flood risk reduction calculations the KRPAN application was considered. Benefits from the aspect of flood risk reduction was assessed on the basis of the existing state of damage

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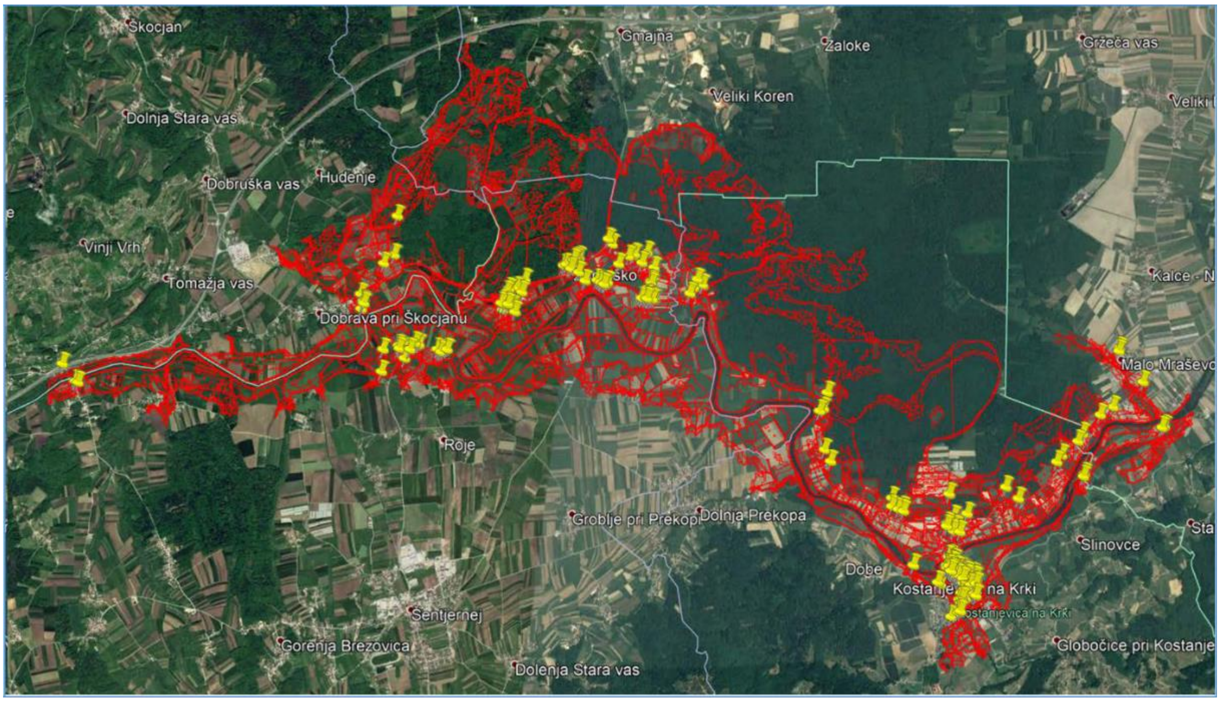
before the measures and the situation of flood risk assessments after the measures. The calculations of benefits by individual scenarios are presented below.

Scenario 1: Taking into account the measures (K1: Deepening of the northern riverbed and inundation on left bank and K3: Corridor for the restoration of floodplains) under scenario 1, the average annual damage was estimated at EUR 2.148.000, which represents additional average annual claims of EUR 57.000. That means that the measures in question further aggravate the existing situation and in this case we have negative benefits from the point of view flood damage reduction.

The damage calculations for Q10, Q100 and Q500 and average annual damages for scenario 1 and incremental annual average damages before and after the measure are shown below.

Figure 40: Damage assessment from KRPAN app. using Google Earth app. - SCENARIO 1



The implementation of measures under Scenario 1 contributes from the point of view of reduction/increase of annual average damages to the following effects:

- in the field of cultural heritage, the average annual damage is reduced by EUR 1.258,

- in the field of infrastructure (roads, electricity, water and sewage network), the average annual damage is reduced by EUR 371,

- in the field of agriculture, the average annual damage increases by EUR 465 (increase in damage in the area of forests and meadows),

- in the area of built-up areas, the average annual damage is reduced by EUR 347,

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- in the field of buildings, the average annual damage increases by EUR 36.544,
- in the field of the environment, the average annual damage increases by EUR 3.158,
- in the field of transport (passenger cars), average damages are reduced by EUR 306,
- in the field of housing, the average damage is reduced by EUR 289,

in the field of industrial and commercial entities, the average annual claims increase by EUR 14.167.

Glossary for figures 41, 42, 44, 45, 48, 49:

VODE – VODOTOKI - Water - Watercourses

INDUSTRIJA IN POSLOVNI SUBJEKTI - industry and businesses STANOVANJA - Apartments

KULTURNA DEDIŠČINA - Cultural heritage

INFRASTRUKTURA - Infrastructure

KMETIJSTVO - Agriculture

GRAJENE POVRŠINE - Building area

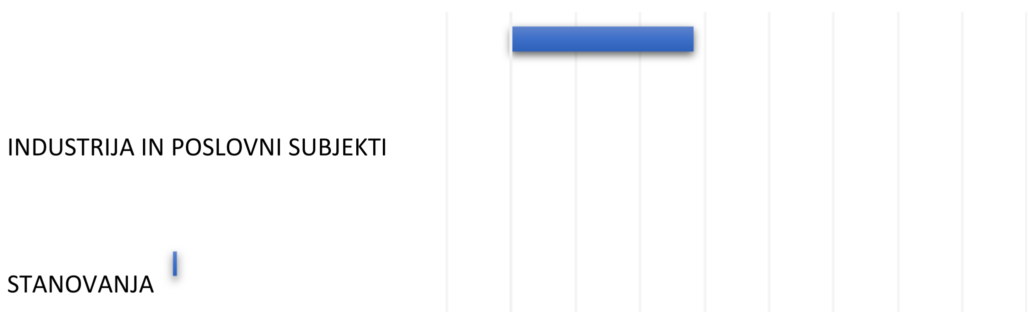
STAVBE - Buildings

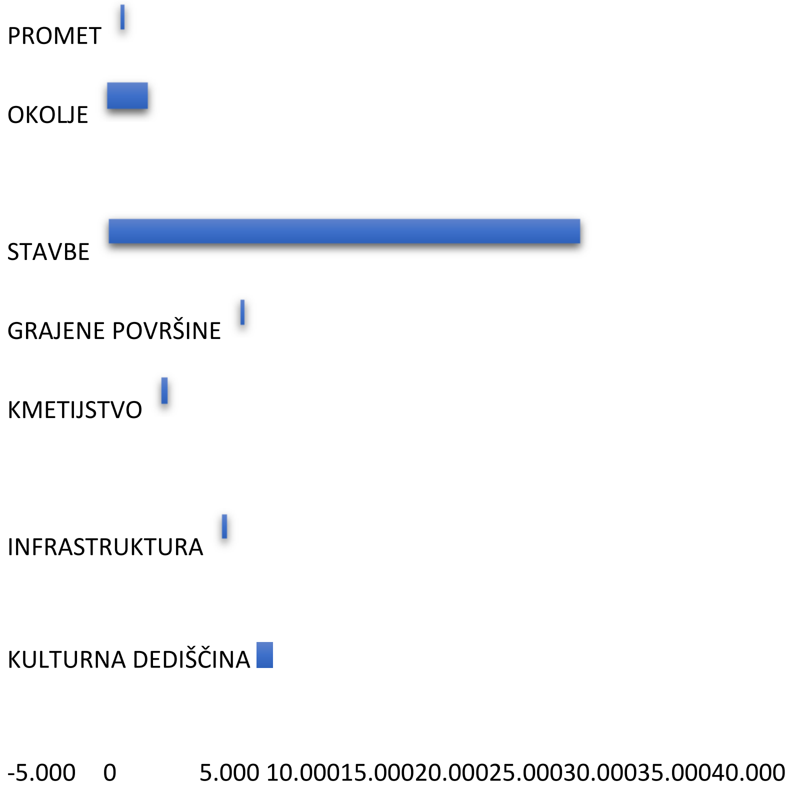
OKOLJE - Environment

PROMET - Traffic

Škoda – Damage

Figure 41: Average annual damage by individual parameters (existing scenario - scenario 1)




PROMET
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STAVBE
GRAJENE POVRŠINE
KMETIJSTVO
INFRASTRUKTURA
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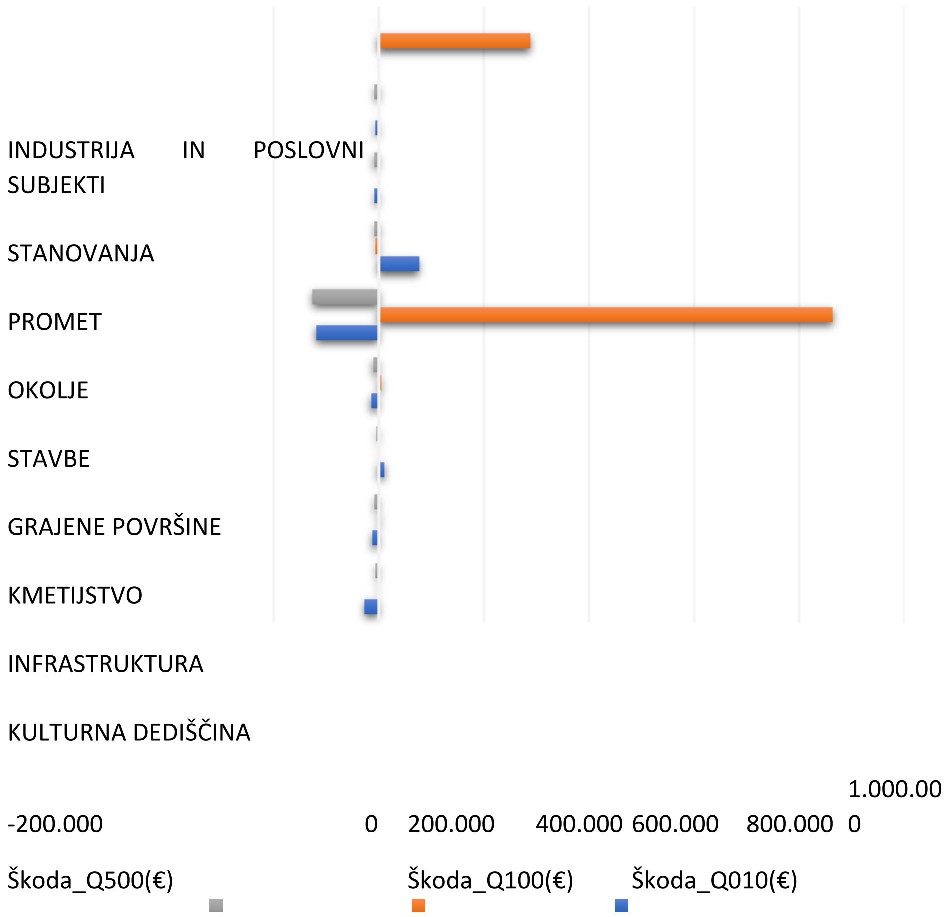
Figure 42: Damage assessment in flood events with a return period of 10, 100 and 500 years (baseline scenario - scenario 1)



Scenario 2: Taking into account the measures (K2: Corridor for restoration of floodplains, K3: Corridor for restoration of floodplains, K4: Corridor for restoration of floodplains, K5: Local protection of the island and the southern part of the settlement), under Scenario 2, an average annual damage of EUR 1.541.000 was estimated, which represents a reduction in the average annual damage of EUR 551.000. That means, that the selected measures improve the existing situation and in this case we have positive benefits in terms of reducing of flood damage.

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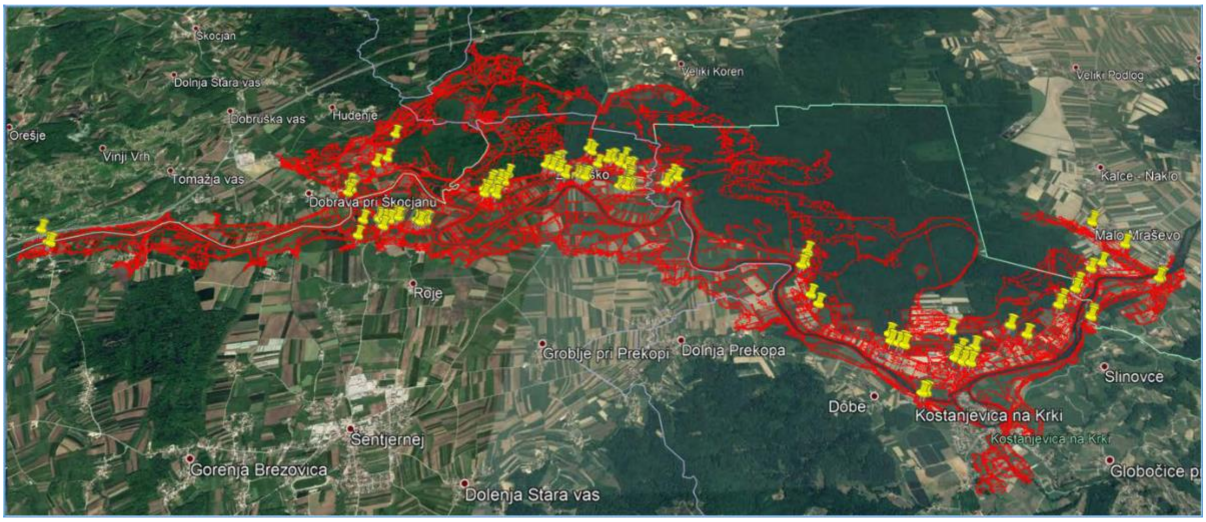
Figure 43: Damage assessment from KRPAN app. using Google Earth app. - SCENARIO 2



The implementation of measures under Scenario 2 contributes from the point of view of reduction / increase of annual average damages (effect of the baseline scenario - Scenario 2) to the following effects:

- in the field of cultural heritage, the average annual damage is reduced by EUR 16.790,

- in the field of infrastructure (roads, electricity, water supply and sewerage network), the average annual damage is reduced by EUR 8.724,

- in the field of agriculture, the average annual damage increases by EUR 1.071 (increase in damage in the area of forests and meadows, in the area of built-up areas, the average annual damage is reduced by EUR 18.199,

- in the field of buildings, the average annual damage is reduced by EUR 450.876,

- in the field of the environment, the average annual damage increases by EUR 4.343,

- in the field of transport (passenger cars), average damages are reduced by EUR 12.967,

- in the field of industrial and commercial entities, the average annual claims increase by EUR 13.653.

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Figure 44: Average annual damage by individual parameters (existing scenario - scenario 2)

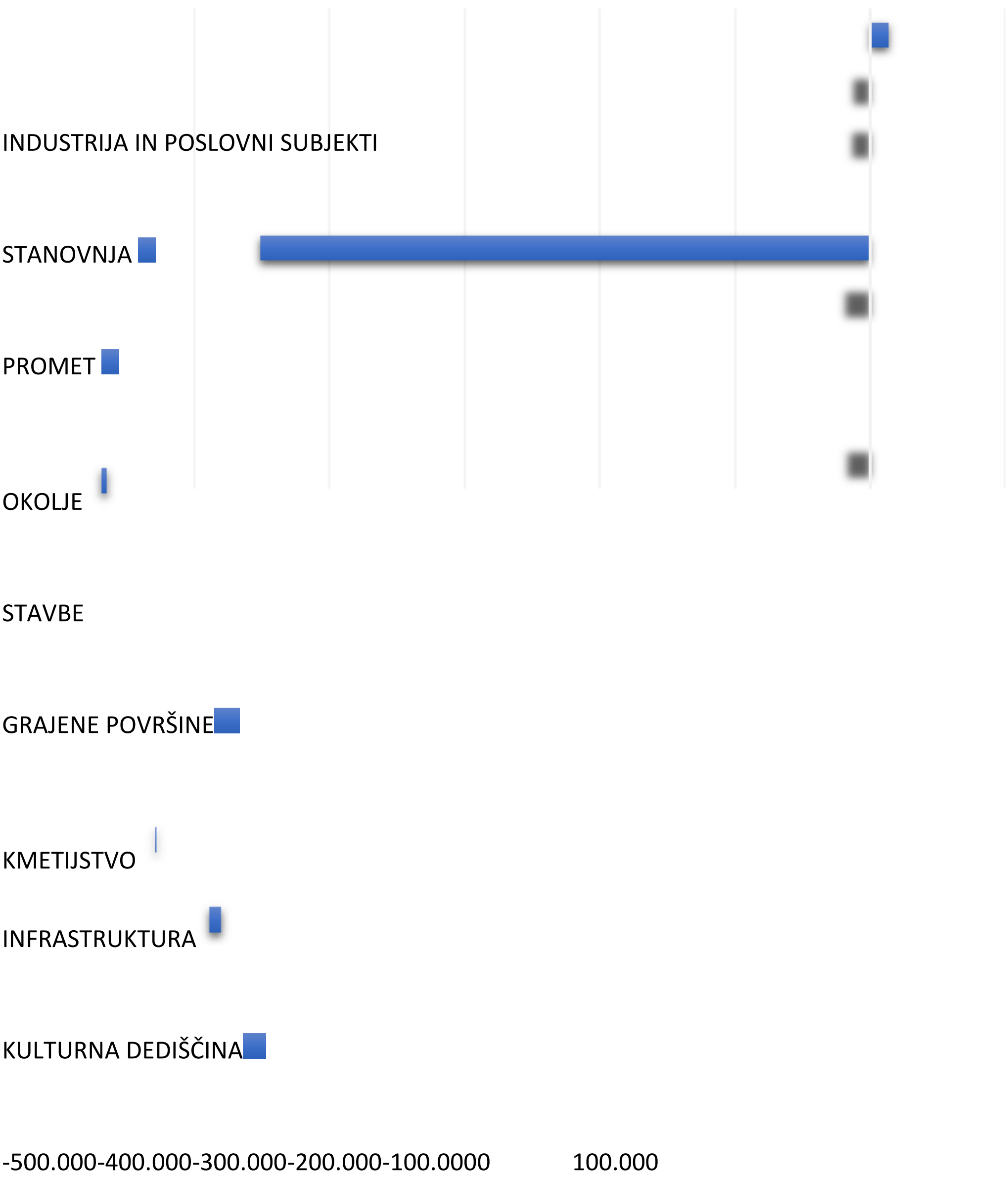
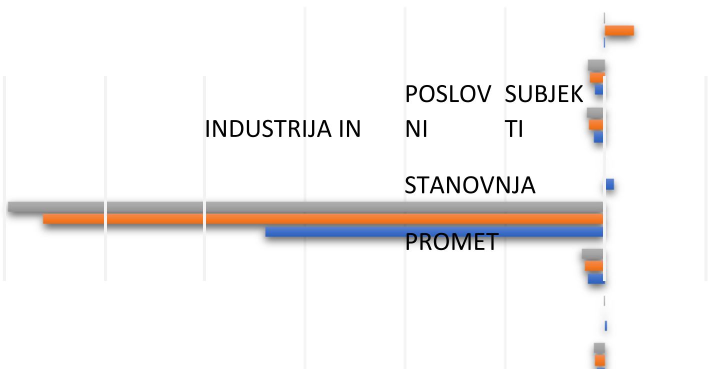


Figure 45: Damage assessment in flood events with a return period of 10, 100 and 500 years (baseline scenario - scenario 2)



The greatest contribution to the reduction of flood damage is made by the measure of construction of embankments and walls , which will protect the entire area of the old part of Kostanjevica na Krki. The figure below shows the damage results (facilities) in the baseline scenario and scenario 2.

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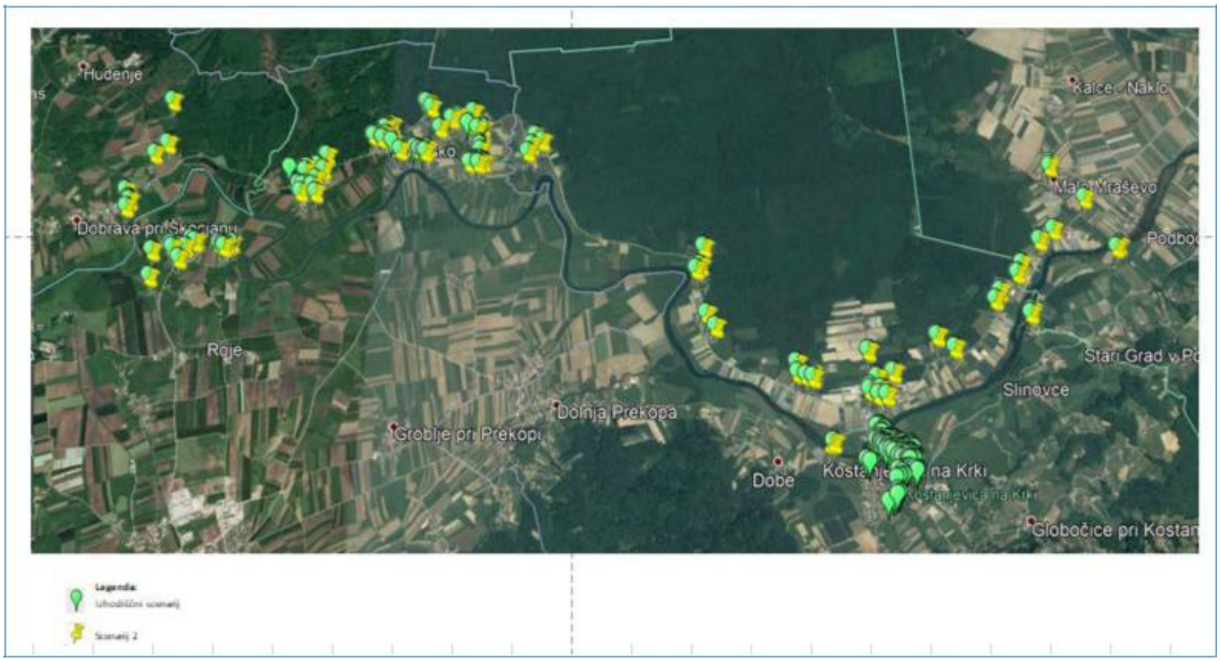
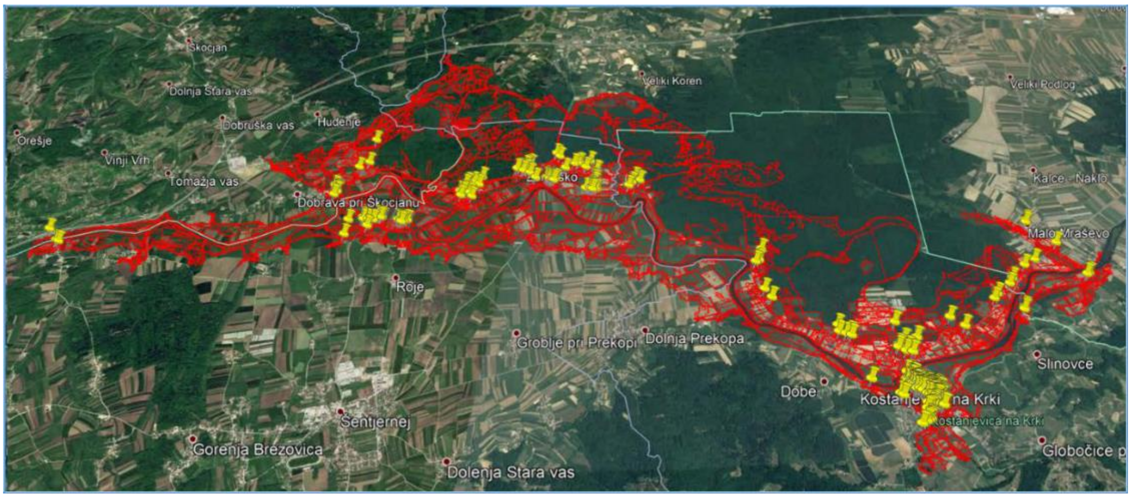
Figure 46: Presentation of damage results (buildings) in the baseline scenario and scenario 2



Scenario 3: Taking into account the measures (K2: Corridor for floodplain restoration, K3: Corridor for floodplain restoration, K4: Corridor for floodplain restoration, K5: Local protection of the island and the southern part of the settlement) under Scenario 3, an average annual damage of EUR 2.136.000 was estimated, representing additional average annual damages of EUR 45.000. This means that the planned measures worsen the existing situation and in this case we have negative benefits in terms of reducing flood damage.

Figure 47: Presentation of damage estimates from KRPAN application using Google Earth - SCENARIO 3



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The implementation of measures under Scenario 3 contributes from the point of view of reduction / increase of annual average damages (effect of the baseline scenario - Scenario 3) to the following effects:

- in the field of cultural heritage, the average annual damage is reduced by EUR 1.337,

- in the field of infrastructure (roads, electricity, water supply and sewerage network), the average annual damage is reduced by EUR 1.083,

- in the field of agriculture, the average annual damage increases by EUR 400 (increase of damage in forest and meadows),

- in the area of built-up areas, the average annual damage is reduced by EUR 776,

- in the field of buildings, the average annual damage increases by EUR 27.733

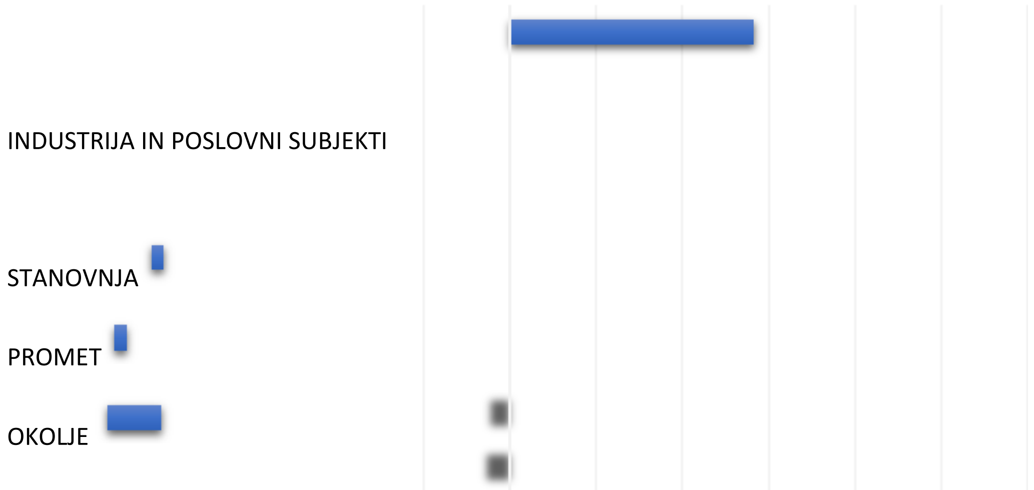
- in the field of the environment, the average annual damage increases by EUR 3.122,

- in the field of transport (passenger cars), average damages are reduced by EUR 722,

- in the area of housing, the average damage is reduced by EUR 682,

- in the field of industrial and commercial entities, the average annual claims increase by EUR 14.167.

Figure 48: Average annual damage by individual parameters (existing scenario - scenario 3)



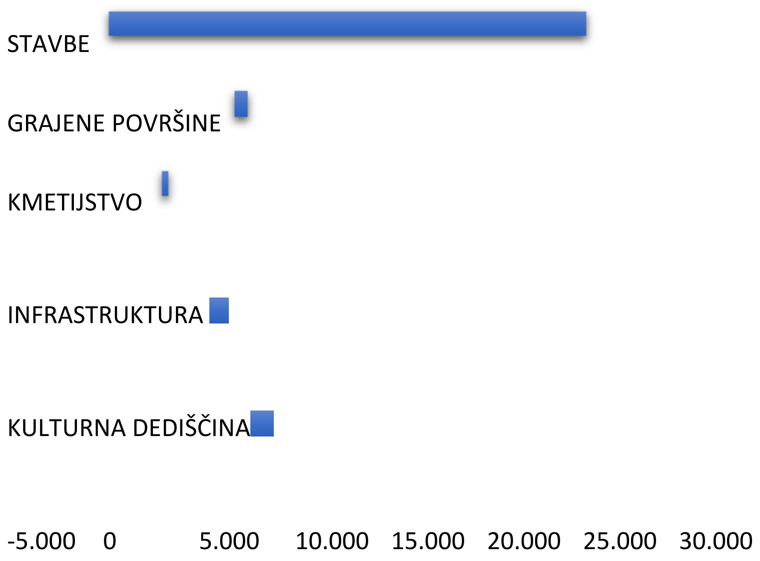

STAVBE
GRAJENE POVRŠINE
KMETIJSTVO
INFRASTRUKTURA
KULTURNA DEDIŠČINA
-5.000
0
5.000
10.000
15.000
20.000
25.000
30.000

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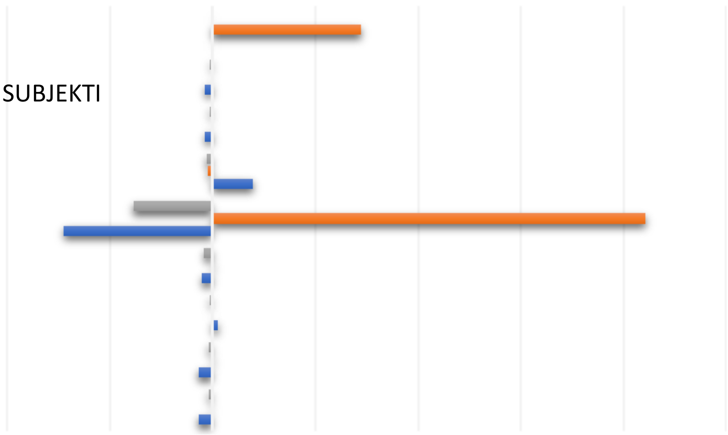
Figure 49: Damage assessment in flood events with a return period of 10, 100 and 500 years (baseline scenario - scenario 3)



INDUSTRIJA IN POSLOVNI SUBJEKTI

STANOVNJA

PROMET

OKOLJE

STAVBE

GRAJENE POVRŠINE

KMETIJSTVO

INFRASTRUKTURA

KULTURNA DEDIŠČINA

-400.000 -200.000 0 200.000 400.000 600.000 800.000 1.000.000

Škoda_Q500(€) Škoda_Q100(€) Škoda_Q010(€)

9 COST AND BENEFIT ANALYSIS FOR INDIVIDUAL SCENARIOS

9.1 Financial analysis

In accordance with EU Regulation 1303/2013, and in accordance with Article 101, it is necessary to provide the information necessary for the approval of the project also in terms of cost-benefit analysis, including economic and financial analysis and risk assessment. Financial analysis should be included in the Cost-benefit analysis (CBA), where it is necessary to calculate the financial indicators of the project. The financial analysis requires:

- Assess the profitability of the project / investment
- Assess the profitability of the project from the perspective of the owner, and some key stakeholders
- Check the financial sustainability of the project, which is a key condition of feasibility for each project typology
- Describe cash flows that support the calculation of socio-economic costs and benefits

The financial model for the CBA is made in accordance with „Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020“ (EC DG Regio, 2014) and a common bilaterally harmonized methodology for the economic assessment of flood damage in transboundary river basins. Accordingly, the methodology to be used to make the financial analysis of the project is the discounted net flow method. The financial analysis is made on the basis of the following assumptions:

59

- The project was studied in terms of discounted cash flows, using the incremental method (without project and with project).

- Only actual cash income and expenses are taken into account, while depreciation, provisions for future costs and contingencies and other accounting items that do not represent actual cash expenses are not taken into account. Cash flows are determined for each year in which they are / will be incurred.

- The financial analysis is made from the perspective of the project owner.

- In accordance with the European Commission's recommendation for the 2014-2020 programming period, a 4% financial discount rate is used to calculate the present value of future cash flows. The discount rate reflects the opportunity cost of capital.

- The cash flow of the project is shown for the entire reference period (economic period of the project), including the preparation time and the operating period; the reference period of the project is 50 years.

- Costs are shown in constant prices.

- All prices are in euros.

- Prices include value added tax (22% VAT) because it is not refundable

9.2 Results of economic analysis

The results of the economic analysis are presented using three basic indicators:

- **Economic Net Present Value (ENVP)** - the difference between discounted economic benefits and discounted total economic costs.

- **Economic internal rate of return (ERR)** - is calculated on the basis of discounted cash flow, and represents the average rate of return of the project for the company.

- **Cost-benefit ratio (B/C)** - is calculated by dividing the discounted sum of all economic benefits by the discounted sum of all costs over the life time of the project.

In order for a project to be economically viable, have a positive impact on society and be eligible for public co-financing, the ENPV must be greater than 0, the ERR must be positive and higher than the economic discount rate and the benefit - cost ratio must be greater than 1. The results of the economic analysis of the project for each scenario are shown in the table below.

Figure 50: Results of economic analysis

ECONOMIC INDICATORS	SCENARIO 1	SCENARIO 2	SCENARIO 3
Net present value (ENSV)	-2.492.214	1.466.468	-3.768.257
Economic rate of return (ESD)	/*	6,32%	/*
Benefit-cost ratio (B/Cratio)	-0,06	1,17	0,02

*The calculation of the economic rate of return cannot be calculated as all values in cash flow except the last year are negative

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10 COMPLETION OF COST-BENEFIT ANALYSIS

Based on the prepared cost-benefit analysis for each individual scenario, we can determine:

- The total investment value of individual scenarios is the highest in the case of scenario 2, namely around EUR 9,8 million,

- Financial indicators are negative in all three scenarios, as the project as such does not generate direct revenues.

- Based on the economic analysis, we can conclude that the positive economic net present value is only in **scenario 2,** which takes into account, among other measures, also protective measures within Kostanjevica na Krki itself, where the greatest effect occurs, especially in terms of benefits due to the reduction of flood risk.

- In the case of scenarios 1 and 3, the risk of flooding even increases and additional costs are incurred.

Figure 51: Comparison of financial and economic indicators in the context of cost-benefit analysis in each scenario

	SCENARIO 1	**SCENARIO 2**	**SCENARIO 3**
Total investment value including VAT:	2.849.302,22	9.833.948,41	4.715.148,90
Annual additional and maintenance operating costs	22.929,14	84.237,83	34.914,89
Financial indicators:			

Financial NET present values	- 2.931.066,76	- 10.559.776, 92	- 4.791.521,46
Financial internal rate of return	- 2.931.066,76	-0,23	-0,19
Economic indicators:			
Average annual benefits from lower average annual claims	-57.000	551.000	-45.000
Average annual benefits from biodiversity conservation and adequate protection of protected nature areas	48.402	58.899	49.568
Net present value (ENSV):	-2.492.214	1.466.468	-3.768.257
Economic rate of return (ESD)	/	6,32%	/
Benefit-cost ratio (B / C ratio)	-0,06	1,17	0,02

4.3. Romania

Feasibility study Bistret

4.4. Serbia

Feasibility study Begecka jama

Activity 4.4
Development of Danube Floodplain Evaluation Tool

Pilot area Begečka Jama in Serbia

D 4.4.1 – Pilot areas pre-feasibility or feasibility studies as a preparation of the next national approval processes, FRMP and DRBMP, including all results from WP4 activities, and recommendations for the realisation

WP	WP4: Flood prevention pilots
Activity	Activity 4.4: Development of Danube Floodplain Evaluation Tool
Deliverable	D 4.4.1: Pilot areas pre-feasibility or feasibility studies as a preparation of the next national approval processes, FRMP and DRBMP, including all results from WP4 activities, and recommendations for the realisation - Pilot area Begečka Jama in Serbia
Activity-leader	TUM and CUEI
Deliverable prepared by	Dragana Ninković, Ljiljana Marjanović, Marko Marjanović (JCWI) Laslo Galamboš, Tanja Bošnjak (INVCP)
Deliverable supported by	Miodrag Milovanović, Dr Prvoslav Marjanović, Zoran Knežević, Nikola Stošić, Branislava Matić, Vasiljka Kolarov, David Mitrinović, Aleksandar Čalenić
Involved partners	JCWI (with External consultancy of INVCP)
Connection with other deliverables/outputs	D 4.1.1, D 4.2.1, D 4.2.2, D 4.2.3, D 4.3.1 (D 4.3.2)

Disclaimer by JCWI

Although defined as a Prefeasibility/Feasibility Study (PFS/FS) for the pilot area, this document does not reflect the PFS/FS content based on Serbian regulations. Its content is suggested by WWF HU within the Danube Floodplain Project and broadly agreed upon by most Project partners. The JCWI team strived to follow it, however, chapter 4 is slightly adapted to meet the Serbian practice.

The Preamble is fully developed by WWF HU. The Literature refers only to this part.

The document serves as a guideline for evaluating the proposed restoration measures for the Begečka Jama pilot area. It is also a good base for further development of technical documentation for the area restoration, especially in terms of using the Ecosystem services and subsequent Extended Cost-Benefit analyses for this kind of projects.

Given the Danube Floodplain procedures and obligations of certain project partners (e.g., ESS assessment, Habitat modelling, Extended CBA, and development of respective deliverables), results presented and discussed in this document are taken from related deliverables.

Within the Danube Floodplain project, the JCWI provided the geodetic surveys (LiDAR, bathymetry) of the Begečka Jama pilot area in 2019, created the digital elevation model and developed 2D hydrodynamic model. Both are at the disposal for further activities on the Begečka Jama maintenance and restoration activities.

List of abbreviations:

Abbreviation	Meaning
APV	Autonomous Province of Vojvodina
BJNatP	Begečka Jama Nature Park
BoQ	Bill of Quantities
CBA	Cost Benefit Analyses
CLC	Corine Land Cover
CUEI	Catholic University of Eichstaett-Ingolstadt
DFP project	Danube Floodplain Project
DRB	Danube River Basin
DRSV	Slovenian Water Agency (project partner)
ESS	Ecosystem Services
EU	European Union
FD	Directive 2007/60/EC on the assessment and management of flood risks
FDAP	Flood defence action plan
FS	Feasibility Study
HD	EU Habitats Directive 92/43/EEC
ICPDR	International Commission for the Protection of the Danube River
INCVP	Institute for Nature Conservation of Vojvodina Province
ISRBC	International Sava River Basin Commission
JCWI	Jaroslav Černi Water Institute (project partner)
KOTIVIZIG	Hungarian Middle Tisza District Water Directorate (project partner)
MAES	Mapping and Assessment of Ecosystems and their Services
MRBA	Czech Morava River Basin Authority (project partner)
NARW	National Administration ”Romanian Waters” (project partner)
NBS	Nature-Based Solution
OG	Official Gazette
WFD	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

PFS	Pre-Feasibility Study
PWMC VV	Public Water Management Company "Vode Vojvodine"
RS	Republic of Serbia
TUM	Technical University of Munich (project partner)
UNECE	United Nations Economic Commission for Europe
VUVH	Water Research Institute of Slovakia (project partner)

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I. Preamble

I-1 Aim of the (pre)feasibility study

The purpose of a feasibility study is to determine if a project is possible, practical, viable as well as economically justifiable (Hoagland & Williamson 2000). A feasibility study will help decision makers make critical quick decisions to select the right opportunities. Feasibility studies that evaluate whether a restoration effort should even be attempted can enhance restoration success by highlighting potential pitfalls and gaps in knowledge before the design phase of a restoration. Feasibility studies also can bring stakeholders together before a restoration project is designed to discuss potential disagreements (Hopfensperger et al. 2007).

Five areas of the project feasibility should be examined: the technical, economic, legal, operational, and scheduling feasibility, this helps to detect constraints the proposed project scenario may face.

Technical feasibility assessment focuses on the technical resources available to the organization. It helps organizations determine whether the technical resources meet capacity and whether the technical team is capable of converting the ideas into working systems.

Economic feasibility assessment typically involves a cost/benefit analysis of the project, helping organizations determine the viability, cost, and benefits associated with a project before financial resources are allocated. It also serves as an independent project assessment and enhances project credibility—helping decision-makers determine the positive economic benefits to the organization that the proposed project will provide.

Legal feasibility assessment investigates whether any aspect of the proposed project conflicts with legal requirements like zoning laws, data protection acts or social media laws.

Operational Feasibility assessment involves undertaking a study to analyse and determine whether—and how well—the organization's needs can be met by completing the project.

In **scheduling feasibility**, an organization estimates how much time the project will take to complete.

I-2 Feasibility of a river and floodplain restoration

Many benefits can be derived from restoring rivers: biological, ecological, socioeconomic, and political. Reinstatement of floodplain wetlands and water meadows may help to control flooding without the need for "hard" river engineering solutions and to "bring the river and floodplain back into continuity" (Holmes, 1995). Moreover, evidence suggests that a more natural river environment can conserve wildlife habitats and the environment (Tapsell et al. 1995). Evidence also shows that a more natural river environment increases people's enjoyment of rivers (ECON, 1993; Tapsell & Tunstall, 1993).

Various factors need to be considered when deciding upon the level of restoration. Small enhancement projects improve the landscape and aesthetic aspects of a river but can also be an attractive option where finance is a constraint or where a more extensive rehabilitation is not feasible. In all cases each method of restoration must be carefully considered from a practical and economic viewpoint (Sonderjyllands amt, 1991).

Any attempt at restoration should not go ahead without the consultation and involvement of local communities and all stakeholders. According to Brookes (1992), the principal concern in restoration schemes is related to the issues of land ownership and land take involved.

In considering a rehabilitation, the past and present ecological conditions of the river and catchment need examining along with the current social context (Tapsell 1995).

I-3 Floodplain restoration in Danube Floodplain project

In the project restoration measures on five selected pilot areas in different countries along the Danube and tributaries were tested. These measures aim to improve catastrophic flood risk, ecological and socioeconomic conditions.

To achieve this aim, three different scenarios with complex methodology were tested. The feasibility study attempts to describe and summarize the current situation and problems that initiated the necessary development, methodologies, different aspects of the feasibility and the constraints and challenges that the project may face during and after the implementation.

II. Executive summary

Deliverable 4.1.1 for the Begečka Jama pilot area is a pre-feasibility study for measures set in two restoration scenarios: a “realistic” one (RS1) that is likely to be implemented and an “optimistic” scenario (RS2) that includes more extensive measures without consideration of real limitations. The document content is defined by WWF HU and does not reflect the PFS/FS content based on Serbian regulations. The document serves as a guideline for the evaluation of the proposed restoration measures for the Begečka Jama pilot area, and as a good base for further development of technical documentation for the area restoration, especially in terms of using the Ecosystem services and subsequent Extended Cost-Benefit analyses.

The Begečka Jama pilot area is in Serbia on the left bank of the Danube River, 25 km upstream from the city of Novi Sad. It represents one of the rare permanent freshwater bodies along the main course of the Danube River in Serbia. Formerly, the area was a part of the larger floodplain that was reduced to the current extent due to agricultural development and flood protection measures dating from the 18th century. Due to geomorphologic types of fluvial erosion of different ages that enabled the develop ment of a mosaic of wetland habitats, Begečka Jama was declared as a Nature Park in 1999. Although the status of the wetland habitats and the hydrological regime have significantly deteriorated over the past 30 years due to siltation and aggradation caused by natural processes and anthropogenic activities (forestry, pollution from the surrounding arable land, flood protection), the area is still an important reproduction area for fish, amphibians and bird species.

Given the current conditions, the main goals of the restoration are improving environmental conditions, restoration of habitats, increasing the quality of the ecosystem services, preserving the landscape and vegetation features and enabling the water interconnectivity between its fragments and with the Danube River. The restoration measures involve sediment removal and deepening of side channels (oxbows), as well as remediation of the existing weir to control the outflow from the area after the Danube flood waters withdrawal. Unlike other Danube Floodplain project pilot areas, the Begečka Jama area has a negligible potential effect on lowering the flood wave peak.

The methodology of the restoration scenarios analyses and comparison of the two scenarios with the current state is done strictly based on the provisions of previously developed DFP project deliverables D 4.1.1 (results of 2D hydrodynamic modelling, TUM), D 4.2.3 (Habitat modelling, CUEI), D 4.2.2 (Ecosystem services, CUEI) and D 4.3.1 (Extended Cost-benefit analyses, TUM). It is concluded that the Ecosystem services are the main benefit of this project. Results show that no one restoration scenario affects the flood peak reduction (as expected already when selecting the pilot area). Both scenarios are acceptable based on the Benefit-Cost difference and Benefit-Cost Ratio. However, the realistic scenario is far more profitable, also reflecting the stakeholders’ preferences and being compatible with the measures set in the Begečka Jama Nature Park (BJNatP) Protection Study.

For the selected scenario, institutional analyses were elaborated, and two potential ways forward were suggested: through the protected area manager’s annual program of works and based on the Law on planning and construction. The content of the technical documentation and the Feasibility study (if necessary) are presented. Furthermore, based on current knowledge, the recommendation for the CBA analyses, Risk evaluation, Implementation of the project, Communication, and Monitoring requirements according to selected indicators, are elaborated too.

1. 1. Introduction to the project idea – the necessity of the proposed project activities

The development of agriculture and expansion of human settlements in the Serbian Province of Vojvodina are the main reasons for river training, narrowing of natural floodplain areas and drainage. Approximately 78% of Vojvodina is covered by agricultural land. The consequence is that the large portions of former natural floodplains along the Danube have been lost. The river training and flood protection works started more than 200 years ago, and the most extensive works have been carried out in the water management sector along with first industrial revolution. The aim was "giving purpose" to "unutilized land" (such as wetlands, floodplains, salt marshes, etc.) by converting the land use to a more intensive one (agriculture, forestry). These actions resulted in massive losses of natural habitats (floodplains, marshes, peatland, salt marshes and meadows, steppes, etc.), along with the functions and services that these areas were providing (water and air purification, fish spawning areas, hunting grounds, habitats for waterfowl and game species).

1.1 Assessment of the situation

The Begečka Jama pilot area (Figure 1) is located in Serbia, in Vojvodina Province, in southern Bačka region, on the left bank of the Danube, approximately 25 km upstream from the city of Novi Sad (capital of Vojvodina Province). It is entirely situated in the inundation zone and represents one of the rare permanent freshwater bodies along the main course of the Danube section in Serbia. Being close to the main course, it is a breeding site for the waterfowl and a stopover for migrating water birds. Begečka Jama was declared as a Nature Park in 1999 ("OG of the city of Novi Sad", N° 14/1999). Figure 2 presented Begečka Jama NatP and Poloj NatP (planned for protection) with protected culture sites in the surroundings.

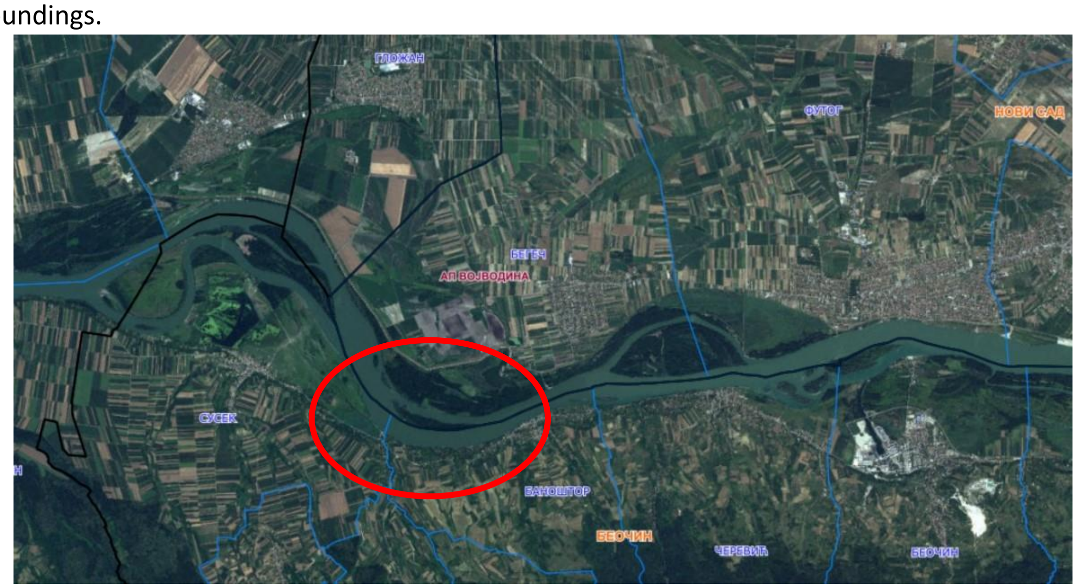


Figure 1: The Begečka Jama pilot area (source: https://a3.geosrbija.rs/)

Figure 2: The protected Nature Park Begečka Jama and Nature Park Poloj (planned for protection) with protected culture sites in the surroundings (source: https://a3.geosrbija.rs/))

Begečka Jama is the remnant of a former, much larger floodplain (Figure 3) that covered the area between the towns of Bačka Palanka, Čelarevo (upstream), Begeč and Futog (both downstream).

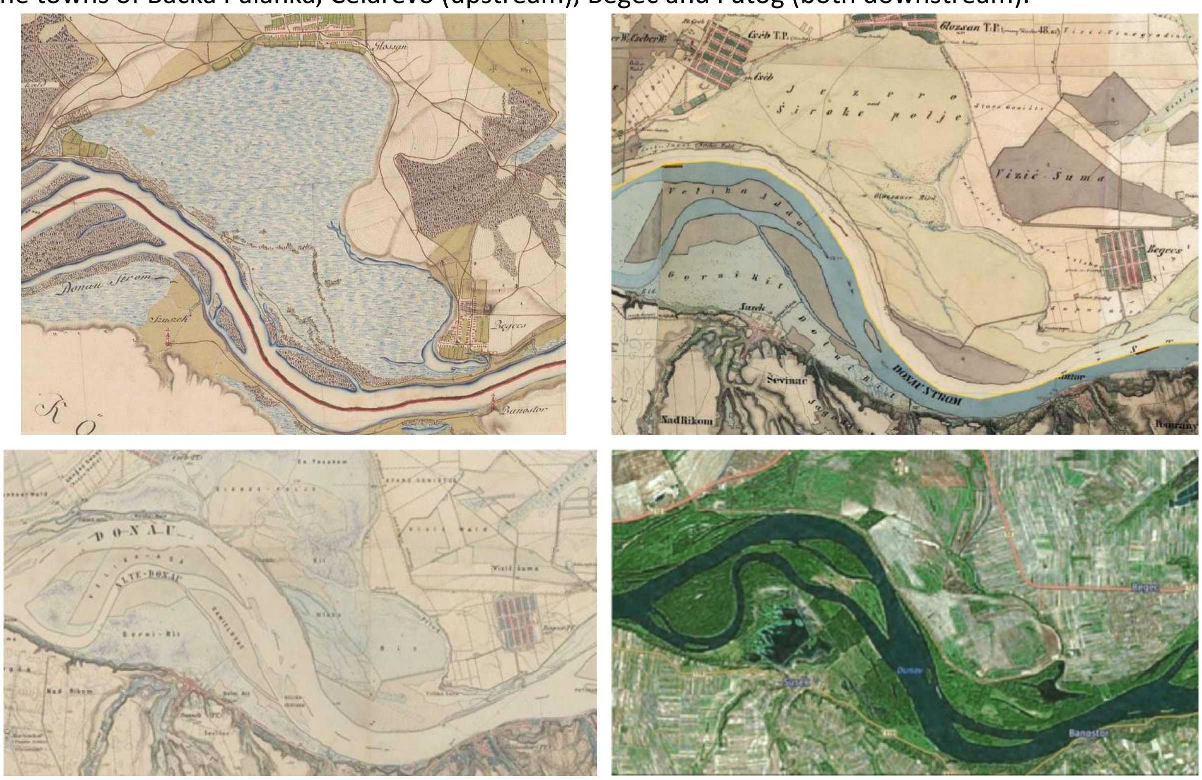


Figure 3: Historical map from the end of 18th century (Königreich Ungarn (1782–1785) - First Military Survey) with formerly flooded areas and the historical map from the beginning of the 19th century (Hungary (1819–1869) - Second military survey) with visible dikes along the riverbank of the Begečka Jama broad area (figures up) and synchronized view of the historical map from the 19th century with Third Military Survey (Habsburg Empire (1869-1877) with the present (figures down) (source: https://mapire.eu/)

Aiming at the flood protection of adjacent settlements and agricultural area, the Begečka jama is surrounded by dikes (Figure 4) managed by the Public Water Management Company "Vode Vojvodine" (PWMC VV).

The area belongs to the Danube River international waterway E-80 (Pan-European corridor VII RhineDanube[2]). The Danube River in the pilot area has category VIc.

From the perspective of the Danube Floodplain project (Work Package 3), the Begečka jama is located in the most downstream reach of the active Danube floodplain RS_DU_AFP01, while immediately downstream is adjacent active floodplain RS_DU_AFP02.

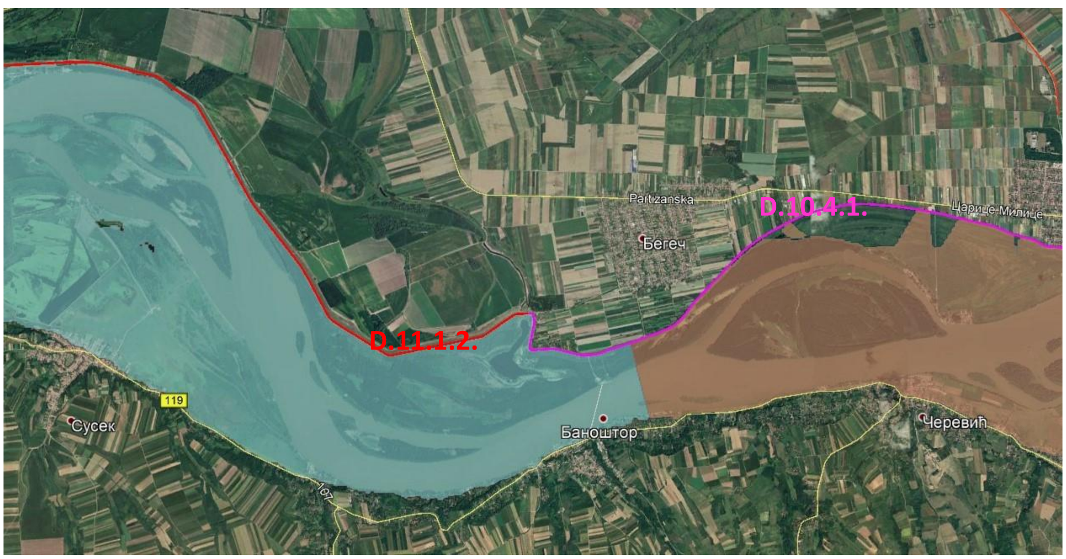


Figure 4: Dikes D.11.1.2 and D.10.4.1 (FDAP 2021) and RS DU AFP01 and RS DU AFP02 (source JCWI)

1.2 Definition of the problem

Formerly, Begečka Jama was a part of the larger floodplain that was reduced to the current extent due to agricultural development and flood protection measures implemented already in the 18th century. Several geomorphologic types of fluvial erosion of different ages - islands, natural levees (ridges), oxbows and

[2] *Convention regarding the regime of navigation on the Danube, Belgrade, 18 August 1948.*

backwaters, created mutually by fluvial erosion and reclamation, enabled the development of a mosaic of wetland habitats at different stages of a succession of floodplain vegetation, which represent a refuge for many animal and plant species. BJNatP is an important reproduction area for many fish, amphibians and bird species.

The status of the wetland habitats (oxbows, backwaters, wet meadows, marshes) and the hydrological regime have significantly deteriorated over the past 30 years due to siltation and aggradation caused by both natural processes and anthropogenic activities (forestry, pollution from the surrounding arable land, flood protection). Intensive land use caused habitat degradation and fragmentation. River training and flood protection measures disrupted the dynamics of flood events. The planting and management of poplar plantations enabled the spreading of invasive plant species, whilst the backwaters, oxbows and wet meadows are being filled up due to the forestry activities and needs. The area became less attractive for visitors due to the reduction of aesthetic and recreational values. The

overall function and processes in the floodplain protected area have deteriorated, and this loss will continue in the future unless restoration and rehabilitation measures are implemented.

Cleaning and widening of the existing connecting channel between the Danube River and Begečka Jama area are planned to increase the water surface area and depth of the Jama lake, oxbows and existing channels. Also, the reconstruction of the existing weir at the Begej canal is planned to prevent water loss from the area in the spawning period.

All measures will subsequently improve the status of spawning areas as a result of habitat restoration and lead to an improvement in overall biodiversity. This would also lead to the improved attractiveness of the BJNatP area to both the local population and visitors.

1.3 Goals

The overall Danube Floodplain project goals regarding the selected pilot areas are enhancing environmental conditions, flood risk reduction and improving socioeconomic conditions.

Given the current conditions and assessed issues on the Begečka Jama protected area, the main goals of the project are:

- Improving environmental conditions: ○ Restoration of habitats towards increasing the quality of the ecosystem services and preserving the landscape and vegetation features and

  - Enabling the water inter-connectivity between its fragments Jama lake and side channels (oxbows) as well as between the Danube River and the area, by sediment removal and deepening of side channels (oxbows).
- Improving socioeconomic conditions: ○ Improving the tourist offer of the area and
  - creating the necessary ground for further sustainable use and management of the protected area, by increasing the attractiveness of the area and improving water quality in Jama lake.

Unlike other selected pilot areas within the Danube Floodplain project (DFP), the Begečka Jama area has a negligible potential effect on lowering the flood wave peak. Therefore, flood mitigation is not considered in the Cost-Benefit Analyses and any previous exercises within the DFP.

1.4 Indicators

Indicators would indicate the progress of the proposed field works on the project site. The indicators mirror the expected results, they should be measurable, and it is recommended that the baseline values of the indicators are available. If no data is available about the baseline, it is more challenging to evaluate the progress. The indicators should cover the interests and aspects of the sectors/stakeholders who are presented. At least one indicator should be referred to all the interests/aspects. Complex picture and evaluation of the proposed scenarios should be helped by choosing good indicators.

Indicators (criteria) for ranking the pilot area improvement scenarios are listed below:

Indicator: <u>Quantity of removed silt deposits, improved water quality</u>. The quantity of removed silt deposits from Begej channel, Mali and Veliki Dunavac oxbows, constructed connecting channels and the south part of Jama lake represents the most relevant indicator. The size of the surface (area) covered with water (shallow water habitats) during fish spawning periods before and after the restoration works could be measured by satellite maps. Excavation of the large sediment bar located at the area where the Begej channel is connected to the Jama lake (that is the direct consequence of the altered flow of water through the Begej canal) and sedimented material in oxbows will influence the improvement of water quality, which can attract more visitors. Water quality parameters are monitored by the Institute for Public Health of Vojvodina; therefore these results can be a baseline for comparing water quality after the implemented measures proposed in restoration scenarios.

Indicator: <u>Estimation of Annual fish production (kg/ha)</u>. At a water level of 180 cm in the Danube (recording at the Novi Sad gauging station), the aquatic habitats cover 21 hectares. Based on this input, the annual fish production in BJNatP is estimated at around 480 kg/ha (total of 10.080 kg fish). The number of sold permits for angling (that are valid only on BJNatP) in 2020 is 178 annual permits and 12 daily permits. With the implementation of the measures in restoration scenarios, it is expected to have an increase in Annual fish production on the floodplain since the surface of the aquatic habitats as well as their quality will increase. The higher fish production will also attract additional anglers; therefore, the number of sold permits (annual and daily) will also increase.

Indicator: Development of new planning documents as support to selected restoration scenario. The proposed restoration measures have been already defined by the Act on the declaration of the protected area Begečka Jama Nature Park ("OG of the city of Novi Sad", No 14/1999). An additional legal background is provided with the initiation of the procedure for the protection of BJNatP in 2020, according to Article 42. paragraph 7. of the Nature Protection Act. (see chapters 2.1 and 2.3.1) that is based on the Nature Protection Study of Begečka jama. After the adoption of the new act on the declaration of the protected area, the proposed specific measures will be legally binding and will be implemented into further planning documents: Protected area management plan, Fishery management plan, Spatial Plan for Special Purposes of Begečka Jama NatP.

Indicator: Area valuation by the visitors, number of visitors of BJNatP per year. Indicators for monitoring the natural features particularly appreciated by visitors help prevent their degradation (e.g., water quality at beaches, the proportion of area in an attractive condition, or sightings of wild species). To understand what aspects visitors value in their nature-based tourism experience, questionnaires and interviews are helpful. The economic value of a nature park may be better measured and monitored using 'visitor satisfaction' or 'visitor motives' as indicators (e.g., to be assessed by means of surveys) than 'travel costs incurred' to reach the park. The baseline for this analysis is the results of the visitors' survey conducted for the purpose of the DF project (online survey). After the completion of the implementation of measures proposed by restoration scenarios, the online survey should be repeated, and the results compared. The number of annual visitors in BJNatP was estimated at 10.000 before the implementation of the scenario. The number of visitors should be re-evaluated after the implementation of the scenario.

1.5 Target groups

The main target groups include the users of the protected area, protected area managers and regional authorities. If the measures and actions proposed by the DTP Danube Floodplain project were to be implemented, the main beneficiaries and stakeholders would be:

- manager of the protected area; the managership has handed over during the DFP Project duration from the private company "DTD Ribarstvo" to the PWMC "Vode Vojvodine"; however, the official procedure hasn't been finished yet.
- Institute for nature conservation of Vojvodina Province,
- Public water management company "Vode Vojvodine",
- "Vojvodinašume" Public Company,
- local angling association "Šveb" from Begeč,
- individual anglers,

- local community of the Begeč village,
- Hunting Society "Podunavlje",
- local government of Novi Sad,
- local water management company “Šajkaška”,
- local entrepreneurs from Begeč (owners of restaurants, bed and breakfasts),
- owners of holiday cottages.

2. 2. Evaluation of background and environment

2.1 Introduction of the geographical environment of the area

Begečka Jama Nature Park is situated in Serbia near the Begeč village, on the left bank of the Danube, approximately 18 km west of Novi Sad (capital of Vojvodina Province). It covers an area of 3.9 km^2, and its length is about 7.8 km along the Danube River (R km 1.276+200 to R km 1.284).

Begečka Jama was declared as a Nature Park (BJNatP) in 1999 (“OG of the City of Novi Sad”, N° 14/1999), and according to the Decree on the ecological network (“OG RS” N° 102/2010), it was declared as part of an ecological corridor of international importance, Danube River.

Begečka Jama (Figure 5) is located in the alluvial plateau of the Danube, in the section of the inundation area of the wetland called “Begečka ada”. The protected area contains a series of geomorphological forms of river erosion of different ages (islands, natural bar/levees and oxbows, abandoned meanders, meander scrolls and a fluvial lake formed by the interaction of sediment erosion and deposition (Jama lake). Accordingly, it is a mosaic of wetland habitats with specific vegetation depending on the microrelief and the dynamics of flooding.

The elevation of the terrain is between 65 and 83 meters above sea level. The terrain where the protected area is located has an incline towards the northeast - opposite to the Danube River, which is a rarity when observing floodplains. However, this indicates the origin of the area, i.e., it represents a remnant of a former river island.

Jama lake is the dominant part of the area. This oxbow, along with the surrounding wetlands, represents an important spawning ground for fish species in the Danube that migrate on to the floodplain for reproduction, as well as a reproductive centre for amphibians in the surrounding area.

The Begej canal connects the Danube River and the Jama lake and thus allows the continual presence of water in the Jama lake. The drainage canal Tatarnica is another water resource of the Jama lake which collects water from the formerly flooded area and discharges it to the Danube through Jama lake and the Begej canal.

Other significant parts of the area are the oxbows in a different phase of succession towards terrestrial habitats. Provala oxbow is a permanent water body. Several former sidearms of the Danube that had been cut off during the natural migration of the main course of the Danube have formed prominent ridges in the landscape. They are represented by oxbows that have been silted up either by natural processes or as a consequence of the intensive forestry in this area. Veliki Dunavac (in Serbian: Large Danube sidearm) and Mali Dunavac (in Serbian: Small Danube sidearm) are now visible only as two oxbows, mostly filled with silt and overgrown by reed and invasive shrubs. Mali Dunavac has deteriorated more than Veliki Dunavac that still has open water surfaces during floods and for a short period after the flood event. The importance of Veliki Dunavac was recognised seven years ago when several restoration projects were implemented in order to remove the vegetation that had overgrown more than half of the oxbow, and also a small channel that connects Veliki Dunavac with Jama lake was dug out. The role of this channel was to create a small watercourse that enables fish (both adults and juveniles) to return to the Danube via Jama lake after spawning/hatching when the water withdraws after the floods.

The hindered flow of water through existing marshes, ponds, and channels, and especially old sidearms that are crucial for proper flooding and water exchange between the river and wetland habitats, contributes to the reduction of open water surfaces. It also causes succession and changes the form of aquatic and semi-aquatic vegetation to shrubs and forests, leading to the loss of natural habitats for many important species and subspecies, which are significant for biodiversity preservation.

Dikes are present in the area of Begečka Jama, but the Pilot Area is in the active flood zone, from the aspect of flood defence.

The Danube River sediment is partially deposited in the floodplain and former sidearms of the Begečka Jama. This natural process is causing the siltation of the floodplain. The processes of siltation and filling up are more intensive at impediments (e.g., in forests and channels) that cause the overflow of water. The width and depth of former sidearms, channels and oxbows have been altered by human activities, causing a decrease in their function for water transport into and around the floodplain; therefore, the flooding of the area is slow and occurs to a smaller spatial extent. These changes result in a much faster water withdrawal from the area after a flood event.

The natural processes, overall changes in the hydrological regime, coupled with the consequences of human activities (reduction of the length and width of channels in the floodplain, backfilling of channels, sidearms, oxbows, etc.), have led to a much faster loss of habitats and natural values of the area.

The Tatarnica canal brings organic and inorganic pollutants, residues of fertilisers, communal wastewater, pesticides, herbicides, and other pollutants. This causes further deterioration of the ecosystem in the Jama lake, especially eutrophication, which is a significant threat resulting in the backfilling of the Jama lake. As a result, detritus is forming and being deposited in other aquatic habitats (oxbows, channels, marshes). The silting up is further intensified by the existing obstacles in the channels (such as the weir on the Begej canal, which connects the area with the Danube River).

In addition to water management, forestry - the major activity in the area - has the most significant impact on the area: hybrid poplar plantations, the presence of invasive plant species, forestry roads intersecting the oxbows and causing siltation, etc. The remaining oxbows have deteriorated in the past 30 years, which requires revitalisation activities to restore the former function of these habitats.

These human impacts have disrupted the distribution and the amount of marsh, meadow, and forest ecosystems in this protected area.

Figure 5: Begečka Jama map

Veliki Dunavac oxbow is still one of the biggest oxbows (9 ha) and a very important spawning area for many fish species represented in this section of the Danube River. As a result of the Danube water and flooding regime changes, the Veliki Dunavac oxbow started silting up more than two decades ago, while the eutrophication process also increased. During the sparse floods, the fish migrate into this area, but with the withdrawal of the floods, most of the juvenile fish and a certain number of adults remain in the oxbow until it dries out, which results in fish kills.

The microrelief characteristics of the entire area closely depend on the Danube river dynamics. Due to the impacts of human activities and disturbed hydrological regimes, the Veliki and Mali Dunavac oxbows have been silted up in the past period; they are filled with water only for a brief period after the withdrawal of the high-water level. They are overgrown with reed and other semiaquatic vegetation.

Hydrological conditions in the "Begečka Jama" Nature Park are primarily determined by the activity of high and flood water of the Danube and shallow underground water. It contains some of the most valuable wetland habitats and, therefore, is a sanctuary for many closely connected species to the river.

A fluvial island called Šašićeva ada near the left bank of the Danube is a prominent feature of the protected area. It is formed by sediment accumulation processes in the river.

Biogeographic characteristics of the area correspond to the regions of the Pannonian perimeter. Alluvial vegetation of the Danube plain in this area encompasses marsh and meadow vegetation and artificially established forests of hybrid poplars (plantations for intensive production). A special botanical feature of the BJnatP represents individual trees of white and black poplars (remnants of former vast forests of native poplar and willow species). On the territory of the protected area 125 plant taxa, 150 bird species, 14 species of freshwater fish, 11 amphibians and 6 reptile species and 18 key insect species have been recorded. Water macrophytes are of special importance as significant components of the fragile marsh/swamp ecosystems preserved in the confluences of the rivers in
Vojvodina. Begečka Jama is an important spawning ground for numerous fish species. Most of the recorded birds have a migratory status: passing, drifters and wintering birds. The picturesque riverine landscape also plays an important role in the promotion of ecotourism in the region.

2.2 Introduction of the socio-economic environment of the area

The area of Begečka Jama had played a significant role for people who lived in the nearby settlements. The wetland ecosystems provided essential resources such as wood and timber (forestry), food (fish and game meat), as well as recreation (fishing and hunting). The use of the area became more and more intensive, which proved to be unsustainable, and consequently resulted in the deterioration of the natural habitats. The landscape also changed following human needs, e.g., flood protection, forestation, etc.

The Land Cover/Land use is presented in Figure 6, based on the Corine Land Cover 2018 data (CLC). Figure 7 gives more detailed information on the land cover, based on the Riparian Zones LC/LU nomenclature guideline (MAES[3] level 3).

[3] *Mapping and Assessment of Ecosystems and their Services (MAES)*

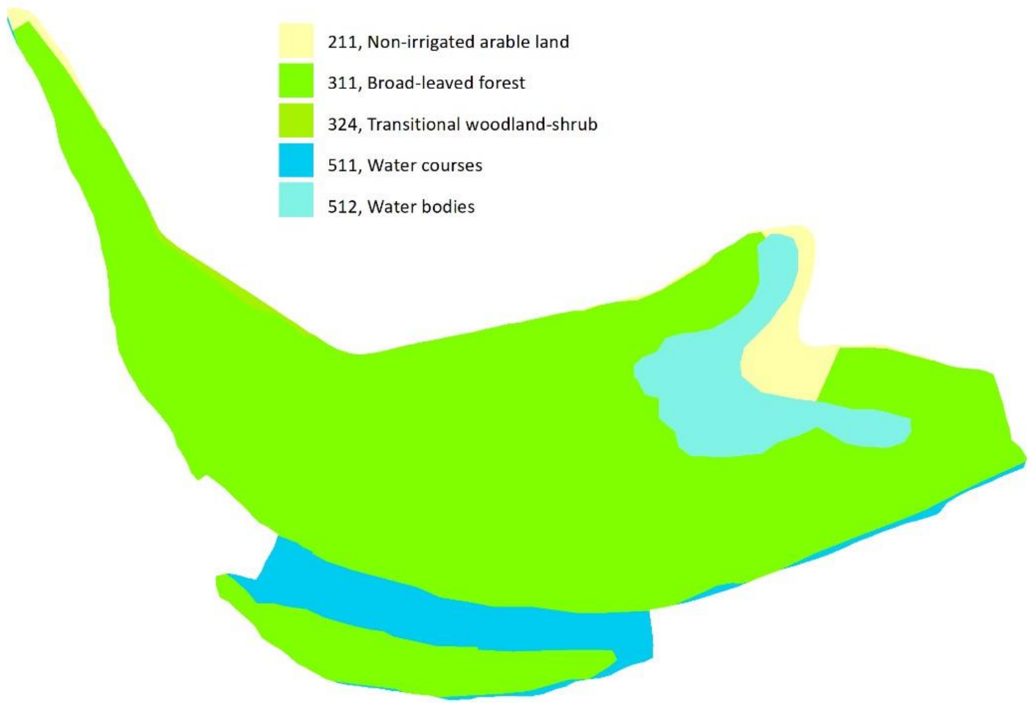


Figure 6: Corine Land Cover/Land Use in the Begečka jama pilot area

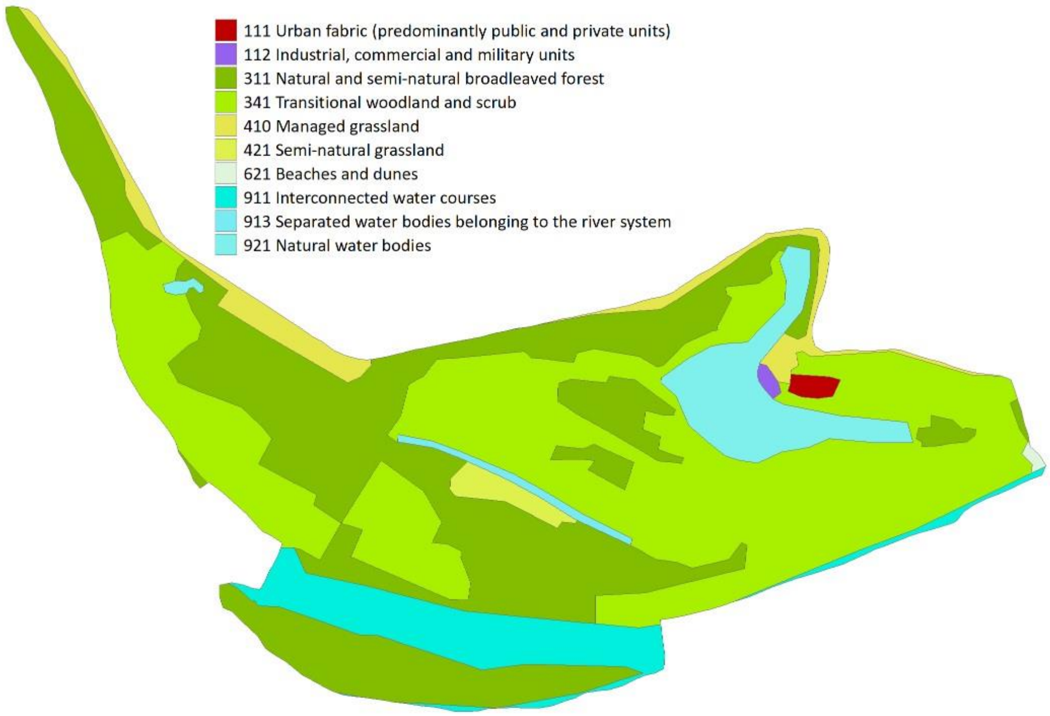


Figure 7: MAES Riparian Zones LC/LU

Forestry represents one of the main economic activities in the Begeč village. The forests in Begečka Jama (mostly plantations of hybrid poplar) are managed by "Vojvodinašume" Public Company.

A small legal settlement of weekend cabins (55) and mobile homes, with small wooden and tin houses (17), is located on the northeaster part of BJNatP. Additionally, 18 illegal cottages have been raised along Jama lake.

The area is predominantly surrounded by agricultural land. The soil is very productive (being on a former floodplain), and the region is famous for vegetable cultivation but also field crops. Orchards and vineyards are sparsely present. Agricultural farming requires intensive application of mineral fertilizers to increase yields and agrochemical measures for crop protection. Therefore, the production has a direct and/or indirect negative impact on the protected area (natural resources), especially on water quality.

The declaration of the protected area caused certain limitations in land use and the use of the area of Begečka Jama. This primarily refers to urbanization, the use of forests, but also traditional activities, such as fishing. Bearing in mind the socio-economic aspects in the area, preserving this vital area represents the overall priority to ensure the survival of endangered species whose habitats are under threat on a European level.

The needs of the local population, as well as the users of the protected area, must be presented to the manager of the protected area and the authority responsible for nature protection through local initiatives. To enable the implementation of the necessary activities that can be used to assess and achieve the goals of economic development, these needs must be included in the Protected Area Management Plan.

The area of Begečka Jama is a popular vacation site. A small sandy beach that attracts visitors is located on the eastern bank of Jama lake. From late spring to the early autumn, numerous visitors are in the area for swimming. In addition, two traditional fish restaurants offer dining options for visitors.

Being an important habitat for many fish species present in the Danube, Jama lake is attracting anglers and sport fishermen. Recreational fishing is regulated under the Law on the protection and sustainable use of the fish fund, while additional restrictions are derived from the Management Plan of the protected area. Hunting has a long tradition in Vojvodina Province. The territory of BJNatP belongs to the "Podunavlje" hunting ground that covers an area of 14,711.74 ha. Hunting in Begečka Jama is limited due to the status of a protected area, and hunting is only allowed for sanitary purposes, meaning that only diseased individual animals can be hunted in the area.

EuroVelo 6 is a long-distance cycling route that runs along 3,653 km some of Europe's major rivers from the Atlantic coast of France to the city of Constanța on the Black Sea, including almost the entire length of the Danube. The route passes just off the borders of BJNatP, on the top of the flood protection dike.

There are no protected cultural sites in the Pilot Area.

An active ferry crossing is downstream from the Begečka Jama, thereby improving accessibility on Pilot Area.

The location of the BJNatP is approximately 20 km away from the border of UNESCO Biosphere reserve "Bačko Podunavlje".

2.3 Legal and policy background

2.3.1 National regulations

Management of the Begečka Jama protected area is defined according to the Law on Nature Protection ("OG RS", N° 36/2009, 88/2010, 91/2010 - correction, 14/2016 and 95/2018 - other law).

The other relevant laws and regulations are:

- The Water Law - WL (OG RS, N° 30/10, 93/12, 101/16, 95/2018 and 95/2018 - other law) regulating the legal status of water resources, integrated water management, and management of water structures and water land.

- The Planning and Construction Law - PCL (OG RS N° 72/09, 81/09, 64/2010, 24/2011, 121/12, 42/13, 50/13, 98/13, 132/14, 145/2014, 145/14, 83/18, 31/19, 37/19 - other law, 9/20 i 52/21) which regulates: the conditions and procedures for spatial management, building land development and use, and construction.
- The higher-level planning documents are the Spatial Plan of the Republic of Serbia 2010-2020 (OG RS N° 88/2010), Decision on the adoption of the Regional Spatial Plan of the Autonomous Province of Vojvodina (OG APV N° 22/2011) and the Decree on the designation of the Spatial Plan of the area of a special purpose of the international waterway E-80 (Pan-European corridor VII) (OG RS N° 14/2015).
- The Spatial Plan for Special Purposes (SPSPA) is currently being developed for the Begečka Jama and the surrounding area to regulate further development and urbanisation of the area in the vicinity of the protected area (OG APV N° 60/2018). A strategic environmental impact assessment is an integral part of the SPSPA.
- Spatial and zoning plans are planning documents that define the conditions and govern the procedures for spatial development and building land development and use.

The Danube River, including the protected area of the BJNatP, is an ecological corridor of international importance. Nature protection measures are prescribed by the Ecological Network Regulation ("OG RS", N° 102/2010 as of December 30, 2010). A set of protection measures for the ecological network is prescribed in Attachment 3 of this law Regulation. Some of the most important measures are:

- conservation and improvement of the corridor parts in line with the landscape and vegetation features,
- stimulating the traditional use of the area that contributes to the preservation and improvement of biodiversity and
- ensuring pollution prevention and reduction.

2.3.2 EU perspectives and impacts on the national legal framework

Since the accession process of the Republic of Serbia to the EU is ongoing, transposition and implementation of the EU water sector legal framework and policies are mandatory, and their requirements should be progressively incorporated in national water management strategies. Evaluation of the implementation of international water management principles and practices into the national strategic and planning documents and success of the international cooperation will affect the Republic of Serbia negotiation processes assessment for the EU membership.

There are a lot of efforts in Serbia as the EU accession country to harmonize all relevant in line with EU Directives' requirements. Transposition of the EU water sector and environmental protection legal framework requirements into the national legislation is an ongoing process in the Republic of Serbia. The most advanced progress is made in EU WFD and EU Flood Directive transposition, while for other directives, it is not the case. For the achievement of all goals and objectives in the water sector, political support and the contribution of all relevant institutions are obligatory. To fulfil the transposition of all EU directives, revision of all existing bylaws, decrees, etc., is planned.

The Republic of Serbia belongs to the UNECE (United Nations Economic Commission for Europe) region, and more than 90% of its territory is within the Danube River Basin (DRB). Cooperation within the UNECE region is based on the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992), which is an obligatory framework for transboundary surface water and groundwater protection (prevention, control, and ecologically acceptable water management). The convention was ratified in Serbia and entered into force in 2010 (Act on ratification of Convention on the Protection and Use of Transboundary Watercourses and International Lakes, "OG RS – international contracts 1/10).

Cooperation among the DRB countries is based on the Danube River Protection Convention, and water management multilateral coordination and cooperation among the countries are achieved under the auspice of the International Commission for the Protection of the Danube River (ICPDR). At the Sava River sub-basin level, the cooperation is realised through the International Sava River Basin Commission (ISRBC) activities. As a result, long term water management courses and objectives have to be in correspondence with that.

The transposition of the EU Habitats Directive 92/43/EEC (EU HD) into the national legislation in Serbia began in 2009 with the adoption of the Law on Nature Protection and its further amendments in 2010 and 2016. The complete transposition is yet to be achieved; therefore, the Directive is partly complied with national legislation and by the following regulations:

- Law on Nature Protection ("OG RS", N° 36/09, 88/10, 91/10 - corrigendum, 14/16, 95/18-other law) and accompanying by-laws.
- Law on Wildlife and Hunting ("OG RS", N° 18/2010, 95/18-other law) and the accompanying bylaws
- The Law on Protection and Sustainable Use of Fish Fund ("OG RS", N° 128/14, 95/18-other law) • The Law on Strategic Environmental Assessment ("OG RS", N° 135/04, 36/09)
- Law on Environmental Impact Assessment ("OG RS", N° 135/04, 88/10).

Additional amendments of these sectoral laws are planned to achieve full transposition. The draft Regulation on the appropriate assessment has been prepared, in accordance with Article 6 of the HD, and its application is conditional on amendments to the Law on Nature Protection, Law on Environmental Impact Assessment and the Law on Strategic Environmental Assessment and their bylaws in order to comply with the HD.

The Ecological Network defined by the Law on Nature Protection, comprising 101 ecologically important areas and ecological corridors, including the Important Bird Areas, was established to conserve, restore, and improve habitat types of particular importance and certain wild species of flora and fauna. Together with the Emerald Network (designated according to the Bern Convention) and the new 79 Important Birds

Areas adopted by BirdLife International, represent the baseline for the designation and the establishment of the Natura 2000 network in Serbia. The stages of the identification and designation of the future Natura 2000 network are continually being monitored within Chapter 27 of the accession negotiations for membership to the European Union. Even though still not legally binding, the importance of the conservation of Annex I habitats and the species listed in HD Annex II has been recognized by some of the national expert institutions. The Natura 2000 species and habitats are listed in the Nature Conservation studies (proposals for the designation of future protected areas), as well as in Fishery management plans.

The transposition of the EU Birds Directive into the national legislation is also partially completed in Serbia through the Law on Nature Protection and the Law on Wildlife and Hunting.

Serbia has also started the process for the identification and designation of potential Sites of Community Importance (SCI) and Special Protection Areas (SPA).

3. 3. Scenario analysis

Harmonized restoration settings and hydrological scenarios are applied to ensure comparability between the five pilot areas (Figure 8). A current state scenario model (CS) is developed and two different restoration scenarios, one realistic (implementation planned, RS1) and one optimistic restoration scenario (RS2), based on local circumstances.

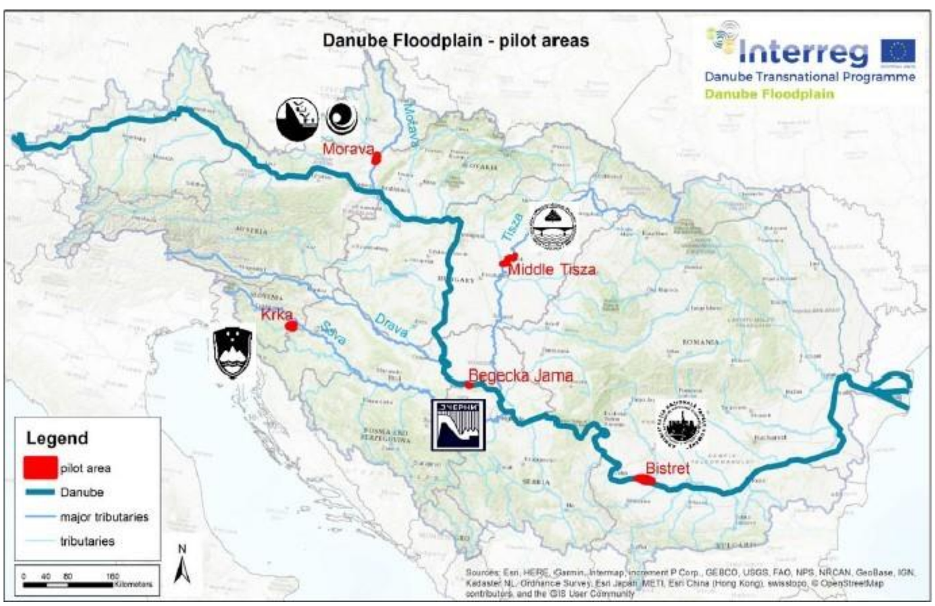


Figure 8 DFP project pilot areas

This chapter is entirely based on the provisions and correspondent results provided within the Danube Floodplain Project Deliverables as follows:

- D 4.1.1 Report on the technical realization scenarios taken into consideration for modelling, the implementation in a 2D model and assessment of the impact (TUM), hereinafter: D 4.1.1
- D 4.2.3 Report on the assessment of biodiversity in the pilot areas (CUEI), hereinafter: D 4.2.3
- D 4.2.2 Report, database and maps of ESS analysis of the pilot areas including a list, description, assessment, and ranking concerning the demands and supplies (CUEI),
- D 4.3.1 Report on assessment results of the CBA applied to the pre-selected pilot areas including ESS, stakeholders and biodiversity (TUM), hereinafter: D 4.3.1
- D 4.3.2. Method documentation describing the implementation of ESS and biodiversity to traditional CBA (TUM), hereinafter: D 4.3.2
- D 4.3.4 Summary of used complex methodology and process description on hydraulic 1D and 2D, CBA, ESS, ecological assessment and stakeholder analysis, hereinafter: D 4.3.4.

Above mentioned project deliverables are developed based on the data and information provided by the "pilot partners": NARW (Bistret, RO), DRSV (Kostanjevica na Krki, SI), KOTIVIZIG (Middle Tisza, HU), MRBA, VUVH (Morava at the SK-CZ border).

3.1 Methodology of the scenario analysis

Based on the commonly agreed **definitions of scenarios** (current state-CS, realistic scenario-RS1, and optimistic scenario-RS2, the same methodology for the scenario analysis is applied. For each restoration scenario, a set of measures is selected (e.g., in-stream measures which change the roughness and the shape of the riverbed, alterations in the floodplain size through, e.g., dike relocation), as well as morphological and/or land cover changes in the floodplain to comply with the scenario goals.

After an agreement on the explicit restoration measures in each scenario with the stakeholders, the **2D hydraulic models** for the pilot areas were set for each restoration scenario.

1. Current State (CS)

   The first model represents the current state of the area (CS). It is set up based on a recent highresolution digital elevation model (DEM) and up-to-date ground survey data. It is the base model for the restoration scenarios models.

2. Realistic restoration scenario 1 (R1)

   In the second 2D model (realistic restoration scenario 1; R1) all planned measures are implemented, e.g., dike relocation, modification of land cover and river geometry.

3. Optimistic restoration scenario 2 (R2)

An optimistic scenario model (optimistic restoration scenario 2; R2) is developed, which includes more extensive measures. With this approach, the maximum capacity of flood protection obtained by restoration measures in the pilot areas without consideration of real limitations is shown.

Figure 9 depicts the interactions of the methodological procedure for the scenario analyses.

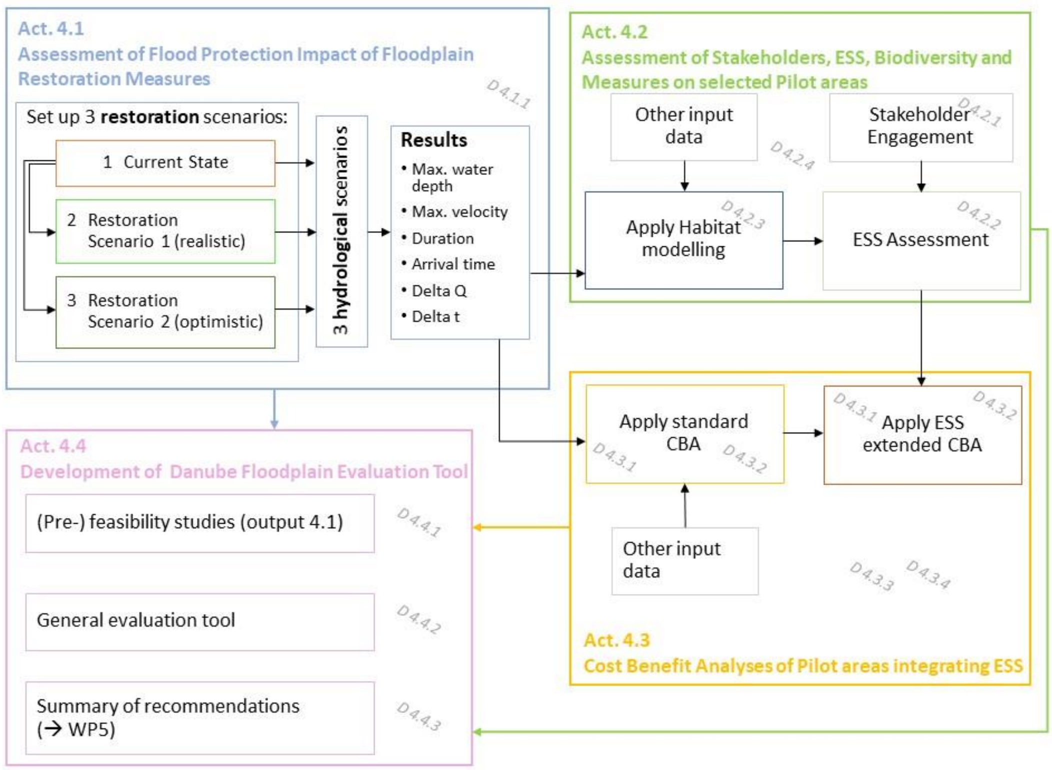


Figure 9 Flow chart showing the methodological procedure for the scenario analyses

The response of floodplain restoration measures to different flood events was assessed. Local and national partners applied **two-dimensional (2D) hydrodynamic models** to investigate the hydraulic efficiency of restoration measures for all restoration scenarios for three hydrological events (HQ_{2-5}, HQ_{10-30}, and HQ_{100}) in each pilot area. For the results' assessment, we used spatial results of the maximum water depth and flow velocity of each scenario. Furthermore, we analysed the results of the simulated streamflow time series at the downstream model border, in particular looking at the reduction of the flood peak discharge and the translation of the flood wave (time shift of maximum discharge).

The results of the hydraulic simulations (water depth, flow velocity, hydrographs of model output, etc.) are quantitatively analysed 4.1.1 and processed for a further assessment of the floodplains regarding its habitats and ecosystem services but also for a standard and extended cost-benefit analysis (CBA).

The **habitat modelling** (D 4.2.3) is carried out for each pilot area using the results from the hydraulic modelling work along with further spatial datasets like, e.g., digital elevation models or landcover data. Its general aim was to evaluate whether the floodplain restoration scenarios are capable of improving typical floodplain habitats. Such prediction was made based on environmental co-variables derived from the previously modelled hydraulic parameters (e.g., water depth, flow velocity, etc.). A semiautomated approach was chosen for deriving potential habitat types. Then, a set of (fuzzy) rules was used to describe the different habitats.

The **Ecosystem Services (ESS) assessment** (D 4.2.2) (i.e., recording and evaluating the ESS of the affected area) was done as a good measure to enable the assessment of the effects of planned measures. ESS provide information about nature's regulatory services like nutrient retention, the supply of natural products like water and the cultural uses within an area. A stakeholder workshop was held in each pilot area to map the kind and intensity of ESS use. During the workshops, stakeholders discussed the project, the planned measures in the pilot areas, and the expected outputs of the project. As a result of the stakeholder meetings, the most relevant ESS were recognized by the stakeholders in the pilot areas. A further method for mapping the provisioning and regulating ESS of pilot areas was estimating the capacities to provide ESS by using land use/land cover data in MAES typology and CLC. By jointly classifying all provisioning and regulating ESS, areas with a particularly high/low provision of ESS (so-called hotspots/cold spots) are identified.

For the **extended cost-benefit analysis** (D 4.3.1), ESS maps from the previous steps were used and focused on six ESS, i.e., **water-related services** (**flood mitigation, Nutrients retention), global climate regulation (carbon storage, greenhouse gases sequestration), cultivated goods provisioning, nutrients retention, and nature-based recreation**. For this, the methodologies (D 4.3.2) suggested in the Toolkit for Ecosystem Service Site-Based Assessment (TESSA) are applied **complemented with alternative approaches** (e.g., questionnaires on social media). The methodology allowed a profitability analysis of the restoration measures.

The extended CBA process is graphically conceptualized in Figure 10.

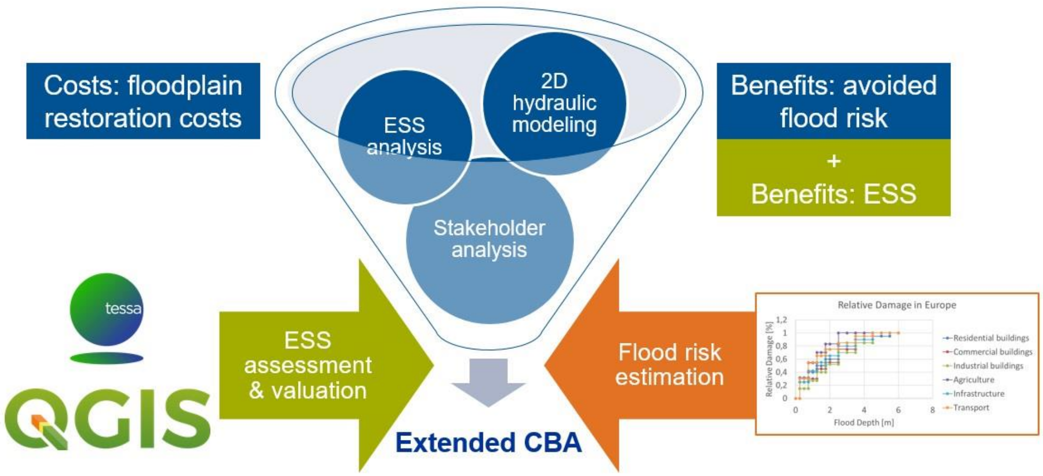


Figure 10 Workflow of the extended cost-benefit analysis for floodplain restoration measures in the DFP Project.

3.1.1 Methodology applied for the Begečka Jama pilot area

Based on the agreed methodology, the JCWI:

- provided survey data in 2019 and respective DEM (Figure 11), land use data to derive roughness criteria from the Corine Land Cover were used; existing hydrological data are used;
- set up the current state 2D model (CS), including calibration and validation in an adequate spatial resolution based on the obtained input data (Table 1);
- decided on the measures for two restoration scenarios (RS1 and RS2) in cooperation with national partner INCVP (Chapter 3.1);
- modified the CS 2D model geometry accordingly to receive the two restoration scenario models RS1 and RS2 (Chapter 3.4);
- performed unsteady simulation runs for all setup models with the three hydrological scenarios (frequent flood event HQ_{2-5}, medium flood event HQ_{10-20}, 100-year flood event HQ_{100}), based on the joint agreement among the project partners;
- delivered results (spatial data and hydrographs) and provided a detailed report on the work steps in a documentation file to the activity leader TUM.

Table 1 Begečka Jama 2D model properties

2D model type and release	Flood events simulated	2D model size in km²	Number of nodes	Nodes per km²	DEM base	Temporal resolution

HEC-RAS 5.0.7	HQ_{2-5}: 5766.9 m^3/s HQ_{10}: 6475.8 m^3/s HQ_{100}: 8372.1 m^3/s	10.13	CS 30855 R1 31412 R2 31997	CS 2656 R1 2701 R2 2751	1x1m Lidar and Bathymetric surveys (2019)	1 hour

Figure 11 Begečka Jama pilot area DEM

TUM visualized and analysed provided results in cooperation with JCWI and drew respective conclusions within the Deliverable 4.1.1.

The floodplain habitat modelling is carried out by CUEI and TUM (Deliverable 4.2.3) using the results from the hydraulic modelling along with other spatial datasets (DEM, landcover data).

The assessment of the ESS was done by CUEI (Deliverable 4.2.2) based on the findings from the Stakeholder workshop organised and held by JCWI in the Begečka Jama pilot area on 24 January 2019, as well as using land cover/land use data provided in close cooperation with JCWI and its external consultants. The main findings regarding the changes of ESS when comparing the current state and restoration scenarios are based on the MAES data. The ESS assessment of the Begečka Jama pilot area within Deliverable 4.2.2 is made in three ways:

- by Stakeholders during the ESS workshop in Begečka Jama on 24 January 2019,
- by JCWI and INCVP experts, based on a more detailed examination of the area and taking into account official data and information from institutions (e.g., INCVP, "Vojvodinašume" Public Company, etc.), and
- using land cover/land use data from the Riparian Zones LC/LU nomenclature guideline (MAES).

For the standard CBA, the JCWI provided standard BoQ for RS1 and RS2 measures, based on the usual unit prices of certain works. Benefits from the avoided flood damages do not exist, given that the area is regularly flooded with or without restoration.

The extended CBA is subsequently applied by TUM, focusing on six ESS, i.e., **water-related services** (**flood mitigation, Nutrients retention), global climate regulation (carbon storage, greenhouse gases sequestration), cultivated goods provisioning, nutrients retention, and nature-based recreation**. For this, the methodologies suggested in the Toolkit for Ecosystem Service Site-Based Assessment (TESSA) are applied complemented with alternative approaches for assessing Nature-based recreation. The latter is carried out through the questionnaire created by TUM and supported by JCWI (encouraging the Begečka Jama stakeholders to participate).

To finalize the cost-benefit analysis (CBA), the benefits and the costs were compared with each other. Before comparing them, benefits and costs were discounted, assuming the discounting parameters presented in Table 2.

Table 2 Parameters used for the cost-benefit analysis

Parameters for discounting
r = 0.04 N = 50

3.2 Preliminary analyses for identification of scenario

Pilot areas in the DFP project are selected and approved already during the preparation of the project. From the very beginning, JCWI experts were aware that the restoration of the Begečka Jama pilot area would not have a significant flood mitigation effect (being a small part of the large active floodplain). The main reason for the selection of this area as a pilot was to show positive restoration effects on the biodiversity and improvement of ESS. Therefore, the main two goals are improvement of habitats conditions and subsequent attractiveness for tourism and recreation.

The Begečka Jama pilot area is investigated by the Jaroslav Cerni Water Institute (JCWI). The JCWI developed two restoration scenarios (RS1 and RS2) in cooperation with the Institute for nature conservation of Vojvodina Province (INCVP).

Conservation policies for the BJNatP are implemented through the 10-year management plan. The conservation measures (e.g., wetland restoration, water regime management, eradication of invasive species) target habitats, species, ecological processes and or the preservation or improvement of functions provided by the area, but they are also improving the provision, quality, and quantity of different ecosystem services. The specific measures are defined in the Act on the declaration of the protected area Begečka Jama Nature Park. In order to conserve the natural habitats and species, under the Act, it is prohibited to alter the natural water regime, discharge wastewater, deposit any kind of pollutants, drain the wetland habitats, increase the surface of poplar plantations, cutting and substitution of native tree species with hybrid poplars, commercial fishing and hunting. Maintenance and management of Begej canal, Jama Lake and aquatic habitats according to approved documents, the substitution of hybrid poplars with native tree species, wetland habitat revitalisation, controlled grazing, reintroduction of native plant and animal species are some of the measures defined in the Act, that need to be implemented to improve and maintain the preservation of the favourable condition of habitats and species populations and communities.

Based on said, the **realistic restoration scenario (RS1)** for the Begečka Jama pilot area is defined in accordance with the BJNatP needs and taking into account the interests of other immediate stakeholders in the area (forestry, local population). The main issues are water scarcity after the withdrawal of floodwaters and deteriorated migratory corridors between the Danube and the area. The measures are selected to enable better interlinkage of existing oxbows and canals within the area as well as with the Danube River (Table 3, column RS1). These measures are additionally supported considering the recent process of revising the protection of the BJNatP, where new boundaries of the protected area and of the protection regimes have been proposed by the INCVP along with new protection measures. The goal is to preserve natural flooded habitats as priority types of habitats for protection. Considering that the updated Protection Study of BJNatP was officially entered into approval procedure, measures proposed in the Protection Study became obligatory. Some of these measures are targeting wetland habitat restoration; therefore changes in the land use are allowed for the purpose of natural habitats restoration and the improvement of Jama Lake. Diversion of water migration routes is possible for management purposes, and the removal of aquatic vegetation and riparian vegetation is possible according to approved plans. Changes in terrain morphology are allowed to improve the ecological status of aquatic habitats with shallow water and riparian habitats. In order to maintain the functions of the floodplain ecosystem, the regular flow of water through the Begej canal needs to be maintained. According to the Law on the Protection and Sustainable Use of Fish Fund (“OG RS”, N° 128/2014 and 95/2018-other law), a specific Fishery management plan of the BJNatP was developed. This document regulates fishing, fishery management, fish stocking, habitat restoration, the establishment of fish warden service, etc.

The **“optimistic” scenario (RS2),** requested by the DFP project and aiming at the maximum capacity of flood protection without consideration of real limitations, are presented in Table 3 (column RS2).

At first glance, restoration scenarios R1 and R2 have similar measures, i.e., cleaning and widening of the existing connecting canal Begej between the Danube River and Begečka Jama lake, weir reconstruction to allow water flow and fish migration, deepening of existing oxbows and channels and the excavation of new channels between the deepened oxbows, which would allow for the controlled inflow/outflow from the system, etc. The main difference is in the large side canal within the scenario R2 aiming at accelerating the flood conveyance and retaining more water in the area during low water periods (although being aware of the insignificance of expected results).

Table 3 Measures in Restoration scenarios in the Begečka Jama pilot area

Restoration scenario	RS1	RS2
1. constructions		
1.1 dike relocation		
1.2 dike removal		
1.3 controlled dike overtopping / gaps in the dike		
1.4 removal of weirs		
1.5 change operation mode of weirs	X	X
1.6 migration permeability at weirs	X	X
1.7 removal of culverts		
2. land cover and lateral branches		
2.1 convert land cover towards natural conditions		
2.2 modify floodplain DEM	X	X
2.3 increasing the roughness of floodplain (afforestation)		
2.4 create and connect new lateral branches or pools / new water regime	X	X
2.5 create retention areas / flood channels		
2.6 connection of lateral branches/oxbows	X	X
2.7 deepening lateral branches/oxbows	X	X
2.8 reconnect old oxbow		
2.9 increase floodplain area		
3. river channel geometry alteration		
3.1 increasing the roughness in the river channel (according to natural bedrock)		
3.2 widening of the river channel		X
3.3 increase of the riverbed (decrease of water depth)		
3.4 increase the diversity of the river morphology (riffles, pools, potholes, sand or gravel banks, cut banks and slip-off-slope, broader and narrower passages of the river,...); diversity of cross profiles of the river	X	X
3.5 removing bank stabilizations / embankments		
Restoration scenario	**RS1**	**RS2**
3.6 riparian vegetation (increase roughness, stabilizes the riverbank, decreases nutrient inflow)		
3.7 implementing groynes, boulders, or dead wood to initiate meandering		
3.8 change course of river (meandering)		
3.9 removing ground sills, plunges		
3.10 create fish spawning areas	X	X
3.11 Removing sand bars		

Besides the measures selected in the Begečka Jama pilot area, Table 3 presents a range of possible restoration measures for this kind of project (light-grey font).

3.3 The case without the project – scenario "0" (CS)

The natural processes, overall changes in the hydrological regime, coupled with the consequences of human activities (reduction of the length and width of channels in the floodplain, backfilling of channels, sidearms, oxbows, etc.), have led to a much faster loss of habitats and natural values of the Begečka Jama pilot area.

Further management of the area without the implementation of restoration measures (continuation of "business as usual") would lead to further deterioration of ecosystems (disappearance of wet habitats) and the loss of natural values based on which the Begečka Jama area was declared a protected area.

The regime of floods in the Danube River basin has already been altered, and the effects are visible in terms of irregular flooding of Begečka Jama. Coupled with the changes in the morphology of the microrelief on the floodplain, the water regime will become even more unfavourable, causing changes in vegetation and directly on animal and plant communities.

The main effect of the "no actions" approach will be the deterioration of the water regime in the Begečka Jama. This will result in an insufficient amount of water in the wetlands throughout the entire year (change from permanent ponds to ephemeral) as well as further siltation and consequent growth of semi-aquatic and terrestrial plant species (among them invasive alien species). Under the impact of the Tatarnica canal and intensive forestry (deadwood, leftover branches after forest cutting, bad maintenance of culverts) eutrophication in Jama lake will increase.

The sluice on the Begej canal (Figure 12) was constructed without acquiring necessary permits, and the potential impacts of the sluice on Jama lake and the water exchange between the Danube and its floodplain has not been evaluated. The sluice impacts the fish species also, representing an obstacle for fish migration during low and medium water levels in the Danube. The sluice has a narrow opening and a shallow base, adversely affecting the movement of the water and therefore causing siltation in the western part of Jama lake (the part where the lake that connects with Begej) in the past 20 years. Unless the sluice is removed or reconstructed to support the management of water on the floodplain, further siltation will occur both in this watercourse (that represents the main connection of Jama lake with the Danube River), as well as in Jama lake. As a consequence, the dynamics of the water exchange between Jama lake and the Danube will deteriorate, causing further eutrophication of the Jama lake. Also, the already large sediment bar located at the area where the Begej canal is connected to Jama lake (that is the direct consequence of the altered flow of water through the Begej canal) will grow further. This will cause an impairment of water quality in Jama lake. Subsequently, the beds of the oxbows on the floodplain will become more elevated, and the sparse floods will reach these areas less often. The ecological conditions in Begečka Jama will change, making this area unsuitable for fish spawning, which will not only have a negative effect on the natural values of this protected area but on a larger scale, outside of the borders of the protected area.

Figure 12 The sluice on Begej canal

The migration of fish species into this important spawning area will become more difficult, and even if successful, the spawning performance will decrease. The duration of high water in the floodplain will be shorter, and the withdrawal of the floods quicker, meaning that the survival rate of the juvenile fish will be lower. The changes in water quality and quantity will also result in fish kills.

3.4 Introduction of project scenarios

Based on the project request, two restoration scenarios have been developed: the realistic one (based on the needs of the protected area and its natural values) and the optimistic one (in order to lower as possible the peak of the flood waves).

To gain the main goals:

- restoration of habitats,
- increasing the quality of the ecosystem services,
- improving the touristic offer of the area,
- creating the necessary ground for further sustainable use and management of the protected area,

both restoration scenarios for the Begečka Jama pilot area are enabling adequate water supply of the area throughout the year in the Jama lake, oxbows and channel system, but have a different impact on floodplain habitats and the ecosystem services the Begečka Jama pilot area is providing.

Major restoration requests are:

- Adequate water supply throughout the year in the Begečka Jama lake, oxbows and channel system and improving habitats for aquatic species.
- Increase in the water surface area and depth of the oxbows and existing channels.
- An extended time of water retention on the floodplain (after the flood events). Increase in biodiversity and spawning areas as a result of habitat restoration.
- Increasing the types of ecosystem services, as well as improvement of the quality and quantity of existing ecosystem services of the area.

The planned restoration measures were discussed on two stakeholders workshops in the Begečka Jama pilot areas with relevant stakeholders – fishery, agriculture, municipal authorities, nature protection, local residents, etc.

1. The current state (CS) is set up based on the detailed terrain surveys (LiDAR and bathymetry) provided by the external contractor for the purpose of the DFP project. It is the base model for the restoration scenarios models.
2. Realistic restoration scenario 1 (RS1): In the second 2D model, realistic restoration scenario (RS1), all planned measures are implemented, e.g., modification of land cover and river geometry.
3. Optimistic restoration scenario 2 (RS2): an optimistic scenario model (RS2) is developed, which includes more extensive measures. With this approach, the maximum capacity of flood protection obtained by restoration measures in the pilot areas without consideration of real limitations is shown.

To quantitatively assess the impacts of restoration measures on flood events, the simulation results of CS and both RS are compared regarding their maximum discharge (Qmax), change in flooded area, flood wave volume, average flood depth and velocity as well as the translation of the flood wave (Δt). Analysing the hydrographs, the temporal and quantitative impact of the modifications on the flood peak are shown, while water depth, where available water level and velocity maps depict the spatial variability and changes after potential restoration projects for the three different flood events.

3.4.1 Scenario 1 (RS1)

Restoration measures for Scenario 1 (Figure 13) - Realistic are:

- Cleaning and widening of the existing connecting canal between Danube River and Begečka Jama lake, weir reconstruction to allow water flow and fish migration.
- Floodplain DEM modification via the deepening of existing oxbows and channels and the excavation of new channels between the deepened oxbows, which would allow for the controlled inflow/outflow from the system.
- Increase the diversity of the river morphology as a result of the excavation, deepening and cleaning of oxbows and existing and new channels.
- Improvement of existing and creating new fish spawning areas, which contribute to the maintenance and increase of the overall biodiversity of the area.

Scenario 1 represents a set of typical floodplain restoration measures aimed at the restoration and rehabilitation of typical floodplain habitats that are increasingly endangered and disappearing due to land-use changes and river training works. The goal is to enable better connectivity of the floodplain with the Danube, provide undisturbed water flow in and out of the oxbows and channels, also water flow that will enable effective sediment transport (prevent the siltation processes and stimulate sediment removal from canals, channel, and oxbows in the floodplain when the water is withdrawing after the flood event). By the implementation of the planned measures, the open water surface should increase, some of the currently ephemeral aquatic habitats will be transformed to permanent water surfaces that will not dry out even at low water level events, thus providing habitat for many endangered animal species (primarily fish, amphibian, and insects, as well as waterfowl). The water will be retained for a longer period on the floodplain, and a lesser number of aquatic habitats will dry out during the dry season.

Floodplain habitats have a very important role for fish species, providing spawning, nursery, feeding and wintering habitats. Loss of habitats, deterioration of connectivity, loss of ecosystem functions leads to a decrease in the populations of phytophilic (spawning on vegetation in shallow water) and phyto-litophylic fish (spawning on silt and vegetation in shallow water) species that are dependent on wetland on floodplain for spawning. By implementing the measures proposed in Scenario 1, the connectivity between the Danube and the floodplain will improve, as well as the possibility for fish migration to the restored floodplain habitats.

Scenario 1 mostly comply with the requests of the BJNatP Protection studies and was broadly approved by the stakeholders at the workshops.,

Figure 13 Scenario 1 measures in the Begečka jama pilot area

3.4.1.1 Technical analysis (derived from the DFP Project Deliverable 4.1.1)

The main results of the 2D hydrodynamic model for selected hydrological scenarios for the current state (CS) and the optimistic scenario (R1) are presented in Table 4 and Figures 14-15.

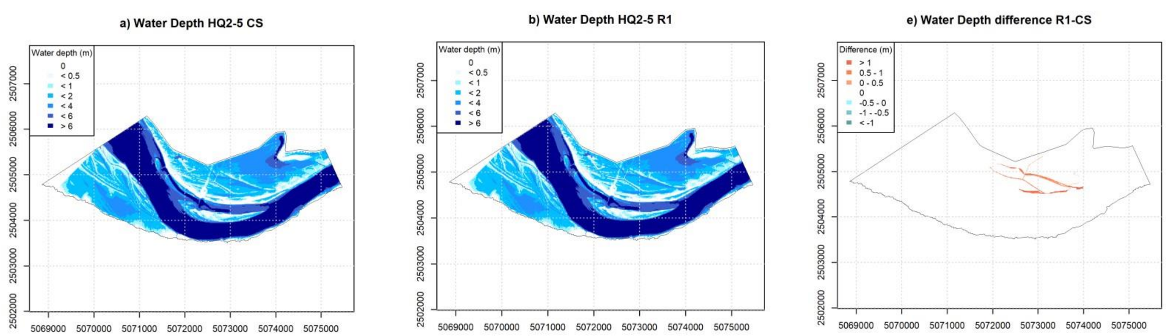
Table 4 Results and analysis of the 2D simulations of the Current State and Scenario 1 in the Begečka Jama

		HQ_{2-5}	**HQ_{10}**	**HQ_{100}**
Qmax (m³/s)	out CS	5766.9	6475.8	8372.1
	out R1	5764.1	6476.0	8370.0
ΔQmax (m³/s)	R1-CS	-2.8	0.2	-2.1
ΔQmax (%)	R1-CS	-0.1	0.0	0.0
Δt (h)	R1-CS	3	-1	0
Change in flooded area (%)	R1-CS	0.0	0.0	0.0
Change in volume (%)	R1-CS	0.3	0.2	0.2
Average water depth (m)	CS	4.44	5.55	6.04
	R1	4.45	5.56	6.05
Average flow velocity (m/s)	CS	0.47	0.63	0.64
	R1	0.47	0.62	0.64

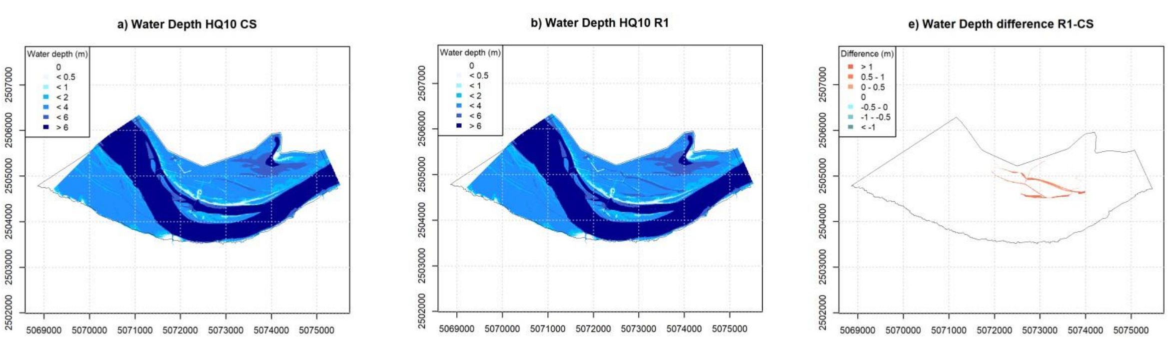
Since restoration measures were focused on the improvement of the habitats and biodiversity in general, the negligible effects of the flood peak (Q_{max}), the translation of the flood wave (Δt) and the volume reduction were expected in Scenario 1.

Analysing the spatial results of the water depth and water level in the Begečka Jama pilot area, the increased capacity of the river channel can be confirmed. The difference maps of the water depth in Figure 14 show the excavated channels of the restoration scenarios (dark orange). Here we can see that the increased capacity of the channels has a larger effect on the water level change during lower HQ events (HQ_{2-5}) than during larger HQ events (HQ_{100}) which in fact is a goal of these measures (improvement of the water level in excavated oxbows and channels during more frequent flows and not during the floods).

Scenario RS1: Begečka Jama water depth results, HQ_{2-5}, 1m resolution



Scenario RS1: Begečka Jama water depth results, HQ_{10}, 1m resolution



Scenario RS1: Begečka Jama water depth results, HQ_{100}, 1m resolution

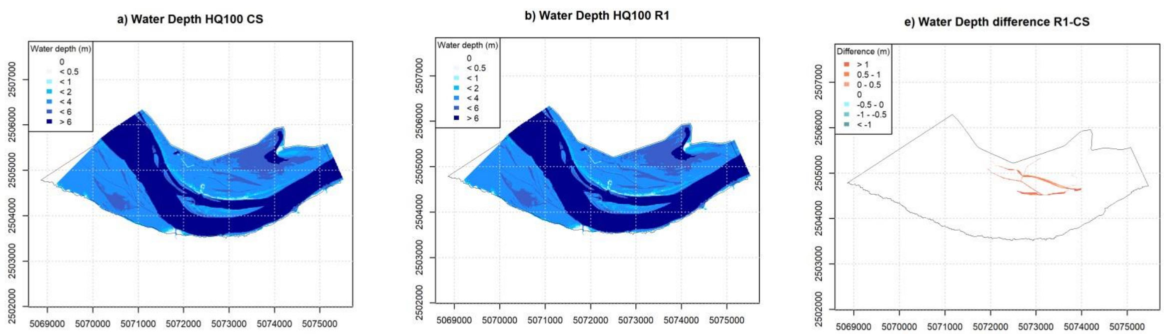
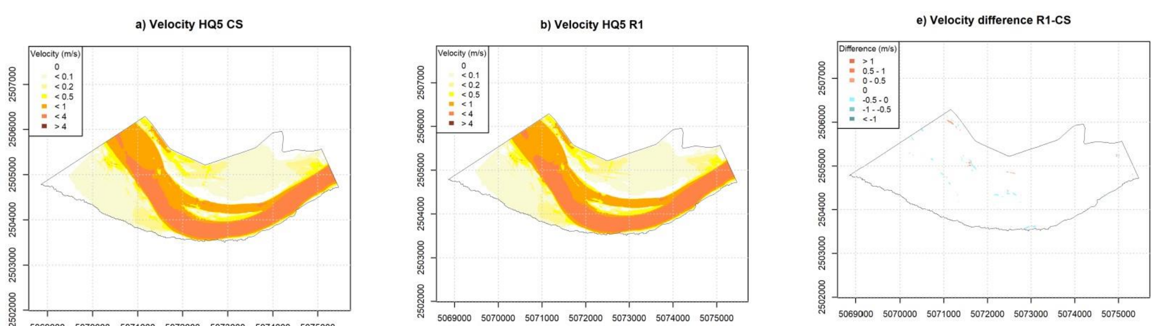


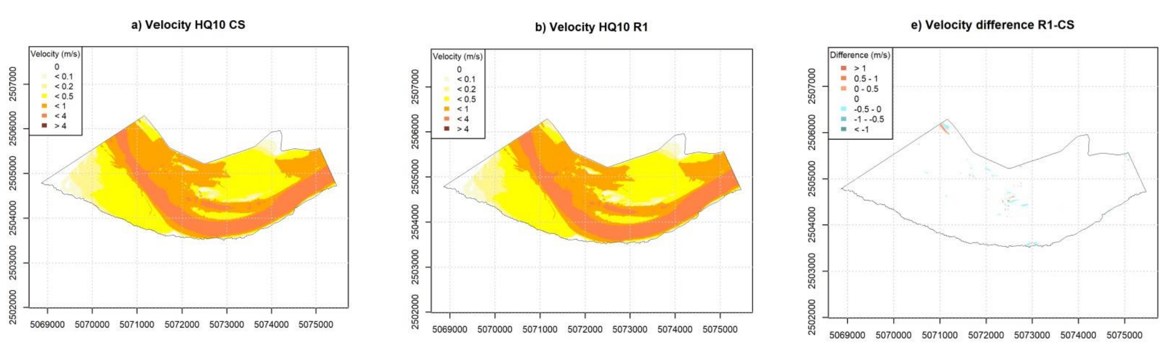
Figure 14: Begečka Jama water depth results, and difference maps (R1-CS) for HQ_{2-5}, HQ_{10} and HQ_{100}

The results of the 2D models show that the purposes of restoration in the Begečka Jama pilot area were met. The capacity in the oxbows and existing channels is increased, relieving the main Danube channel. This effect is already observable in the more frequent flood events of magnitude HQ2-5. The subsequent improved water supply in the Begečka Jama Lake is expected to lead to an upgrade of habitat quality and ecosystem services.

Scenario RS1: Begečka Jama velocity results, HQ_{2-5}, 1m resolution



Scenario RS1: Begečka Jama velocity results, HQ_{10}, 1m resolution



Scenario RS1: Begečka Jama velocity results, HQ_{100}, 1m resolution

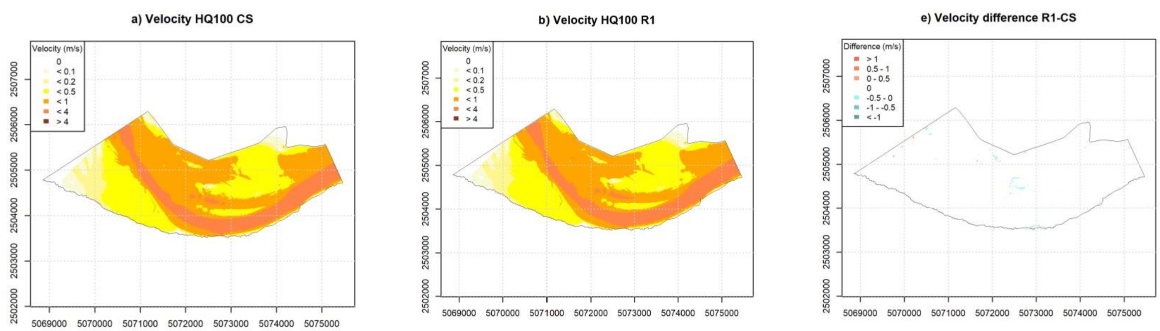


Figure 15 Begečka Jama velocity results and difference maps (R1-CS) for HQ2-5, HQ10 and HQ100

3.4.1.2 Effects

Effects based on the Habitat modelling (derived from the DFP Project Deliverable 4.2.3)

In the realistic restoration scenario, the connection between the backwaters is improved by creating/widening didges between the different backwater systems. In addition, the connection to the Danube is improved by opening a canal from the lake in the northeast of the pilot area to the Danube.

The area of the hydrologically connected floodplain slightly decreased to 200 ha as the backwater area increased to 47.7 ha. The connectivity of the remaining area does not change significantly. Thus, no hydrologically driven change of vegetation can be expected. However, in total, the area hydrologically connected to the Danube increased from 232.5 ha to 247.7 ha. Also, the connectivity within the backwater system has significantly improved due to a system of canals in the central part of the floodplain. In addition, the connection to the Danube has improved as well.

This increases the suitability of the backwaters to be spawning habitats for fish species migrating between the main channel and the backwaters. As flow velocity remains low, the backwater system remains a suitable habitat for stagnophilic fish species as well. However, the habitat suitability for amphibian species like Bombina bombina is likely to decrease due to the pressure from fish. The area and characteristics of the channel area do not change in the realistic restoration scenario.

Effects based on the Ecosystem Services assessment (derived from the DFP Project Deliverable 4.2.2)

The main findings regarding the changes of ESS by implementing Scenario 1 are based on the MAES data and presented below.

With the implementation of the measures of restoration scenario RS1, parts of the broadleaved forest and transitional wood and scrub areas will be changed into intermittently running watercourses (Figure 16).

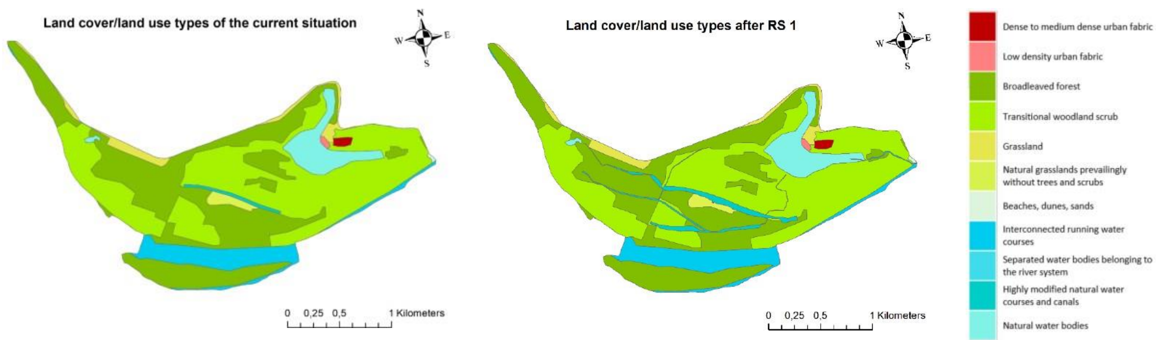


Figure 16 Land cover/land use of the current situation, after the implementation of restoration scenario 1 (RS1)

Provisioning ESS

The current situation of the potential to provide the ESS wood is mainly high to very high. It will decrease by implementing the restoration measures in the affected areas, considering that former forest areas will be transformed into water bodies (Figure 17).

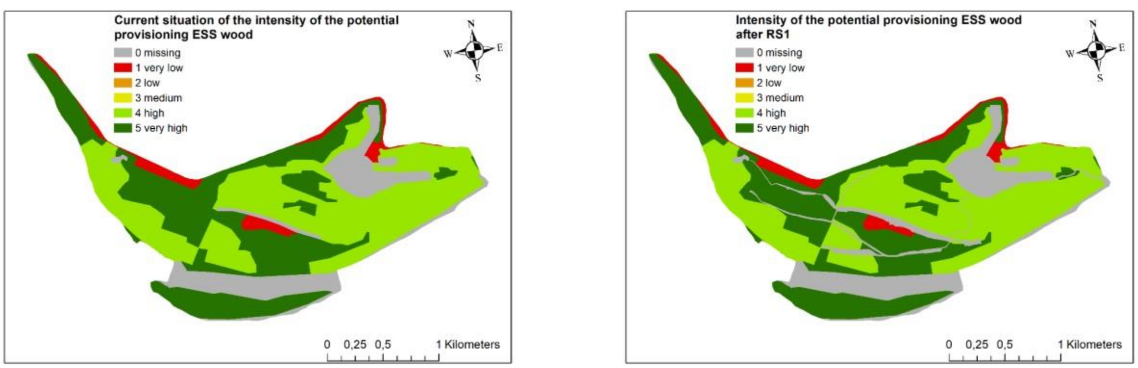


Figure 17 Provisioning ESS wood in Begečka Jama, CS and RS1

In contrast, the intensity of the potential to provide the ESS animal product is low to very low and only in the grassland areas is a very high potential for ESS animal product (Figure 18).

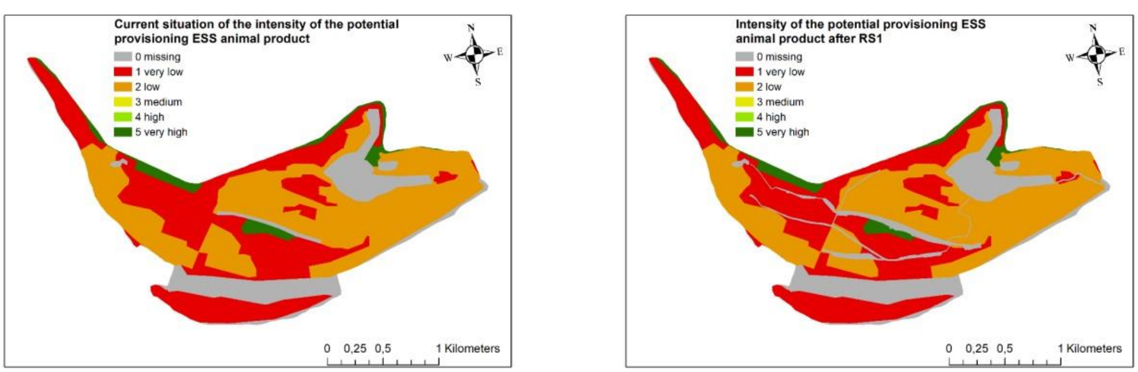


Figure 18 Provisioning ESS animal product in Begečka Jama, CS and RS1

The potential to supply the ESS fish is very high in the oxbow lakes and the Danube River but medium or low in the disconnected oxbow channel and will increase after implementing the RS1 measures from a medium to a high provision (Figure 19).

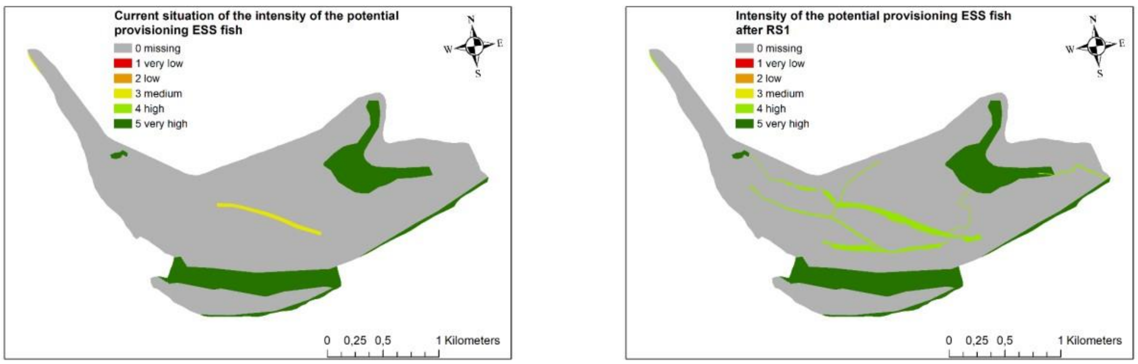


Figure 19 Provisioning ESS fish in Begečka Jama, CS and RS1

The potential to provide the ESS water is very high in the Danube River and the oxbow lakes but low in the disconnected oxbow channel. After implementing restoration scenario 1, the potential to provide the ESS water will be high in the oxbow channels (Figure 20).

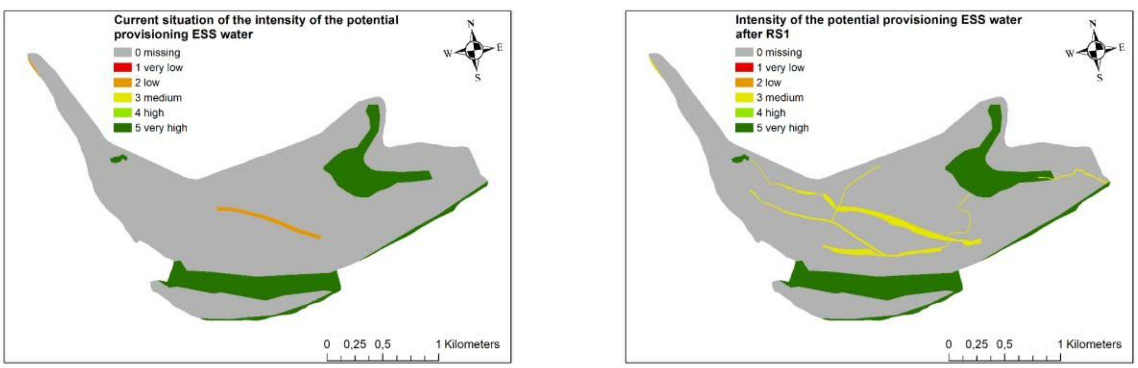


Figure 20 Provisioning ESS water in Begečka Jama, CS and RS1

Regulating ESS

The potential to provide the ESS air purification is very high in the natural forests (broadleaved forest) but low in the 'transitional woodland and scrub' and grassland areas. In RS1, this potential will be lost with the transformation of natural forests into watercourses (Figure 21).

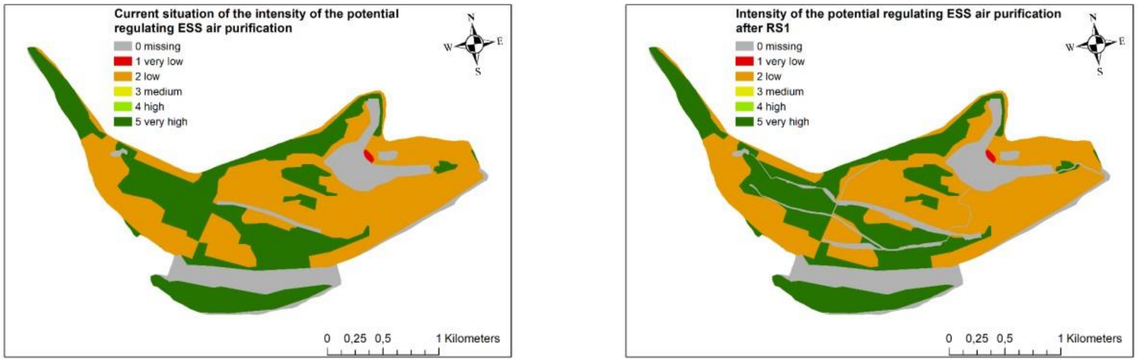


Figure 21 Regulating ESS air purification in Begečka Jama, CS and RS1

Also, the potential to provide the ESS noise regulation (Figure 22) is strongly connected to forest areas, whereas the value of the potential to provide the ESS noise regulation is very high. Forests reduce noise by the refraction of sound waves. Water areas with their nearly plane surfaces do not have this effect. The sound waves can get transmitted without any restraints; thus the potential of the ESS noise regulation is missing. It can thus be said that the potential for providing the ESS noise regulation in the action areas is disappearing.

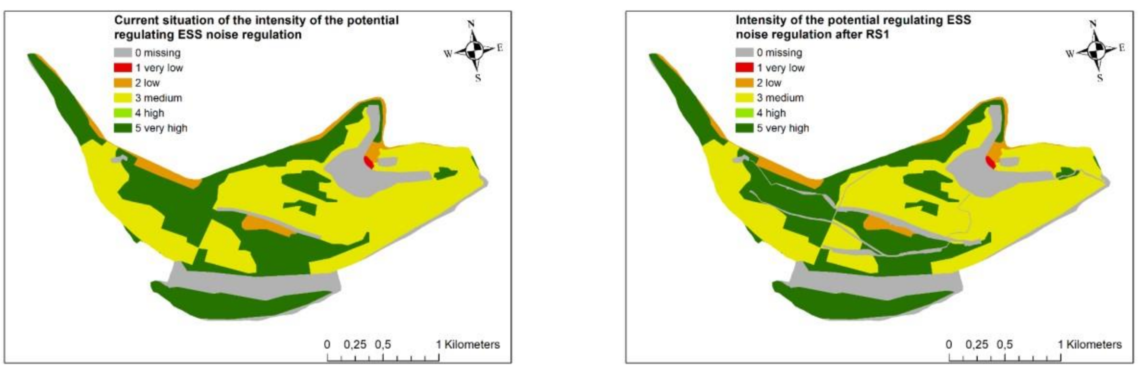


Figure 22 Regulating ESS noise regulation in Begečka Jama, CS and RS1

The potential supply of ESS local climate regulation (Figure 23), ESS low water regulation (Figure 24), ESS flood retention (Figure 25), ESS nutrient retention (Figure 26) and ESS provision of habitats (Figure 27) benefits from the restoration measure in RS1. The potential of all these ESS increases with the cleaning, widening and reconnecting of oxbow channels and the formation of new watercourses through the improvement of lateral connectivity and the creation of habitats that are typical of floodplains and not artificially influenced.

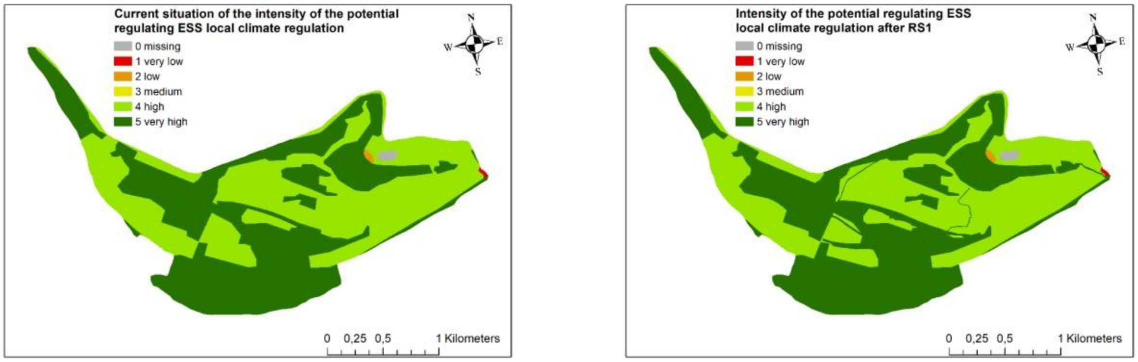


Figure 23 Regulating ESS local climate regulation in Begečka Jama, CS and RS1

The ESS nutrient retention (Figure 27) also has its highest potential in the water bodies and the nearnatural forest and grassland areas. After the implementation of RS1, the potential for nutrient retention will increase.

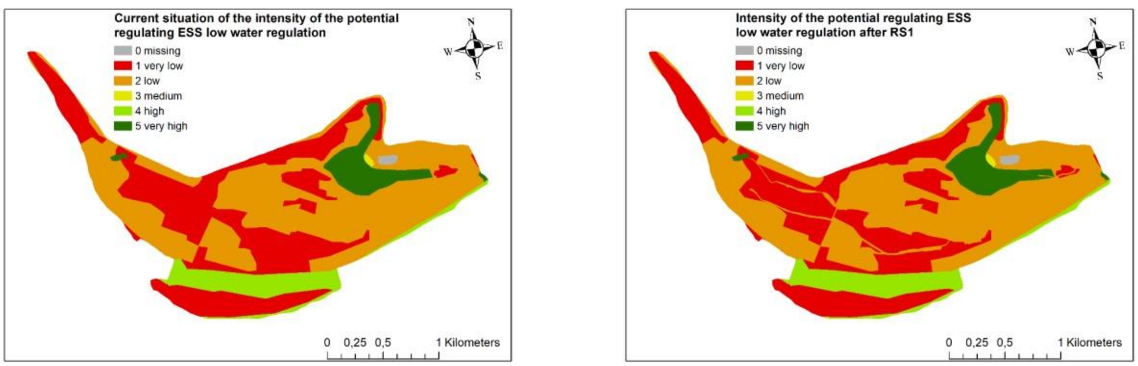


Figure 24 Regulating ESS low water regulation in Begečka Jama, CS and RS1

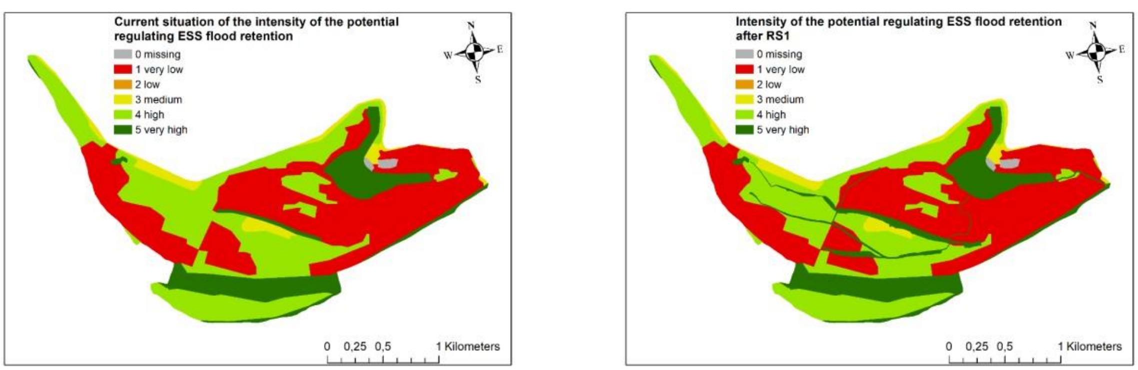


Figure 25 Regulating ESS flood retention in Begečka Jama, CS and RS1

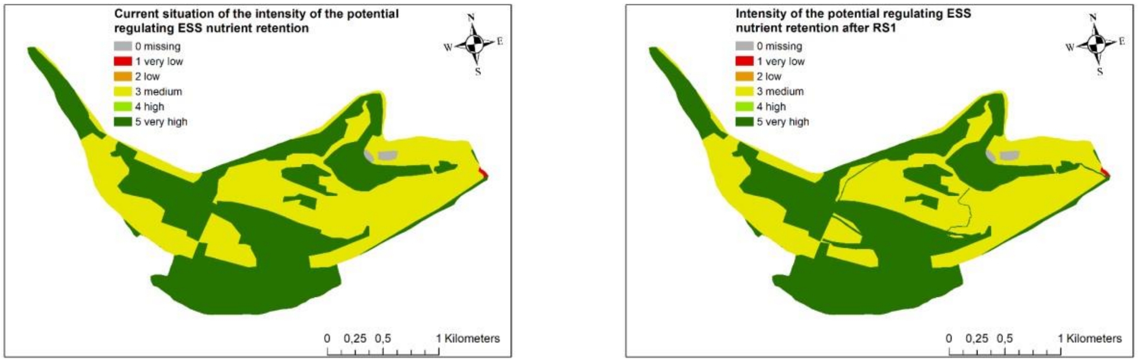


Figure 26 Regulating ESS nutrient retention in Begečka Jama, CS and RS1

The potential provision of the ESS provision of habitats is very differentiated depending on the land cover/land use type in the current situation. Restoration scenario 1 will improve the ESS provision of habitats by cleaning and widening the oxbow channel and creating new natural water channels.

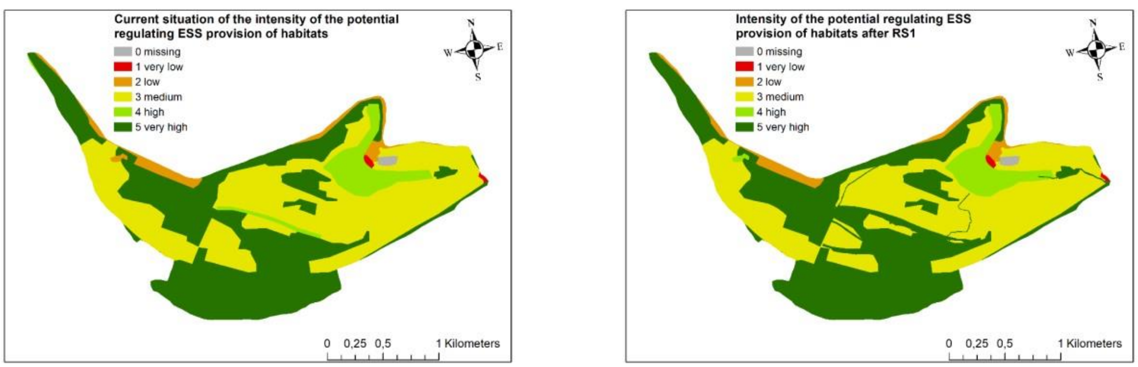


Figure 27 Regulating ESS provision of habitats in Begečka Jama, CS and RS1

<u>Cultural ESS</u>

Cultural ESS were not considered for the Begečka Jama pilot area in the Deliverable 4.2.2.

Joint consideration of all potential provisioning ESS and all potential regulating ESS

All provisioning ESS taken together shows a rather low availability of the supplying services in the current situation (Figure 28). Only natural grassland has medium potential for the provisioning of ESS. The heavily modified watercourses, on the other hand, show only a very low potential. The supply of all provisioning ESS will increase with measures of RS1, depending mainly on the improvement of the provision of ESS water and ESS fish.

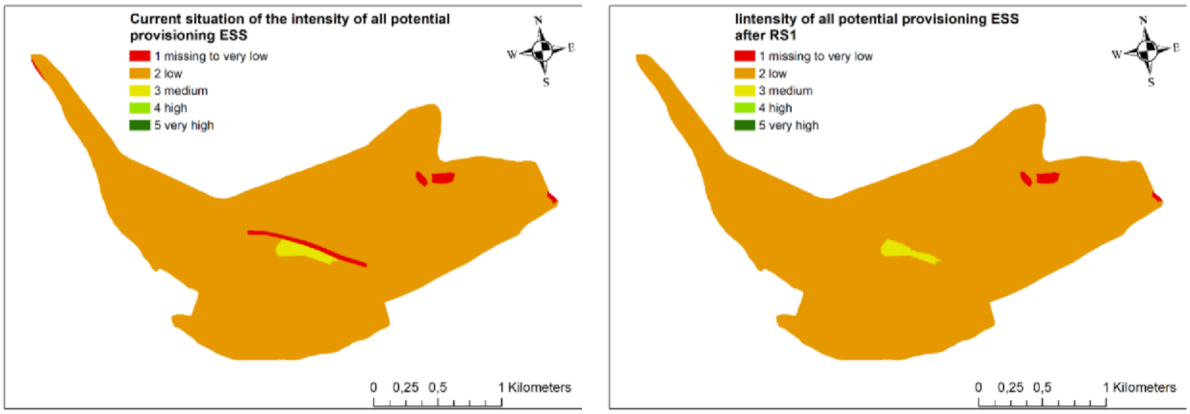


Figure 28 Intensity of all potential provisioning ESS in the current situation and the restoration scenario RS1

The provision of all regulating ESS is mainly medium in managed forest and grassland areas or very high in near-natural forest areas in the current situation (Figure 29). This will not change after the implementation of the measures of RS1. However, the improvement of the lateral connectivity and the establishment of new floodplain habitats by the cleaning and widening of the oxbow channel and the creation of new watercourses will increase the supply of all potential regulating ESS in the water bodies.

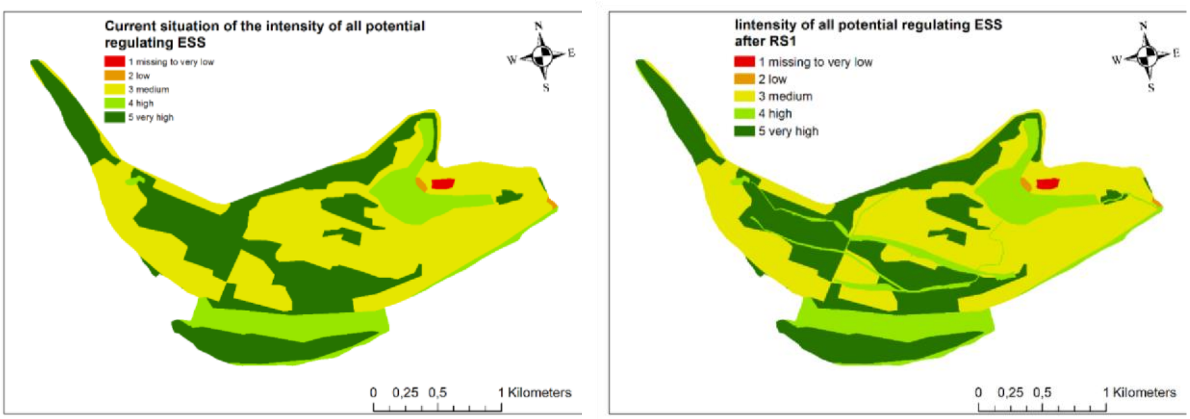


Figure 29 Intensity of all potential regulating ESS in the current situation and the restoration scenario RS1

Taking into account all considerations regarding the increase/decrease of ESS in the Begečka Jama pilot area, as well as the expert opinion, the JCWI provided the overall assessment of the ESS by applying Restoration Scenario 1. Table 5 presents results of the stakeholders' ESS assessment from the workshop as well as JCWI assessment of increased (↗) and decreased (↘) ESS by implementing RS1 individually (for each ESS) and grouped (provisioning, regulating and cultural-recreation, waterrelated, education, tourism) ESS.

Table 5 Overview of the ESS assessment (CS and RS1) by JCWI

			Stakeholders CS	JCWI CS-RS1	JCWI-grouped CS-RS1
provisioning ecosystem services	agricultural product		-	-	↗
	wood		5	↘	
	animal product		1	no change	
	game meat		-	-	
	honey		-	-	
	fish		2	↗	
	water		3	↗	
	gas		-	-	
regulating ecosystem services	local climate regulation		4		↗
	air purification		5	↘	
	low water regulation		-	↗	
	flood retention		3	↗	
	nutrient retention		3	↗	
	noise regulation		-	↘	
	provision of	terrestrial or	5		
		aquatic habitats	3**	↗	
	jogging		-		

recreational activity	cycling	5	no change	
	hiking	5	no change	
	photography	-		
	bird-/wild-life watching	5	no change	↗
	mushroom picking	-		
	sport hunting	-		
water related activit	swimming	3	↗	
	water sport	3	↗	
	sport fishing	3	↗	
education	cultural heritage	-		
	research	-		thermal bath -
	information events	3	↗	
tourism	fishing tourism	4	↗	
	hunting tourism	-		
	cruise ships/ports	-		
	hotels/accommodations	-		

3.4.1.3 Economic & financial cost estimation (derived from the DFP Project Deliverable 4.3.1)

The estimated results of the ESS assessment, evaluation, and inclusion into the extended CBA for the Begečka Jama pilot area are provided below. All details regarding the applied methods are subject to D 4.3.1 and the corresponding Methodology presented in D 4.3.2.

Based on the implemented measures (shp files for the aerial extent and targeted depths of oxbows and connection canals), the costs calculated by JCWI in the form of BoQ for RS1 is presented in Table 6.

Table 6 Costs (BoQ) for the restoration measures in RS1

No.	Description of works	Unit	Unit price (Euro/unit)	Qty	Total cost (Euro)
1.	**Preparation works**				**448,000.00**
1.1	The cleaning of shrubs and other vegetation of a diameter of up to 10 cm from the future channel routes that will bring water to tributaries. This should include the cleaning of channels and adjacent land (3m buffer) to enable the use of mechanization for rough levelling of the terrain. The price includes the combined (manual/mechanical) cutting of shrubs and trees up to 10cm in width, their removal, or grinding with a tarup for biomass, their removal from the zone of work (loading and transport to a secured landfill – at a distance of up to 2,0km); The burning of material is forbidden. Calculations per m^2 of cleaned channel.	m^2	2.00	166,000.00	332,000.00
1.2	The removal of vegetation from the route of the tributary of a river and the belt planned for the operation of mechanization (buffer 3m). This position/point includes: the cutting down and transport of trees, if necessary, accompanied with an approval from the user of the forest and in accordance with the conditions of INVCP. The calculations are done per piece of cut, classified and transported tree	piece	25.00	1800	45,000.00

1.3	The removal of logs from the canal route and belt intended for the operation of mechanization. This includes: the extraction of stumps from the canal route with their direct loading and transport to a landfill - up to 2 km away. Calculation done per extracted and transported or buried stump of a definite thickness	piece	25.00	1800	45,000.00
1.4	The geodetic works for marking and recording the position of the side branch and channel. This includes: the geodetic work along with the development of a control geodetic record of the initial state, the geodetic marking of the positions of the side branch and channel and the designed cross-sections, the renewal and maintenance of the network of geodetic points during the execution of works, geodetic control surveys of the designed positions and of the channel dimensions and marking of the temporary area that is being used and expropriated. Calculation per m^2 of the marked channel route.	m'	4.00	6500	26,000.00
2.	**Earth works**				**852,500.00**
2.1	Excavation of the old side branch. This position includes: the mechanical excavation of material from the bottom and slopes of a channel along with the side removal of earth up to the location for its temporary removal or its transpsort to an appropriate area. Calculation per m^3 of excavation. All of it in accordance with the graphic documentation and general technical conditions for the carrying out of work and conditions set by the Institute For Nature Conservation Of Vojvodina	m^3	5.00	55000	275,000.00
2.2	Excavation of the old side branch which is flooded. This position includes: the mechanical excavation of the old side branch which is under water. Calculation per m^3 of excavation. All of it in accordance with the graphic documentation and general technical conditions for the carrying out of work	m^3	1.50	55000	82,500.00
2.3	The transport of material includes: the transport of the excavated sediment and soil up to a landfill. Calculation per m^3 of excavated and transported material, measured at the point of excavation. If this solution is chosen, it is necessary to include the formation of landfills for the deposition of material and take the costs into account	m^3	4.50	110000	495,000.00
3.	**Other works**				**11,000.00**
3.1	The creation of culverts at channel junctions and access roads. An alternative would be the 'paving' of the bottom and sides of a canal at the junction points	m'	200.00	40	8,000.00
3.2	Remediation/ Reconstruction of the existing weir and bridge or the removal of the existing weir and the putting up of a new weir with a passage/bridge (all the earth, assembly and concrete reinforcement works)	lump sum	3,000.00	1	3,000.00
				RS1 Total costs (Euro):	**1,311,500.00**

The extended CBA focuses on six ESS: **water-related services** (**flood mitigation, nutrients retention), global climate Regulation (carbon storage, greenhouse gases sequestration), cultivated goods provisioning, nutrients retention, and nature-based recreation**. The TESSA toolkit is applied complemented with alternative approaches for assessing Nature-based recreation. The latter is carried out through the questionnaire created by TUM and supported by JCWI (encouraging the Begečka Jama stakeholders to participate).

The results of Global Climate Regulation (carbon storage, greenhouse gases) are presented in Tables 7 and 8, respectively.

Table 7 RS1 Carbon storage results for the Begečka Jama, where the total carbon stocks are calculated as the sum of above-ground biomass (ABG), below-ground biomass (BGB), litter biomass (LB), dead wood biomass (DWB), and soil organic carbon (SOC)

Carbon stocks	**CS**	**RS1**
AGB [ton C]	7334	7917
BGB [ton C]	1985	2029
LB + DWB [ton C]	2806	2866
SOC [ton C]	37417	37676
Total Carbon Stocks [ton C]	49541	50489
Total Carbon Stocks [USD2020]	3,451,356	3,517,400
RS1-CS [ton C]	948	
ES value of the RS1 [USD2020]	**66,044**	

Table 8 RS1 Greenhouse gases flux results for the Begečka Jama (negative net values indicate equivalent CO2 emissions; positive net values indicate equivalent CO2 sequestration)

GHG flux	**CS**	**RS1**
Carbon Stock Increment [ton CO2/yr]	5,104	4,957
Carbon Stock Losses [ton CO2/yr]	-45,577	-38,694
CO2 Em. [ton CO2/yr]	0	0
CH4 Em. [ton CO2/yr]	-9	-9
N2O Em. [ton CO2/yr]	-9	-9
GHGs flux [ton CO2/yr]	-40,493	-33,755
RS1-CS [ton CO2/yr]	6,738	

ESS value of the RS2 [USD2020/yr]	**128,022**

The results of Water-related services (Flood mitigation, Nutrients retention) are presented in Tables 9 and 10, respectively.

Table 9 RS1 Results of flood risk estimation for the Begečka Jama

Flood risk reduction	Expected annual floodcaused damage [EUR2019/yr]	CS - RS1 [EUR2019/yr]	percentage CS - RS1
CS	1,660,519	-306	-0.02%
RS1	1,660,825		

Table 10 RS1 Results of nutrients retention ESS value for the Begečka Jama. The retained and filtered water volume was extracted according to the description presented in D 4.3.2

Nutrients retention	CS	RS1
Retained and filtered water volume [m³]	14,864,416	14,897,355
Flooded area (tree-, grass-, and wetlanddominated) [ha]	106.15	100.84
ESS value [USD2019/yr]	1,974	1,879
RS1-CS [USD2019/yr]	-95	

The results of cultivated goods' provisioning ESS value for crops, livestock, and aquaculture are reported in Table 11.

Table 11 RS1 Results of cultivated goods provisioning ESS value for Begečka Jama (unit prices are specified in D 4.3.2)

Cultivated good	CS [USD2017/y]	RS1 [USD2017/y]
Crops	0	0
Livestock	16,305	15,838
Aquaculture	0	0
SUM	16,305	15,838
RS1-CS	-467	

Results of nature-based recreation ESS value are presented in Table 12.

Table 12 RS1 Results of nature-based recreation ESS value for Begečka Jama

Nature-based recreation	CS	RS1
Consumers surplus [EUR^{2019}/visit]	122.70	
Nature based recreation [EUR^{2019}/yr]	1,227,040	2,178,571
Area [ha]	393.86	
Nature based recreation per unit [EUR^{2019}/ha·yr]	3115.42	5531.33
RS1-CS [EUR^{2019}/yr]	951,530	

The total absolute value of the ESS benefits of the realistic floodplain restoration measures is summarised in Table 13 and presented in Figure 30.

Table 13 Summary of the ESS values results shown in the previous tables and their sum, i.e. added ESS value of the floodplain restoration scenarios RS1 in comparison to the current state (CS) homogenized to USD^{2019}/yr in Begečka Jama

All ESS	RS1-CS
Carbon storage [USD^{2020}]	66,044 [55,616; 86,900]
GHGs flux [USD^{2020}/yr]	128,022 [107808;168450]
Flood mitigation [USD^{2019}/yr]	-343 [-542;-253]
Nutrients retention [USD^{2019}/yr]	-95 [-1787;592]
Cultivated goods [USD^{2019}/yr]	-487 [-786;-368]
Nature-Based Recreation [USD^{2020}/yr]	1,065,543 [994551;1147450]
SUM [USD$_{2019-20}$/yr]	1,192,641 [1,099,244; 1,315,871]

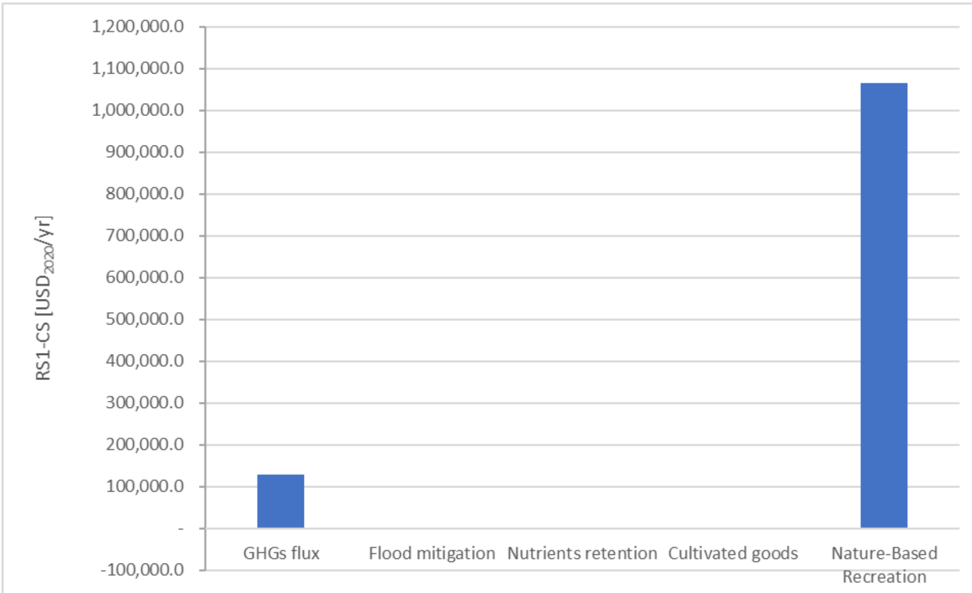


Figure 30 Added ESS value of the floodplain restoration scenarios RS1 in comparison to the current state (CS) homogenized to USD2019/yr in Begečka Jama

3.4.2 Scenario 2 (RS2)

Based on the DFP project request to introduce the "optimistic" scenario (which includes more extensive measures, Figure 31), we defined scenario 2 to address the needs of the BJNatP crucial demands related to the improvement of habitats and biodiversity in general but also to decrease the flood peak.

Restoration measures for Scenario 2 - Optimistic are:

- Cleaning and widening of the existing connecting channel between Danube River and Begečka Jama lake and weir reconstruction, which allow fish migration.
- Floodplain DEM modification via the deepening of existing oxbows and channels and the excavation of new channels between the deepened oxbows, which would allow for the controlled inflow/outflow from the system.
- Excavation of a new branch along the route of old oxbows.
- Increase the diversity of the river morphology and diversity of cross profiles of the river as a result of the excavation, deepening and cleaning of oxbows and existing and the new channels, as well as widening of the existing river channel.
- Creation of new fish spawning areas which contribute to the maintenance and increase of biodiversity.

Figure 31 Scenario 2 measures in the Begečka Jama pilot area

The proposed measures within Scenario 2 will result in the creation of a large artificial sidearm on the left bank of the Danube that will enable a quicker flow of the flood wave. The construction of this sidearm should provide a larger surface of the open water habitats, but these will be mainly rheophilic habitats that are characterized by higher flow velocity and larger depths. The ecological conditions will be similar to the existing ones in the main course of the Danube. The newly gained habitats will be mainly suitable to fish species preferring sandy and gravel substrate for spawning and feeding and higher water velocity.

Even though sediment removal is planned for the purpose of the restoration of existing floodplain habitats (marshes, oxbows and channels), the sidearm construction will result in the loss of already endangered typical floodplain habitats (a decrease in the mosaic of aquatic and terrestrial habitats on the floodplain) and species and impact the hydrological regime and biodiversity of the remaining floodplain.

The potential implementation of Scenario 2 conflicts with the goals of nature conservation (BJNatP Protection studies)due to the sidearm excavation and its adverse effects, as well as the long-term management goals of BJNatP. The stakeholders' workshop participants disagreed with this scenario.

3.4.2.1 Technical analysis (derived from the DFP project Deliverable 4.1.1)

The main results of the 2D hydrodynamic model for selected hydrological scenarios for the current state (CS) and the optimistic scenario (R2) are presented in Table 14 and Figures 32-33.

Table 14 Results and analysis of the 2D simulations of the Current State and Scenario 2 in the Begečka Jama

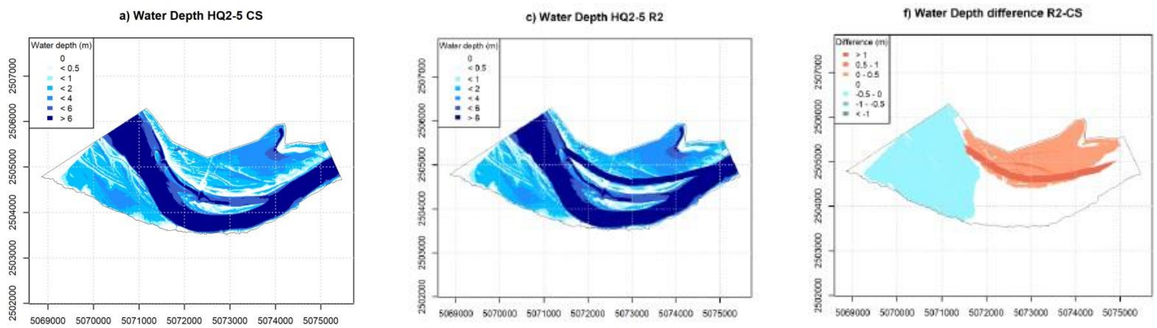
		$HQ_{2\text{-}5}$	**HQ_{10}**	**HQ_{100}**
Qmax (m³/s)	out CS	5766.9	6475.8	8372.1
	out R2	5767.4	6475.5	8370.5
ΔQmax (m³/s)	R2-CS	0.5	0.2	-2.1
ΔQmax (%)	R2-CS	0.0	0.0	0.0
Δt (h)	R2-CS	0	-1	0
Change in flooded area (%)	R2-CS	1.2	0.0	0.0
Change in volume (%)	R2-CS	7.2	5.2	4.7
Average water depth (m)	CS	4.44	5.55	6.04
	R2	4.74	5.83	6.32
Average flow velocity (m/s)	CS	0.47	0.63	0.64
	R2	0.48	0.60	0.61

Since restoration measures were focused on the improvement of the habitats and biodiversity in general, the negligible effects of the flood peak (Q_{max}), the translation of the flood wave (Δt) and the volume reduction were expected in Scenario 2 as in Scenario 1, despite excavation of a new branch along the route of old oxbows.

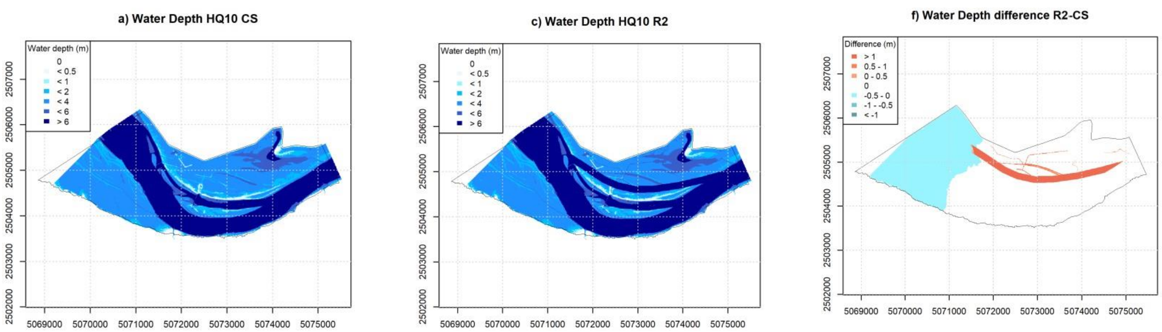
Analysing the spatial results of the water depth and water level in the Begečka Jama pilot area, the increased capacity of the river channel can be confirmed. The difference maps of the water depth in Figure 32 show the excavated channels of the restoration scenarios (dark orange). The difference maps of the water level (Figure 33) show the effective change of water height. Here we can see that the increased capacity of the channels has a larger effect on the water level change during lower HQ events ($HQ_{2\text{-}5}$) than during larger HQ events (HQ_{100}) which in fact is a goal of these measures (improvement of the water level in excavated oxbows and channels during more frequent flows and not during the floods). The flow velocity in the floodplain increases in the floodplain due to its reactivation but decreases in the Danube main riverbed Figure 11, Figure 14, Figure 17). This effect is most visible in the R2 scenario. In the average velocity over the whole area, no major modification is observable.

The results of the 2D models show that the purposes of restoration in the Begečka Jama pilot area were met. The capacity in the oxbows and existing channels is increased, relieving the main Danube channel. This effect is already observable in the more frequent flood events of magnitude $HQ_{2\text{-}5}$ and is more effective in the scenario RS2. The subsequent improved water supply in the Begečka Jama Lake is expected to upgrade habitat quality and ecosystem services.

Scenario RS2: Begečka Jama water depth results, $HQ_{2\text{-}5}$, 1m resolution



Scenario RS2: Begečka Jama water depth results, HQ_{10}, 1m resolution



Scenario RS2: Begečka Jama water depth results, HQ_{100}, 1m resolution

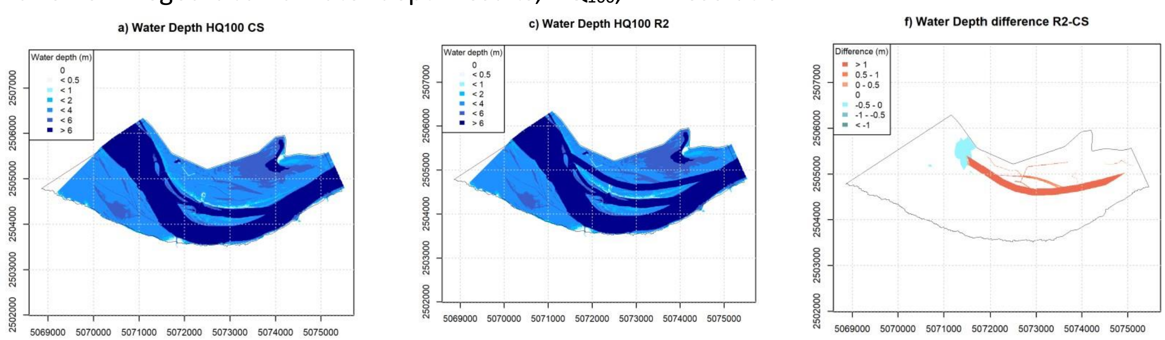
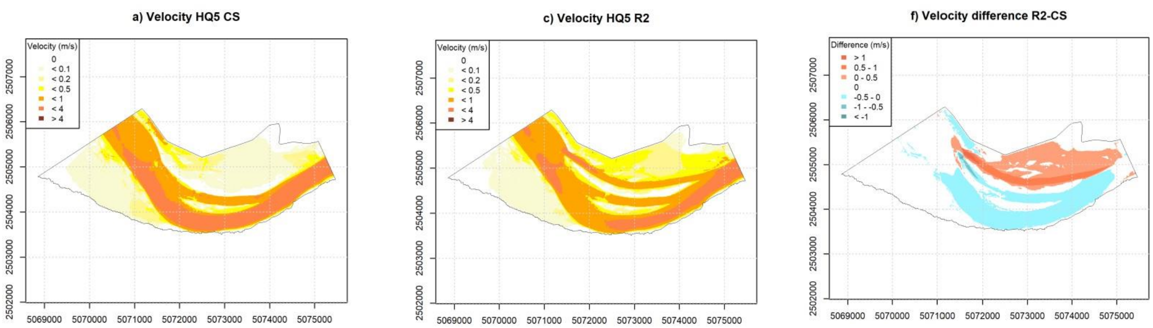
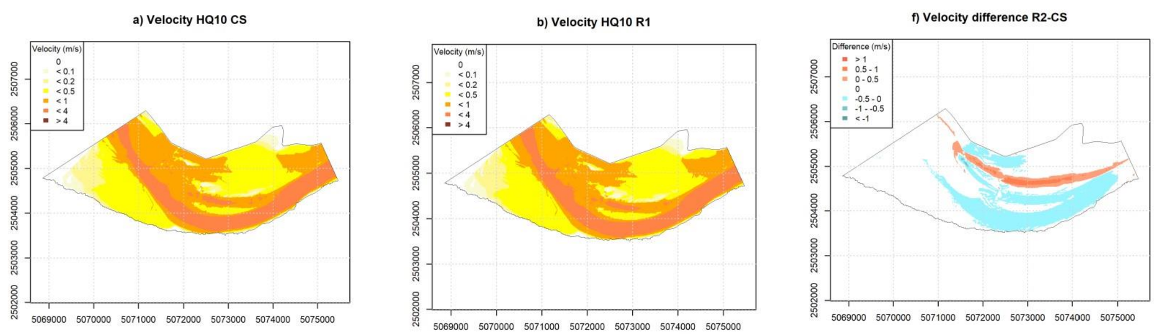


Figure 32: Begečka Jama water depth results and difference maps (R1-CS) for $HQ_{2\text{-}5}$, HQ_{10} and HQ_{100}

Scenario RS2: Begečka Jama velocity results, $HQ_{2\text{-}5}$, 1m resolution



Scenario RS2: Begečka Jama velocity results, HQ_{10}, 1m resolution



Scenario RS2: Begečka Jama velocity results, HQ_{100}, 1m resolution

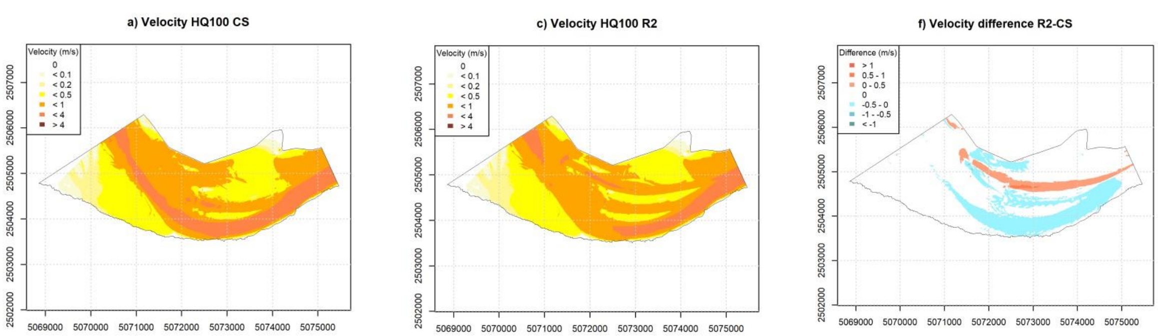


Figure 33 Begečka Jama velocity results and difference maps (R1-CS) for HQ2-5, HQ10 and HQ100

The proposed measures within Scenario 2 will result in the creation of a large artificial sidearm of the Danube that will enable a quicker flow of the flood wave. With the construction of this sidearm, the surface of the open water habitats will increase, as well as water depth. Sediment removal is planned for the purpose of the restoration of existing floodplain habitats (marshes, oxbows and channels).

The expected results and benefits of the proposed measures are presented with the water depth differences between Scenario 0 and Scenario 2. There is an increase in aquatic habitats, but mainly in rheophilic habitats.

3.4.2.2 Effects

Effects based on the Habitat modelling (derived from the DFP Project Deliverable 4.2.3)

The optimistic restoration scenario plans to construct a new side-channel in addition to the increase in backwater connectivity. This increases the total channel area in the pilot area from 30 ha to 71.5 ha. The backwater area in this scenario is 34.5 ha, thus smaller compared to the realistic scenario. In addition, the flow velocity in the backwater system slightly increased what might lead to a slight decrease in habitat suitability for stagnophilic fish species like Misgurnus fossils or also amphibians. On the contrary, habitat conditions will improve for other fish species like Gymnocephalus baloni or similar species migrating between the main channel and backwater. The area of the hydrologically connected floodplain slightly decreases to 183.6 ha due to the conversion to the channel.

Effects based on the Ecosystem Services assessment (derived from the DFP Project Deliverable 4.2.2)

The main findings regarding the changes of ESS by implementing the Scenario RS2 are based on the MAES data and presented below.

In restoration scenario RS2, interconnected watercourses connecting the Danube River with the Jama lake and rewetting the forest areas will be created as well as a new sidearm of the Danube River. Thus, forest and transitional woodland scrub areas will decrease (Figure 34).

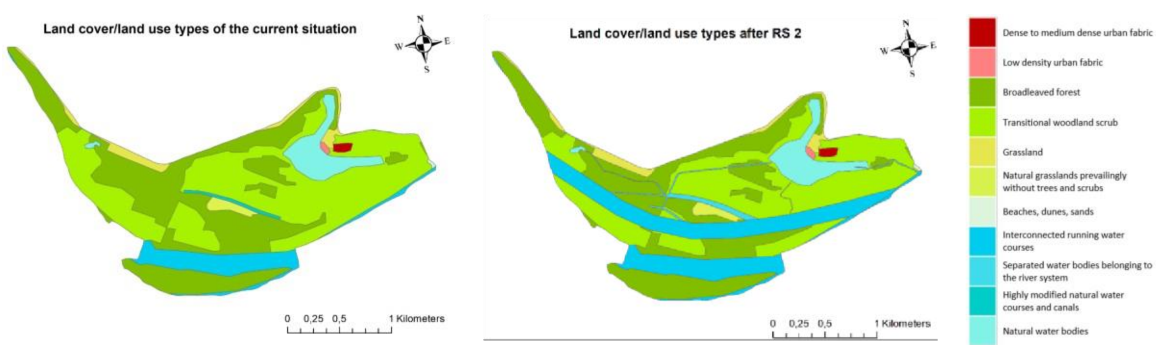


Figure 34 Land cover/land use of the current situation, after the implementation of restoration scenario 2 (RS2)

Provisioning ESS

The current situation of the potential to provide the ESS wood is mainly high to very high and will decrease by implementing the restoration measures in the affected areas, considering that former forest areas will be transformed into water bodies (Figure 35).

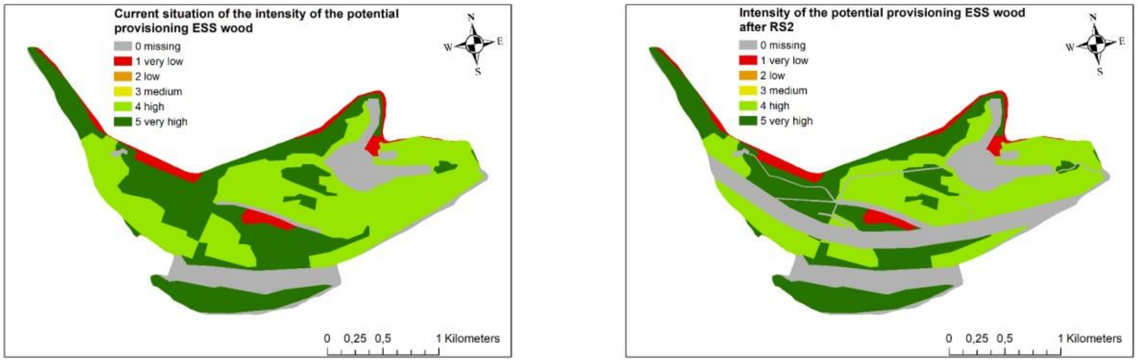


Figure 35 Provisioning ESS wood in Begečka Jama, CS and RS2

In contrast, the intensity of the potential to provide the ESS animal product is low to very low and only in the grassland areas is a very high potential for ESS animal product (Figure 36).

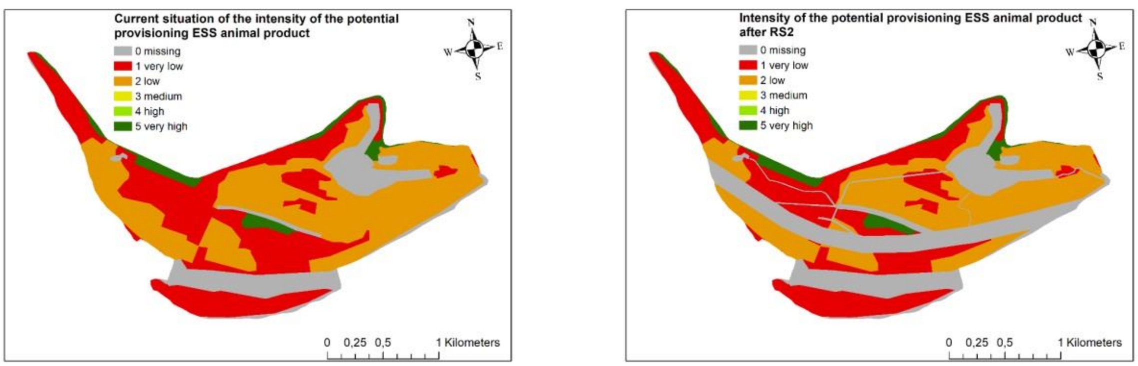


Figure 36 Provisioning ESS animal product in Begečka Jama, CS and RS2

The potential to supply the ESS fish is very high in the oxbow lakes and the Danube River but medium or low in the disconnected oxbow channel. This will increase after implementing the RS2 measures from a medium to a very high level (Figure 37).

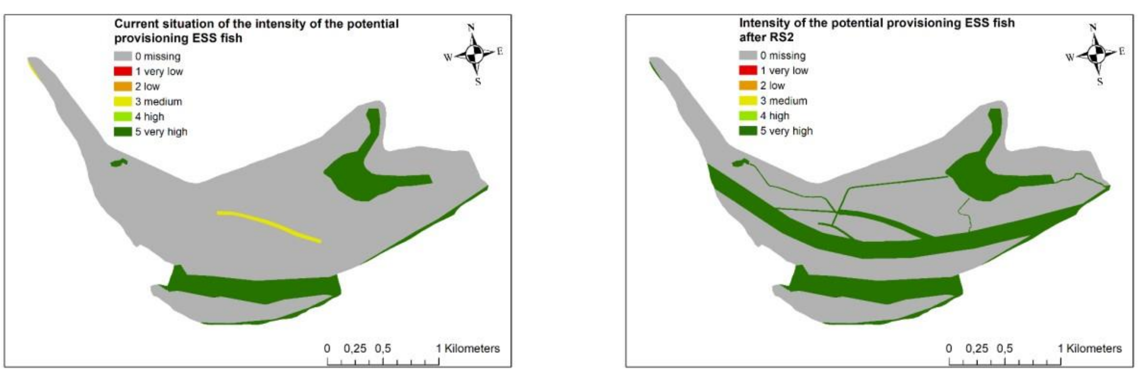


Figure 37 Provisioning ESS fish in Begečka Jama, CS and RS2

The potential to provide the ESS water is very high in the Danube River and the oxbow lakes but low in the disconnected oxbow channel. After implementing restoration scenario 2, the potential to provide the ESS water will be very high in the oxbow channels, connected watercourses and sidearm (Figure 38).

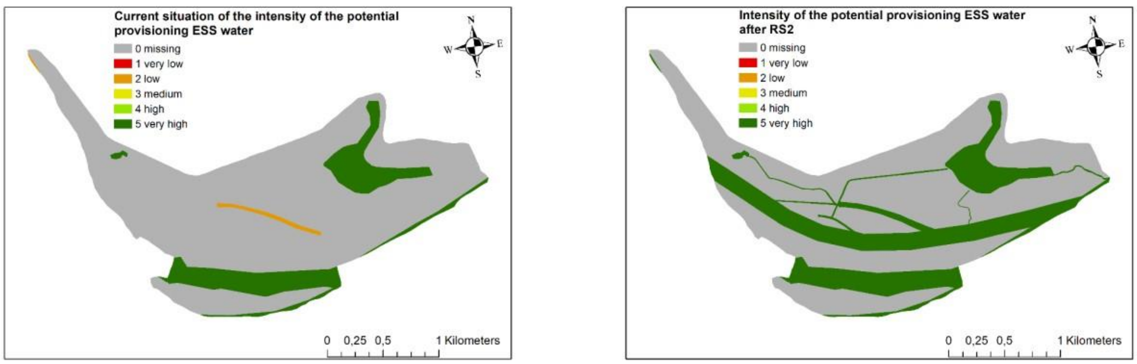


Figure 38 Provisioning ESS water in Begečka Jama, CS and RS2

Regulating ESS

The potential to provide the ESS air purification is very high in the natural forests (broadleaved forest) but low in the 'transitional woodland and scrub' and grassland areas. In RS2, this potential will be lost with the transformation of natural forests into watercourses (Figure 39).

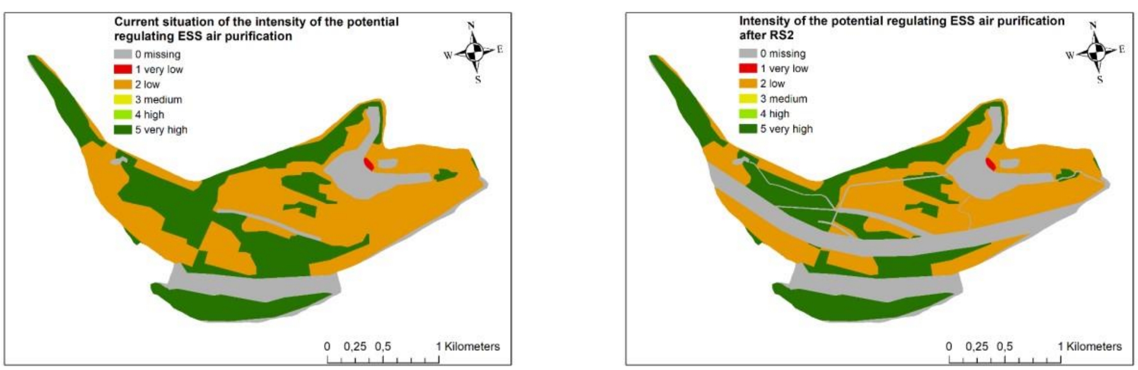


Figure 39 Regulating ESS air purification in Begečka Jama, CS and RS2

Same as in scenario RS1, the potential to provide the ESS noise regulation (Figure 40) is strongly connected to forest areas, whereas the value of the potential to provide the ESS noise regulating is very high. Forests reduce noise by the refraction of sound waves. Water areas with their nearly plane surfaces do not have this effect. The sound waves can get transmitted without any restraints; thus, the potential of the ESS noise regulation is missing. Therefore, the potential for providing the ESS noise regulation in the action areas is disappearing.

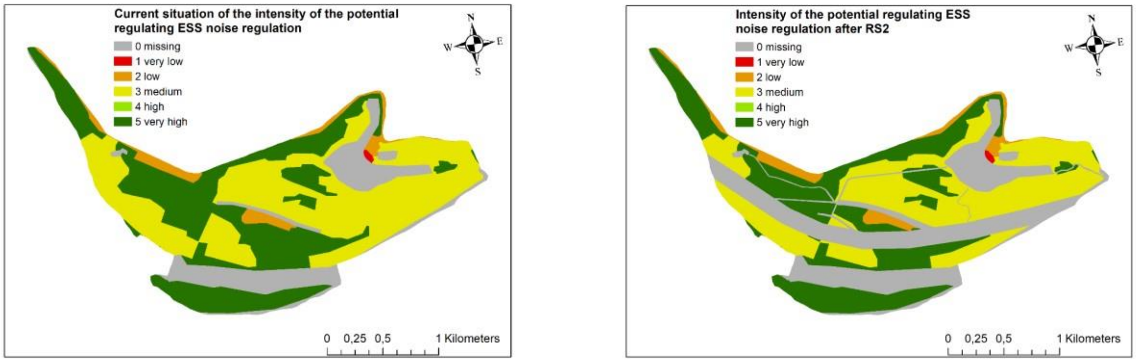


Figure 40 Regulating ESS noise regulation in Begečka Jama, CS and RS2

The potential supply of ESS local climate regulation (Figure 41), ESS low water regulation (Figure 42), ESS flood retention (Figure 43), ESS nutrient retention (Figure 44)and ESS provision of habitats (Figure 45) benefits from the restoration measure in RS2. The potential of all these ESS increases with the cleaning, widening and reconnecting of oxbow channels and the formation of new watercourses, through the improvement of lateral connectivity and the creation of habitats typical of floodplains and not artificially artificial ones influenced.

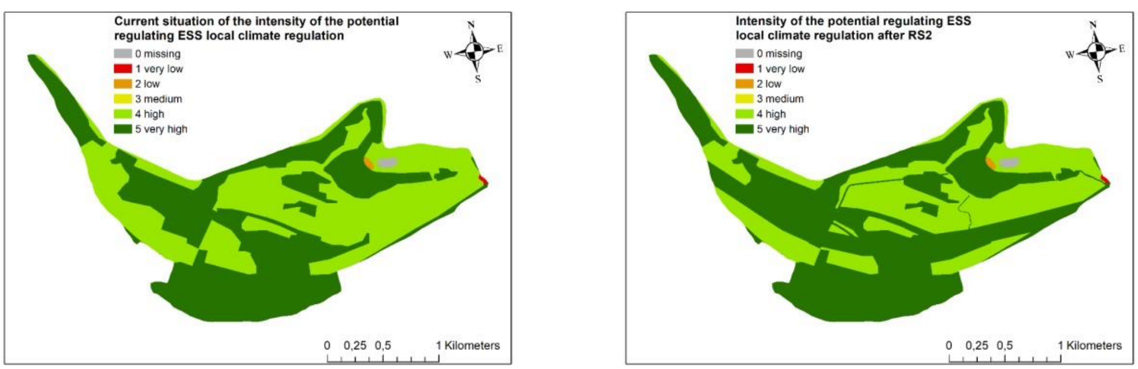


Figure 41 Regulating ESS local climate regulation in Begečka Jama, CS and RS2

The ESS nutrient retention (Figure 44) also has its highest potential in the water bodies and the nearnatural forest and grassland areas. After the implementation of RS2, the potential for nutrient retention will increase.

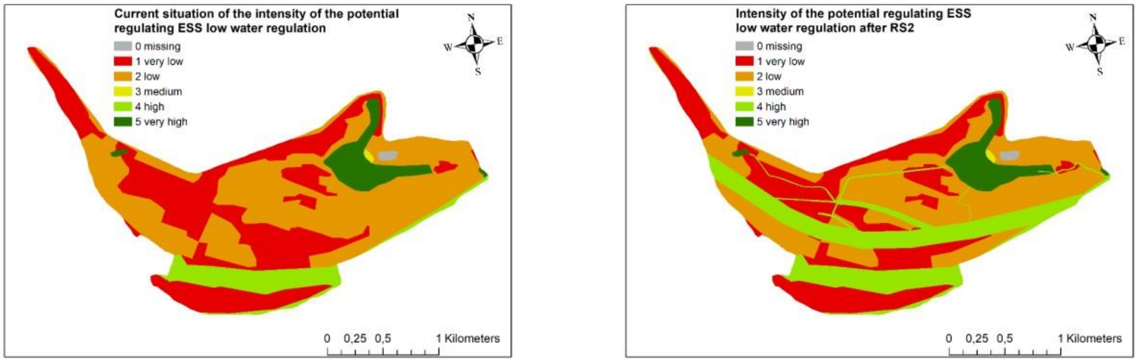


Figure 42 Regulating ESS low water regulation in Begečka Jama, CS and RS2

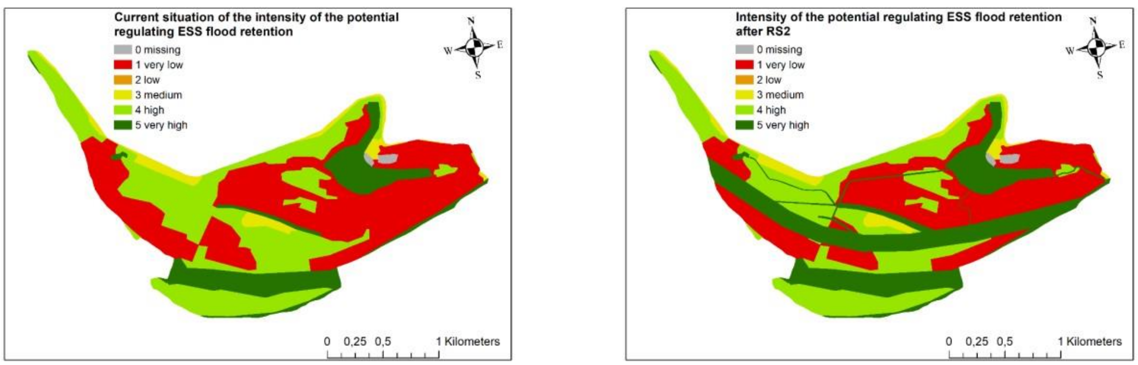


Figure 43 Regulating ESS flood retention in Begečka Jama, CS and RS1

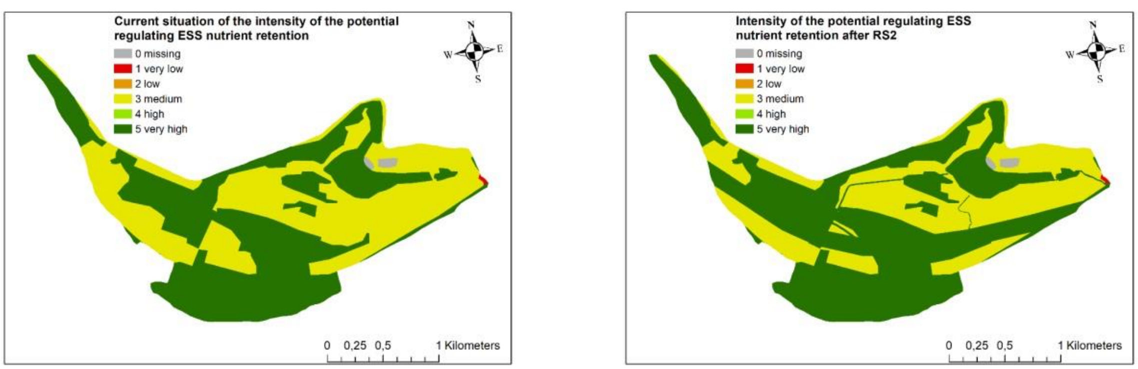


Figure 44 Regulating ESS nutrient retention in Begečka Jama, CS and RS2

The potential provision of the ESS provision of habitats (Figure 45) is very differentiated depending on the land cover/land use type in the current situation. Restoration scenario 2 will significantly increase the potential of the ESS provision of habitats by creating a new sidearm and new natural watercourses.

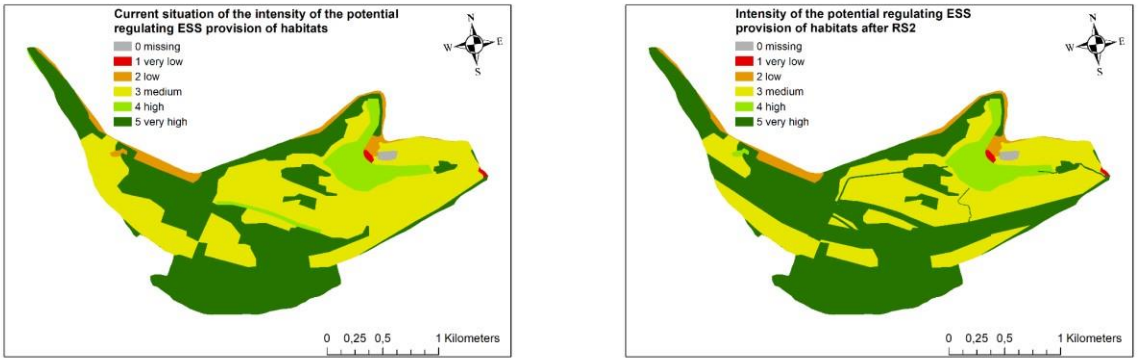


Figure 45 Regulating ESS provision of habitats in Begečka Jama, CS and RS2

<u>Cultural ESS</u>

Cultural ESS were not considered for the Begečka Jama pilot area in the Deliverable 4.2.2.

Joint consideration of all potential provisioning ESS and all potential regulating ESS

All provisioning ESS taken together shows a rather low availability of the supplying services in the current situation (Figure 46). Only natural grassland has medium potential for the provisioning of ESS. The heavily modified watercourses, on the other hand, show only a very low potential. The supply of all provisioning ESS will increase with measures of RS2, depending mainly on the improvement of the provision of ESS water and ESS fish.

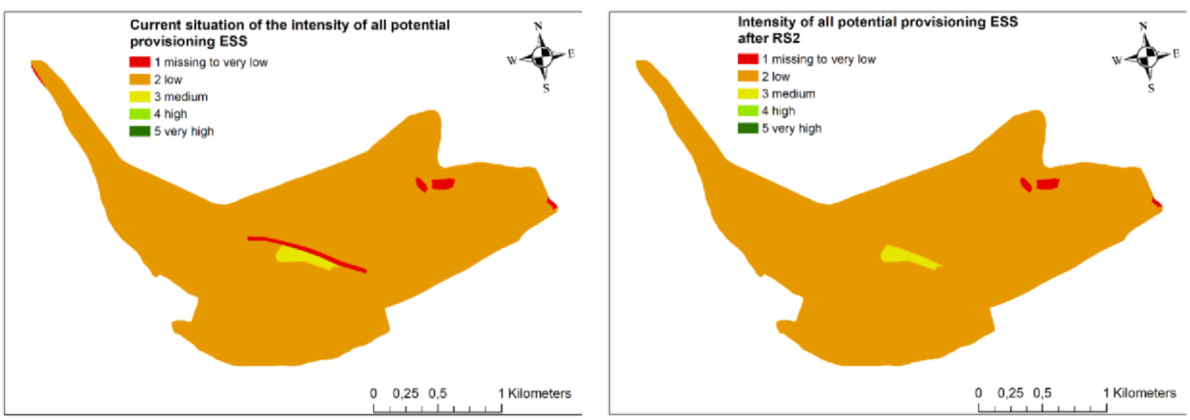


Figure 46 Intensity of all potential provisioning ESS in the current situation and the restoration scenario RS2

The provision of all regulating ESS is mainly medium in managed forest and grassland areas or very high in near-natural forest areas in the current situation (Figure 47). This will not change after the implementation of the measures of RS2. However, the improvement of the lateral connectivity and the establishment of new floodplain habitats by the cleaning and widening of the oxbow channel and the creation of new watercourses will increase the supply of all potential regulating ESS in the water bodies.

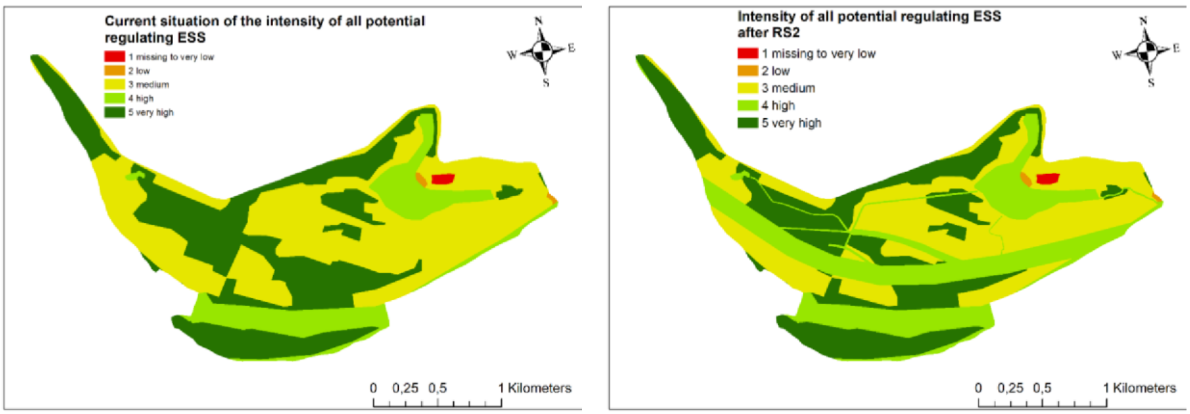


Figure 47 Intensity of all potential regulating ESS in the current situation and the restoration scenario RS2

Taking into account all considerations regarding the increase/decrease of ESS in the Begečka Jama pilot area, as well as the expert opinion, the JCWI provided the overall assessment of the ESS by applying Restoration Scenario 2. Table 15 presents results of the stakeholders' ESS assessment from the workshop as well as JCWI assessment of increased (↗) and decreased (↘) ESS by implementing RS2 individually (for each ESS) and grouped (provisioning, regulating and cultural-recreation, waterrelated, education, tourism) ESS.

Table 15 Overview of the ESS assessment (CS and RS2) by JCWI

		Stakeholders	JCWI	JCWI-grouped
		CS	**CS-RS2**	**CS-RS1**
provision ing ecosyste	agricultural product	-	-	↗
	wood	5	↘	
	animal product	1	no change	
	game meat	-	-	
		Stakeholders	**JCWI**	**JCWI-grouped**
	CS **CS-RS2** **CS-RS1** honey	-	-	
	fish	2	↗↗	
	water	3	↗↗	

	gas	-	-	
regulating ecosystem services	local climate regulation	4		↗
	air purification	5	↘↘	
	low water regulation	-	↗	
	flood retention	3	↗	
	nutrient retention	3	↗	
	noise regulation	-	↘↘	
	provision of terrestrial or	5		
	provision of aquatic habitats	3**	↗	
recreational activity	jogging	-		↗
	cycling	5	no change	
	hiking	5	no change	
	photography	-		
	bird-/wild-life watching	5	no change	
	mushroom picking	-		
	sport hunting	-		
water relatec activit	swimming	3	↗	
	water sport	3	↗	
	sport fishing	3	↗↗	
educa tion	cultural heritage	-		
	research	-		
	information events	3	↗	
tourism	fishing tourism	4	↗	thermal bath -
	hunting tourism	-		
	cruise ships/ports	-		
	hotels/accommodations	-		

3.4.2.3 Economic & financial cost estimation

The estimated results of the ESS assessment, evaluation, and inclusion into the extended CBA for the Begečka Jama pilot area are provided below. All details regarding the applied methods are subject of the D 4.3.1 and the corresponding Methodology presented in D 4.3.2.

Based on the implemented measures (shp files for the aerial extent and targeted depths of oxbows and connection canals), the costs calculated by JCWI in the form of BoQ for RS2 is presented in Table 16.

Table 16 Costs (BoQ) for the restoration measures in RS2

No.	Description of works	Unit	Unit price (Euro/unit)	Qty	Total cost (Euro)
1.	**Preparation works**				**2,390,860.00**

No.	Description of works	Unit	Unit price (Euro/unit)	Qty	Total cost (Euro)
1.1	The cleaning of shrubs and other vegetation of a diameter of up to 10 cm from the future channel routes that will bring water to tributaries. This should include the cleaning of channels and adjacent land (3m buffer) to enable the use of mechanization for rough levelling of the terrain. The price includes the combined (manual/mechanical) cutting of shrubs and trees up to 10cm in width, their removal, or grinding with a tarup for biomass, their removal from the zone of work (loading and transport to a secured landfill – at a distance of up to 2,0km); The burning of material is forbidden. Calculations per m^2 of cleaned channel.	m^2	2.00	630,930.00	1,261,860.00
1.2	The removal of vegetation from the route of the tributary of a river and the belt planned for the operation of mechanization (buffer 3m). This position/point includes: the cutting down and transport of trees, if necessary, accompanied with an approval from the user of the forest and in accordance with the conditions of INCVP. The calculations are done per piece of cut, classified and transported tree	piece	25.00	21900	547,500.00
1.3	The removal of logs from the canal route and belt intended for the operation of mechanization. This includes: the extraction of stumps from the canal route with their direct loading and transport to a landfill - up to 2 km away. Calculation done per extracted and transported or buried stump of a definite thickness	piece	25.00	21900	547,500.00
1.4	The geodetic works for marking and recording the position of the side branch and channel. This includes: the geodetic work along with the development of a control geodetic record of the initial state, the geodetic marking of the positions of the side branch and channel and the designed cross-sections, the renewal and maintenance of the network of geodetic points during the execution of works, geodetic control surveys of the designed positions and of the channel dimensions and marking of the temporary area that is being used and expropriated. Calculation per m^2 of the marked channel route.	m'	4.00	8500	34,000.00
2.	**Earth works**				**27,822,500.00**
2.1	Excavation of the old side branch. This position includes: the mechanical excavation of material from the bottom and slopes of a channel along with the side removal of earth up to the location for its temporary removal or its transport to an appropriate area. Calculation per m^3 of excavation. All of it in accordance with the graphic documentation and general technical conditions for the carrying out of work and conditions set by the Institute For Nature Conservation Of Vojvodina	m^3	5.00	2635000	13,175,000.00
2.2	Excavation of the old side branch which is flooded. This position includes: the mechanical excavation of the old side branch which is under water. Calculation per m^3 of excavation. All of it in accordance with the graphic documentation and general technical conditions for the carrying out of work	m^3	1.50	465000	697,500.00
2.3	The transport of material includes: the transport of the excavated sediment and soil up to a landfill. Calculation per m^3 of excavated and transported material, measured at the point of excavation. If this solution is chosen, it is necessary to include the formation of landfills for the deposition of material and take the costs into account	m^3	4.50	3100000	13,950,000.00

3.	**Other works**				**9,000.00**
3.1	The creation of culverts at channel junctions and access roads. An alternative would be the 'paving' of the bottom and sides of a canal at the junction points	m'	200.00	30	6,000.00
3.2	Remediation/ Reconstruction of the existing weir and bridge or the removal of the existing weir and the putting up of a new weir with a passage/bridge (all the earth, assembly and concrete reinforcement works)	lump sum	3,000.00	1	3,000.00
				RS2 Total costs (Euro):	**30,222,360.00**

The extended CBA is focusing on six ESS: **water-related services** (**flood mitigation, nutrients retention), global climate Regulation (carbon storage, greenhouse gases sequestration), cultivated goods provisioning, nutrients retention, and nature-based recreation**. TESSA toolkit is applied complemented with alternative approaches for assessing Nature-based recreation. The latter is carried out through the questionnaire created by TUM and supported by JCWI (encouraging the Begečka Jama stakeholders to participate).

The results of Global Climate Regulation (carbon storage, greenhouse gases) are presented in Tables 17 and 18, respectively.

Table 17 RS2 Carbon storage results for the Begečka Jama, where the total carbon stocks are calculated as the sum of above-ground biomass (ABG), below-ground biomass (BGB), litter biomass (LB), dead wood biomass (DWB), and soil organic carbon (SOC)

Carbon stocks	CS	RS2
AGB [ton C]	7334	10608
BGB [ton C]	1985	2220
LB + DWB [ton C]	2806	3132
SOC [ton C]	37417	39769
Total Carbon Stocks [ton C]	49541	55730
Total Carbon Stocks [USD2020]	3,451,356	3,882,523
RS2-CS [ton C]	6,189	

ES value of the RS2 [USD2020]	**431,167**

Table 18 RS2 Greenhouse gases flux results for the Begečka Jama (negative net values indicate equivalent CO2 emissions; positive net values indicate equivalent CO2 sequestration)

GHG flux	**CS**	**RS2**
Carbon Stock Increment [ton CO2/yr]	5,104	4,237
Carbon Stock Losses [ton CO2/yr]	-45,577	-38,694
CO2 Em. [ton CO2/yr]	0	0
CH4 Em. [ton CO2/yr]	-9	-9
N2O Em. [ton CO2/yr]	-9	-9
GHGs flux [ton CO2/yr]	-40,493	-34,477
RS2-CS [ton CO2/yr]	6,016	
ESS value of the RS2 [USD2020/yr]	**114,304**	

The results of Water-related services (Flood mitigation, Nutrients retention) are presented in Tables 19 and 20, respectively.

Table 19 RS2 Results of flood risk estimation for the Begečka Jama

Flood risk reduction	**Expected annual floodcaused damage [EUR2019/yr]**	**CS – RS2 [EUR2019/yr]**	**percentage CS – RS2**
CS	1,660,519	-1,099	-0.07%
RS2	1,661,618		

Table 20 RS2 Results of nutrients retention ESS value for the Begečka Jama. The retained and filtered water volume was extracted according to the description presented in D 4.3.2

Nutrients retention	**CS**	**RS2**
Retained and filtered water volume [m^3]	14,864,416	15,694,581
Flooded area (tree-, grass-, and wetlanddominated) [ha]	106.15	106.81
ESS value [USD2019/yr]	1,974	2,097

RS2-CS [USD2019/yr]	123

The results of cultivated goods' provisioning ESS value for crops, livestock, and aquaculture are reported in Table 21.

Table 21 RS2 Results of cultivated goods provisioning ESS value for Begečka Jama (unit prices are specified in D 4.3.2)

Cultivated good	CS [USD_{2017}/y]	RS2 [USD_{2017}/y]
Crops	0	0
Livestock	16,305	13,637
Aquaculture	0	0
SUM	16,305	13,637
RS2-CS	-2,668	

Results of nature-based recreation ESS value are presented in Table 22.

Table 22 RS2 Results of nature-based recreation ESS value for Begečka Jama

Nature-based recreation	CS	RS2
Consumers surplus [EUR^{2019}/visit]	122.70	
Nature based recreation [EUR^{2019}/yr]	1,227,040	2,478,123
Area [ha]	393.86	
Nature based recreation per unit [EUR^{2019}/ha·yr]	3115.42	6291.89
RS2-CS [EUR^{2019}/yr]	1,251,083	

The total absolute value of the ESS benefits of the realistic floodplain restoration measures are summarised in Table 23 and presented in Figure 48.

Table 23 Summary of the ESS values results shown in the previous tables and their sum, i.e., added ESS value of the floodplain restoration scenarios RS2 in comparison to the current state (CS) homogenized to USD^{2019}/yr in Begečka Jama

All ESS	RS2-CS

Carbon storage [USD^{2020}]	431,167 [363,088; 567,325]
GHGs flux [USD^{2020}/yr]	114,304 [96256;150400]
Flood mitigation [USD^{2019}/yr]	-1231 [-2205;-857]
Nutrients retention [USD^{2019}/yr]	123 [44;320]
All ESS	**RS2-CS**
Cultivated goods [USD^{2019}/yr]	-2783 [-4494;-2104]
Nature-Based Recreation [USD^{2020}/yr]	1,400,989 [1307647;1508680]
SUM [USD$_{2019-20}$/yr]	1,511,402 [1,397,248; 1,656,439]

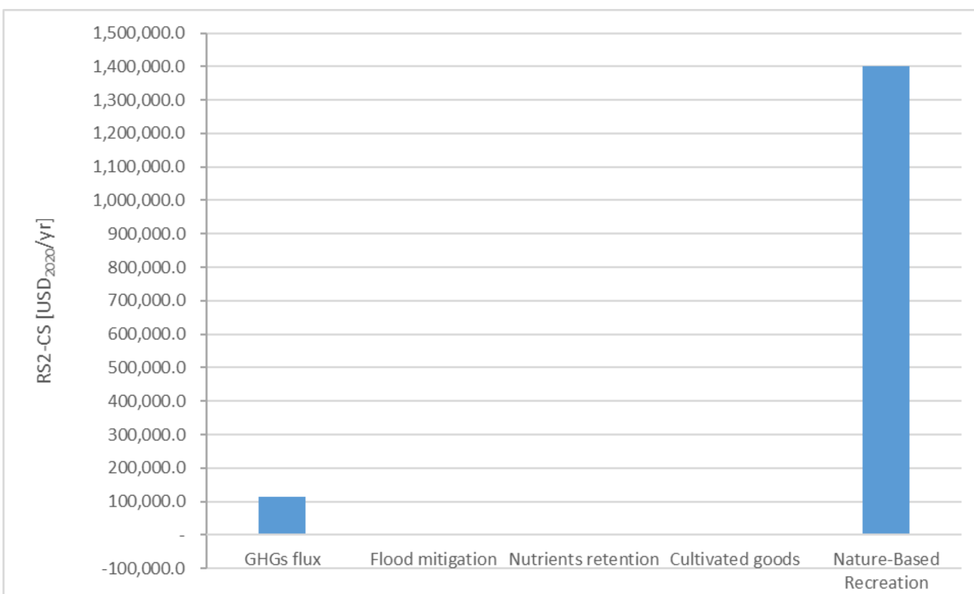


Figure 48 Added ESS value of the floodplain restoration scenarios RS2 in comparison to the current state (CS) homogenized to USD2019/yr in Begečka Jama

3.5 Evaluation of the scenarios and selection of the proposed scenario

The evaluation of the scenarios is based on the Extended CBA analyses. The costs of the restoration measures in RS1 and RS2 (Table 6, Table 16, respectively) are discounted based on the parameters from Table 2 and shown in Table 24. The scenarios' benefits and the costs are compared with each other in two ways: by subtracting the costs from the benefits (Figure 49) and by dividing the benefits by the costs (Figure 50), obtaining the benefits-costs ratio (BCR). All analyses were done by TUM and elaborated in the D 4.3.1.

Table 24 Costs of the restoration measures discounted according to Table 2

Costs [USD^{2019}] (discounted)		
CS	RS1	RS2
0	1,468,645	33,843,628

The comparison of the costs and Scenario 1 benefits is done by subtracting the costs from the benefits (Figure 31, extracted from the D 4.3.1, Fig. 16), and by dividing the benefits by the costs (Figure 17, extracted from the D 4.3.1, Fig. 17).

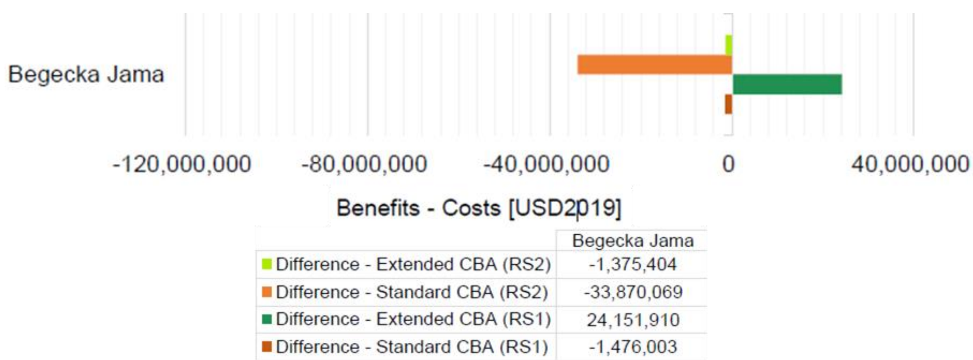


Figure 49 Difference between discounted benefits and discounted costs in Begečka Jama

Figure 50 Benefit-cost ratio (BCR) between discounted benefits and discounted costs in Begečka Jama

Table 25 shows other aspects of the scenario evaluation (stakeholders opinion, compatibility with BJNatP Protection study requests).

Table 25 Other aspects of the restoration scenario analyses

	RS1	RS2
Stakeholders' opinion	☺	☹
Compatibility with the BJNatP Protection Study	☺	☹

The proposed measures in **RS1** will improve the functions and processes of the floodplain ecosystem. They will contribute to the preservation of the mosaic of aquatic and terrestrial habitats on the floodplain, as well as to the protection of species that depend on these habitats, and their population size will increase. Benefits from the measures will especially reflect on the status of typical floodplain habitats (oxbows, marshes, ephemeral channels, and flooded meadows). The ongoing processes of succession from aquatic to terrestrial habitat will be halted and reversed. New habitats will be available for fish spawning and nursery, especially for phytophilic and phyto-litophilic species that are dependent on floodplains. Additional nesting and feeding grounds will be provided for waterfowl in the restored habitats. With the implementation of planned technical solutions (weir, fords), the flow of water through the floodplain will be supported. This will also contribute to the visual integrity of the landscape that will change to the better, and due to this, the aesthetic value as well (natural landscape with diverse plant and bird species).

The construction of a sidearm in **RS2** will create rheophilic habitats that are similar to the existing ones in the Danube River. Based on the proposed extent and dimensions, it will be a uniform habitat with only scarce mezo-habitats. In order to maintain the functionality of the sidearm, additional technical solutions will be implemented, such as groynes and riprap. In general, it will be an artificial and extensively modified habitat. The size of the surface of the aquatic habitats will increase, but it will cover only rheophilic, riverine habitats. The planned restoration action on the floodplain will improve the flow of water by dredging existing channels and oxbow, but a significant portion of the floodplain will be lost due to the construction of the sidearm, causing the loss of floodplain habitats. This scenario will have minor positive impacts on the floodplain. The proposed measures in RS2 are in conflict with the designated protected area and its conservation measures. In order to implement RS2, an overriding public interest should be declared. Based on the opinion of the local stakeholders, RS2 will cause “loss of nature”.

Considering all assessed parameters and information, we conclude that restoration scenario 1 (realistic) should be chosen.

4. 4. Recommendations for further steps in the realisation of the chosen scenario[4]

If we assume that the Begečka Jama restoration scenario 1 is already selected based on the previous analyses and considerations, the further steps to its realisation and evaluation are presented below.

4.1 Institutional, operational analysis

Due to the specific nature of the scenario 1 works, it is not possible to define the procedure of gaining approval for the execution of the works at the moment. The JCWI interviewed the Republic Water Directorate, Ministry of Planning and Construction and the PWMC Vode Vojvodine, but no clear procedure for realisation of the measures is provided.

There are two general options for the selected scenario realisation:

- works execution through the Annual program of the BJNatP manager and
- based on the Law on Planning and Construction.

[4] *From this point on the Content of this document does not fully comply with the one suggested by WWF HU*

4.1.1 The realisation of scenario 1 through the BJNatP manager's Annual program of works

The Law on nature protection (OG RS Nº 36/2009, 88/2010, 91/2010, 14/2016 and 95/2018) is relevant for the BJNatP. Article 4 defines the improvement of nature as a set of measures and activities necessary to revitalize natural habitats and populations to restore favourable natural conditions, as well as a set of activities on revitalisation and remediation of natural ecosystems and landscapes.
Article 35 stipulates that in the III degree of protection, the management interventions are to be

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carried out to restore, revitalise and generally improve the Protected area, preservation of traditional activities of the local population, selective and limited use of natural resources and space with the necessary infrastructure and other construction, etc.

Said activities are prescribed by the Act on protection through the measures of preservations and improvement and present the starting point and the base for related projects and activities necessary for the realisation of measures and gaining the financial resources for their implementation.

Given the nature of measures selected in the rehabilitation scenario R1, it is necessary to harmonise the planning documents of especially forestry and water management, with the restoration works. Also, the conditions/permits/agreement from these two sectors are often necessary for the execution of works.

According to Law on water (OG RS Nº 30/2010, 93/2012, 101/2016, 95/2018, 95/2018), the water conditions are issued within the development of technical documentation for construction/reconstruction of structures, as well as execution of other works that can permanently, occasionally or temporarily affect the changes of water regime, i.e., endanger the environmental goals. The same is valid for the development of planning documents for the management of the fishery and protected areas and forestry management.

Accordingly, and based on the Articles 117 and 118, the works defined in the selected scenario can be classified as:

- the protected areas management plans and programs, or
- other structures and works that can permanently, occasionally or temporarily affect or be affected by the changes of water regime.

In both cases, the Autonomous Province of Vojvodina competent authority would be in charge of issuing the water conditions.

4.1.2 The realisation of scenario 1 based on the Law on Planning and Construction

The scheme of the development of the technical documentation and issuing the relevant permits based on the Law on Planning and Construction (LPC) is presented in Figure 51.

CD	• for obtaining the location conditions (Article 53a of the LPC) • as a part of the urban design for the purpose of urban - architectural elaboration of the location (Article 117a of the LPC)
	• CONCEPTUAL DESIGN is an overview of the planned facility conception, showing and listing all the data necessary to determine the location conditions.
PD	• for preparation of the feasibility study (Art. 114 of the LPC) - subject to design revision (expert control) (Art. 131 of the LPC) • for obtaining Approval of Works (Article 145 of the LPC)
	• PRELIMINARY DESIGN is a set of mutually harmonized designs that determine: the purpose, position, shape, capacity, technical-technological and functional features and appearance of the facility and provide provisional evidence of the fulfillment of the basic requirements for the construction.
CPD	• for obtaining the construction permit (Article 118a of the LPC)
	• CONSTRUCTION PERMIT DESIGN is a set of mutually harmonized designs defining the position and capacity of the facility on location, functionality from the aspect of technological and other requirements, spatial shaping, selection of the construction system, dimensioning of the main elements of construction, general selection of construction materials, installations and equipment, thus ensuring the fulfillment of location conditions and basic requirements for the construction, etc.

Figure 51: Technical documents to be developed based on the LPC

In case the restoration works are subject to this procedure, the Feasibility Study is to be developed in the phase of the Preliminary design.

The detailed content of the Feasibility study is prescribed in the Rulebook on the content and scope of the preliminary works, pre-feasibility study and the feasibility study (OG RS No 1/2012).

4.2 The content of the technical documentation for the revitalisation of Begečka Jama based on the selected scenario

No matter which of the two options for the scenario realisation described in 4.1.1 and 4.1.2 is applicable, the first step is defining the project funding subject (Client). Most likely investors would be BJNatP manager, INVCP, Public Water Management Company "Vode Vojvodine".

The second step would be the development of the Terms of References for the execution of works defined in scenario 1. It has to include general information and data on the subject of the project, main technical requests (goals) of the project, deadlines and conditions for the project realisation, etc.

The selected scenario RS1 includes the following measures:

- Cleaning and widening of the existing connecting channel between Danube River and Begečka Jama lake and weir reconstruction, which allow fish migration.

- Deepening of existing oxbows and channels and the excavation of new channels between the deepened oxbows, which would allow for the controlled inflow/outflow from the system.
- Rehabilitation of the weir at the Begej canal to support controlled outflow from the system.

The project of the Begečka Jama revitalisation should include:

- Introduction part describing the problem, current situation, project idea, etc.
- Information on available technical documents related to the area
- Available bases (e.g., geodetic basis, hydrological data, geology, planning documents, etc.)
- Technical solutions:
    - excavation of sediment deposited in the Begej canal, the southern part of the Jama lake and the former oxbows,
    - the morphology of the Begej supply canal (geometry, slope, depth),
    - the reconstruction of the weir on the Begej canal to enable control of the outflow from the area during the withdrawal of the Danube after floods,
- Numerical part, e.g., Hydraulic calculation (2D model of existing and restoration conditions)
- Bill of quantities
- References
- Graphical part (overview maps of current and restoration conditions, longitudinal profiles of watercourses – current and designed, cross-sections, etc.)

The geodetic base, hydrological data and the 2D hydrodynamic models can be provided by JCWI as already created within the DFP project.

In case the applied procedure for Scenario 1 implementation asks for it, the **Feasibility study** should be done accordingly. Its content is prescribed in the Rulebook on the content and scope of the preliminary works, pre-feasibility study and the feasibility study (“OG RS” No 1/2012):

- Data and information on the Study authors
- Introduction (goals, terms of reference, available documentation, methodologies (description of the software used), short presentation of the PFS results
- Goals and purpose of the project (investment): social, economic and other targets,
- Project description (location, importance within the broader system, functions, available technical and planning documents, graphical part (maps, longitudinal profiles, cross-sections, etc.), planned life duration of works, timeline of the project implementation, stages in the project implementation),
- Analyses of the development capacities of the investor
- The methodological basis for the FS (Laws, bylaws, link to the technical and planning documentation, data sources, a procedure for definition and evaluation criteria),
- A technical solution from the design (excerpt from the project),
- Market aspects (international and national market, market efficiency),

- Spatial aspects (compatibility of the technical solution with the spatial plans, socio-economic consequences, etc.)
- Environmental aspects (environmental impact, etc.),
- Economic costs (costs of works and equipment, operational, maintenance and management costs, additional costs, etc.),
- Cost-benefit analyses
- Financial efficiency with assessment of profitability and liquidity
- Socio-economic efficiency,
- Sensitivity analysis and investment risk,
- Analysis of funding sources of, financial liabilities and dynamics, • Analysis of organizational possibilities and human resources, • Conclusion on the investment feasibility.

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Although being the Feasibility study subject to be further developed in practice (if necessary), the next chapters present some aspects of the scenario 1 realisation based on the current information and expert knowledge.

4.3 Summary of the environmental effects and achieving the sustainable *development goals*

Referring to the guidelines of the Sustainable Development Goals (https://sdg.guide/, Figure 52) in September 2015, Heads of State and Government agreed to set the world on a path towards sustainable development through the adoption of the 2030 Agenda for Sustainable Development. This agenda includes 17 Sustainable Development Goals, or SDGs, which set out quantitative objectives across the social, economic, and environmental dimensions of sustainable development — all to be achieved by 2030. The goals provide a framework for shared action "for people, planet and prosperity" to be implemented by "all countries and all stakeholders, acting in collaborative partnership". As articulated in the 2030 Agenda, "never before have world leaders pledged common action and endeavour across such a broad and universal policy agenda." 169 targets accompany the 17 goals and set out quantitative and qualitative objectives for the next 15 years. These targets are "global in nature and universally applicable, taking into account different national realities, capacities and levels of development and respecting national policies and priorities".

Figure 52: Sustainable Development Goals (https://sdgs.un.org/goals)

ESS improvement intersects with the achievement and monitoring of the Sustainable Development Goals (D 4.3.1). ESS assessment would act for different purposes, such as to encourage a sustained, inclusive, and sustainable economic growth (Goal 8) and to facilitate sustainable management of water (Goal 6) and terrestrial ecosystems (Goal 15) (United Nations General Assembly, 2015).

Floodplain restorations not only help in flood risk management and improvement of lots of ecosystem services but also serves the fulfilment of SDG goals:

- **6. goal: Clean water and sanitation** - *Ensure availability and sustainable management of water and sanitation for all*. More efficient use and management of water are critical to addressing the growing demand for water, threats to water security, and the increasing frequency and severity of droughts and floods resulting from climate change.

  Restorations works in Nature Park Begečka Jama will help in the mitigation of climate change impacts.
- **Goal 8: Decent work and economic growth** - *Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*. Inclusive and sustainable economic growth can drive progress and generate the means to implement the Sustainable Development Goals. Globally, labour productivity has increased and unemployment is back to pre-financial crisis levels. However, the global economy is growing at a slower rate. More progress is needed to increase employment opportunities, particularly for young people, reduce informal employment and the gender pay gap and promote safe and secure working environments to create decent work for all.

Restoration and increase of attractivity of Nature Park Begečka Jama will help with new job opportunities.

- **15. goal: Life on land** - Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Protecting important sites for terrestrial and freshwater biodiversity is vital for ensuring the long-term and sustainable use of terrestrial and freshwater natural resources.

  Restorations work in Nature Park Begečka Jama help also in sustaining healthy freshwater biodiversity, which is a base of human life and providing ecosystem services.

4.4 Cost-benefit analysis and financial sustainability of the project

Being the project that aims at the improvement of biodiversity only and not the flood mitigation, the Begečka Jama restoration based on scenario 1 should be evaluated using the extended and not the standard CBA. As shown in D 4.3.1 and elaborated in this document (Chapter 3.5), the Ecosystem services are the main benefit of this project. The standard CBA misses recognizing the profitability of the restoration measures, which is instead identified by the extended CBA, both when looking at the benefits-costs-difference (BC-difference) and the BCR.

Considering the costs of the measures and the discounting of the ESS added values, the extended CBA result is promising in Begečka Jama, where is a benefits-costs-ratio (BCR) approximately equal to or higher than 1, when using an extended CBA. The standard BCR shows instead result smaller than one and closer to zero for RS1.

4.5 Risk evaluation of the chosen scenario and risk management strategy

The implementation of measures proposed within scenario 1 represents a large-scale habitat restoration project, which requires acquiring different permits and approvals that are handed out by different expert and professional institutions and organisations and governmental bodies (e.g. nature conservation conditions, water management conditions, approval from the forestry sector, etc.). Due to a massive and slow administration, the acquiring of all documents can be a lengthy period. Since BJNatP is a protected area for all activities, plans and projects, a Ruling on nature conservation provisions needs to be acquired from the INCVP. This legally binding document represents one of the most important steps in the planning of measures implementation since this document gives the permission for all planned measures in the protected area and defines the allowed, limited and prohibited actions.

The spatial distribution of animal and plant species and their period of reproduction can cause major limitations for the implementation of the measure. Also, the hydrological conditions of the area (floods) should also be taken into consideration since a flood event can halt the implementation of the measures, but also to create setbacks (e.g., siltation and deadwood deposit on already dredged areas). The lack of data on sediment quality can prove to have a limiting factor as well.

Before the implementation of the RS1 measures, a specific monitoring survey should be conducted to determine water and sediment quality. If chemical pollutants or heavy metals are found, the procedure of sediment removal will then become more complicated (the sediment would be treated as hazardous material according to national legislation, which requires special treatment that is very expensive).

The forestry sector has a long history of a very rigid approach to nature conservation. Therefore, major negotiations and numerous meetings should be organized to enable removing trees and forests of economically very important hybrid poplar plantations and the loss of forest land in favour of wetlands.

Even political relations at the local, regional, and state level can affect both the planning and implementation phase. Also, the change in personnel (decision-makers) and policy (goals and plans of organisations) can affect the flow of the planning and implementation of the measures.

Last but not least important is the current global pandemic COVID-19. In case of massive outbreaks, lockdowns can be expected, workers engaged in implementing the measures can be unavailable due to contracting the disease, and funding sources can become unavailable to reallocate funds for more important economic sectors. The spread of disease in governmental organisations and expert institutions can also hinder the permitting processes.

Since there are many variables that can have an impact on the dynamics and the implementation of the measures, a detailed project (technical documentation) should be designed, where the technical background of the RS1 would be structured in different stages of implementation to be able to meet deadlines, permits and approvals. Similar approaches were taken in previous projects that targeted habitat restoration on protected areas designated on floodplains.

4.6 Implementation of the project and timeline

Defining a specific timeframe for the implementation of the measures at this point is very difficult. The overall timeframe depends on the stages, funding sources and field conditions (floods, reproducing species etc.). It is strongly dependant on the risks.

Similar projects and measures on floodplain protected areas in Serbia were implemented in multiple stages to enable meeting deadlines, permits and approvals. Therefore, this should be considered as an option when planning and implementing the measures on BJNatP.

Sources for the funding of these measures can vary greatly. The local, regional, or state governments provide some funds through regular funding of the protected area. Based on existing experiences, the available amount provided by the local government is very low (equivalent to 1000-3000 EUR). Targeted national or international projects can provide funds for the implementation of multiple measures. This process needs political and economic support but can be feasible in cooperation with other protected area managers, provincial government, expert institutions (e.g., JCWI, INCVP), water management authority or forest management authority. Some part of the measures could be financed from the own sources of the protected area manager (if available). In either funding option, a willing and well organised protected area manager is needed, who can provide expert and financial support (e.g., for defining the order of measures implementation, project application etc.). They should be able to provide cooperation and partnership with a governmental organisation, expert and professional institutions, international partners.

Based on existing experiences, any kind of works (including restoration projects) has to comply with the Ruling on nature conservation provisions, a legally binding document setting out certain limitations in order to protect the natural values of a given project (in this case, BJNatP). These provisions prescribe a limitation of the period for the implementation of the measures. Namely, the reproduction period of animal species that are related to aquatic habitats (amphibians, fish, birds) needs to be avoided in order to provide successful and undisturbed spawning, nesting, development of juveniles, etc. Usually, this period covers the period from 1st March to 15th July. If, for example, a nest of a white-tailed eagle (Haliaeetus albicilla) is present in the forest, then a tailor-made buffer zone needs to be defined, where all activities are forbidden.

The potential location for the disposal of the removed sediment could also be limited with the nature conservation provisions if the plan is to deposit the sediment within the protected area. The handling of removed sediment and silt can also generate some delays. According to the existing national legislation, before removing the sediment, expert analysis needs to be conducted to determine if it contains chemical pollutants, heavy metals, pesticide residues, etc. If pollutants are present after the removal, the sediment will be treated as hazardous waste and have to be handled according to the existing bylaws.

Permission needs to be granted by the forest management authority and the regional government in charge of the forestry sector for the removal of trees and parts of the forest in order to implement the proposed measures. The permitting process can be time-consuming.

Since the area of BJNatP is in the active floodplain, high water levels (flood waves) can also have an impact on the dynamics of the works. Based on existing hydrology data, high water levels on this section of the Danube can occur in July, August and also September. Considering the limitation arising from the reproductive period of fish, birds and amphibians, floods can further narrow the time period for the works.

4.7 Communication and publicity

Stakeholder involvement, especially local ones, is a prerequisite for such a large-scale habitat restoration project. As seen during the Begečka Jama workshops within the DFP project, the diverse stakeholders who participated have the overall understanding of the ongoing processes in BJNatP, and, in general, are aware of actions that need to be implemented to improve the status of the area.

To maintain the support of stakeholders and the broader public, it is essential to have a transparent process where clear and timely information is provided to all interested parties. It is important to explain what measures will be implemented and why, also to explain that maybe during the first couple of steps, the implementation of the measures might seem like a step in the wrong direction (e.g., high water turbidity and the disturbance of anglers as the result of silt deposit removal).

Since BJNatP is in a rural environment, meetings should be organized (with the informative character) at the local community centre where the interested stakeholders can meet and get informed about the project. Information should be provided on the message board of the local community and the protected area as well. PR activities should also be conducted via local and regional newspapers. The webpage and social media platforms of the protected area manager should also provide sufficient information about the project.

Proactive actions of the protected areas rangers service are needed to inform on-site the visitors and local stakeholders on the stages and status of measures implementation.

4.8 Monitoring requirements

The monitoring requirements are in close correlation with the indicators.

Indicator: <u>Quantity of removed silt deposits, improved water quality</u>

After the implementation of the project, the water level gauge should be installed on the weir in the Begej canal for continual water stages monitoring. To ensure the proper operation of the weir, it is very important to create its operation rules and record its manipulation steps in the coming period. For example, the size of surface (area) covered with water (shallow water habitats) during fish spawning periods before and after the restoration works could be observed using seasonal satellite shots (e.g., Google Earth) or immediately measured using, e.g. drone. All measured data (water stage at the Begej canal weir, shallow water habitats area) should be related to water level data from the water level gauge at Novi Sad gauging station. Water quality parameters are monitored by the Institute for Public Health of Vojvodina. Therefore these results can be a baseline for the comparison of water quality after the implemented measures.

Indicator: Estimation of Annual fish production (kg/ha)

The number of sold annual and daily permits for angling, valid only on BJNatP will be used for estimation of annual fish production (kg/ha), calculating the area of aquatic habitats at a water level measured at Novi Sad gauging station (also related to water level gauge on the weir on Begej channel).

Indicator: Development of new planning documents as support to measures implemented

It would be significant to "monitor" the policy of implementing new bylaw of protected area and management plan, as well as the implementation of measures for the preservation and improvement of natural values (Protected area management plan, Fishery management plan, Spatial Plan for Special Purposes of Begečka Jama Nature Park).

Indicator: Area valuation by the visitors, number of visitors of BJNatP per year

Monitoring would include simply counting the number of visitors of BJNatP per year. The number of annual visitors in BJNatP was estimated at 10.000 before the implementation of the measures. The number of visitors should be re-evaluated after the implementation of the measures.

The economic value of a protected area (nature park) may be better measured and monitored using 'visitor satisfaction' or 'visitor motives' as indicators (e.g., to be assessed by means of surveys like questionnaires and interviews). After completing the implementation of measures, the online survey should be repeated, and the results compared.

4.5. Czech republic

Feasibility study in the Danube Floodplain project

(Act. WP4 A 4.4)

Pilot area Morava

Preamble

Aim of the feasibility study

The purpose of a feasibility study is to determine if a project is possible practical viable as well as economically justifiable (Hoagland & Williamson 2000). A feasibility study will help decision makers make critical quick decisions to select the right opportunities. Feasibility studies that evaluate whether a restoration effort should even be attempted can enhance restoration success by highlighting potential pitfalls and gaps in knowledge before the design phase of a restoration. Feasibility studies also can bring stakeholders together before a restoration project is designed to discuss potential disagreements (Hopfensperger et al. 2007).

Five areas of the project feasibility should be examined: the technical, economic, legal, operational and scheduling feasibility, this helps to detect constraints the proposed project scenario may face.

Technical feasibility assessment focuses on the technical resources available to the organization. It helps organizations determine whether the technical resources meet capacity and whether the technical team is capable of converting the ideas into working systems.

Economic feasibility assessment typically involves a cost/benefit analysis of the project, helping organizations determine the viability, cost, and benefits associated with a project before financial resources are allocated. It also serves as an independent project assessment and enhances project credibility—helping decision-makers determine the positive economic benefits to the organization that the proposed project will provide.

Legal feasibility assessment investigates whether any aspect of the proposed project conflicts with legal requirements like zoning laws, data protection acts or social media laws.

Operational Feasibility assessment involves undertaking a study to analyse and determine whether — and how well — the organization's needs can be met by completing the project.

In **scheduling feasibility**, an organization estimates how much time the project will take to complete.

Feasibility of a river and floodplain restoration

Many benefits can be derived from restoring rivers: biological, ecological, socioeconomic and political. Reinstatement of floodplain wetlands and water meadows may help to control flooding without the need for 'hard' river engineering solutions and to "bring the river and floodplain back into continuity" (Holmes, 1995). Moreover, evidence suggests that a more natural river environment can conserve wildlife habitats and the environment (Tapsell et al. 1995). Evidence also shows that a more natural river environment increases people's enjoyment of rivers (ECON, 1993; Tapsell & Tunstall, 1993).

Various factors need to be considered when deciding upon the level of restoration. Small enhancement projects improve the landscape and aesthetic aspects of a river but can also be an attractive option where finance is a constraint or where a more extensive rehabilitation is not feasible. In all cases each method of restoration must be carefully considered from a practical and economic viewpoint (Sonderjyllands amt, 1991).

Any attempt at restoration should not go ahead without the consultation and involvement of local communities and all stakeholders. According to Brookes (1992), the principal concern in restoration schemes is related to the issues of land ownership and land-take involved.

In considering rehabilitation the past and present ecological conditions of the river and catchment need examining along with the current social context (Tapsell 1995).

Floodplain restoration in Danube Floodplain project

In the project restoration measures on five selected pilot areas in different countries along the Danube and tributaries were tested. These measures aim to improve catastrophic flood risk, ecological and socioeconomic conditions.

To achieve this aim, three different scenarios with complex methodology were tested. The feasibility study attempts to describe and summarize the current situation and problems that initiated the necessary development, methodologies, different aspects of the feasibility and the constraints and challenges that the project may face during and after the implementation.

Content

V.4.1.2 Effects

V.4.1.3 Economic & financial cost estimation

V.4.2 Scenario B-R2

V.4.2.1 Technical analysis

V.4.2.2 Effects

V.4.2.3 Economic & financial cost estimation

V.5 Evaluation of the scenarios and selection of the proposed scenario

VI. Detailed evaluation of the chosen scenario

VI.1 Description of the technical background of the chosen scenario

VI.2 Institutional, operational analysis

VI.3 Summary of the environmental effects and achieving the sustainable development goals

VI.4 Financial sustainability of the project and the cost-benefit analyse

VI. 5 Risk evaluation of the chosen scenario and risk management strategy

VI.6 Implementation of the project and timeline

VI.7 Communication and publicity

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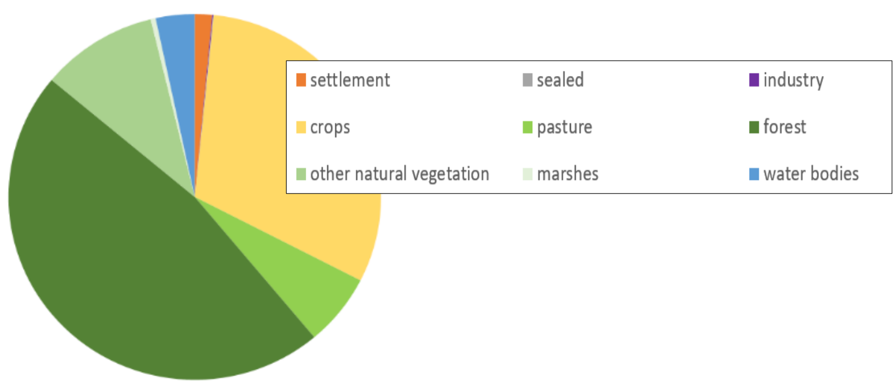
VII. Appendixes

VIII. Literature

I. Content

II. Executive summary

Pilot Area	**Morava**
River	Morava
Country	Slovakia, Czech Republic
Responsible PP	VUVH/MRBA
Pilot area size [km²]	147.37
Geographical / morphological characteristics	The **Morava River** is a lowland river, in the past strongly meandering, extensive river training works were done (channel straightening, cut-off meanders, uniform channel with bank protection, reduction of floodplain areas, interruption of longitudinal continuity by weirs and sills); confluence of Morava and Thaya on CZ side with large retention area to release flood discharges; several villages along the area but outside the floodplain area; modelling area delineated by present flood dykes and the retention area on the confluence with Thaya river.
land cover (CORINE 2020) of 2D model area	
Current ecological status and deficits	Heavily modified water body (HMWB) - Ecological status: 3 - moderate; Hydromophological quality: 4 - poor

Pilot Area	Morava
Major restoration purposes	• Improvement of flow conditions in the river floodplains with respect to flood protection and nature protection goals • Optimization of water regime in the floodplains • Enhancement of conditions for diverse biotopes, which can be found in the area of interest • Improvement of conditions for fish migration
Scenario 1 - realistic	• removal of weirs • Removal or adjustment of selected barriers (weirs, sills) • removal of levees • relocation of flood dykes (to include the cut off sidearms in the floodplain area)
Restoration measures Scenario 2 - optimistic	• R1 + relocation of flood dykes (further than in R1) • Renewal of river pattern Reconnection of oxbows with the main Morava channel (at present state they are behind the dyke) Deepening of existing oxbows
Major recent floods	2010: >HQ100 (ICPDR 2012)
HQs investigated	HQ5
	HQ30
	HQ100

III. Introduction to the project idea – necessity of the proposed project activities

III.1 Assessment of the situation

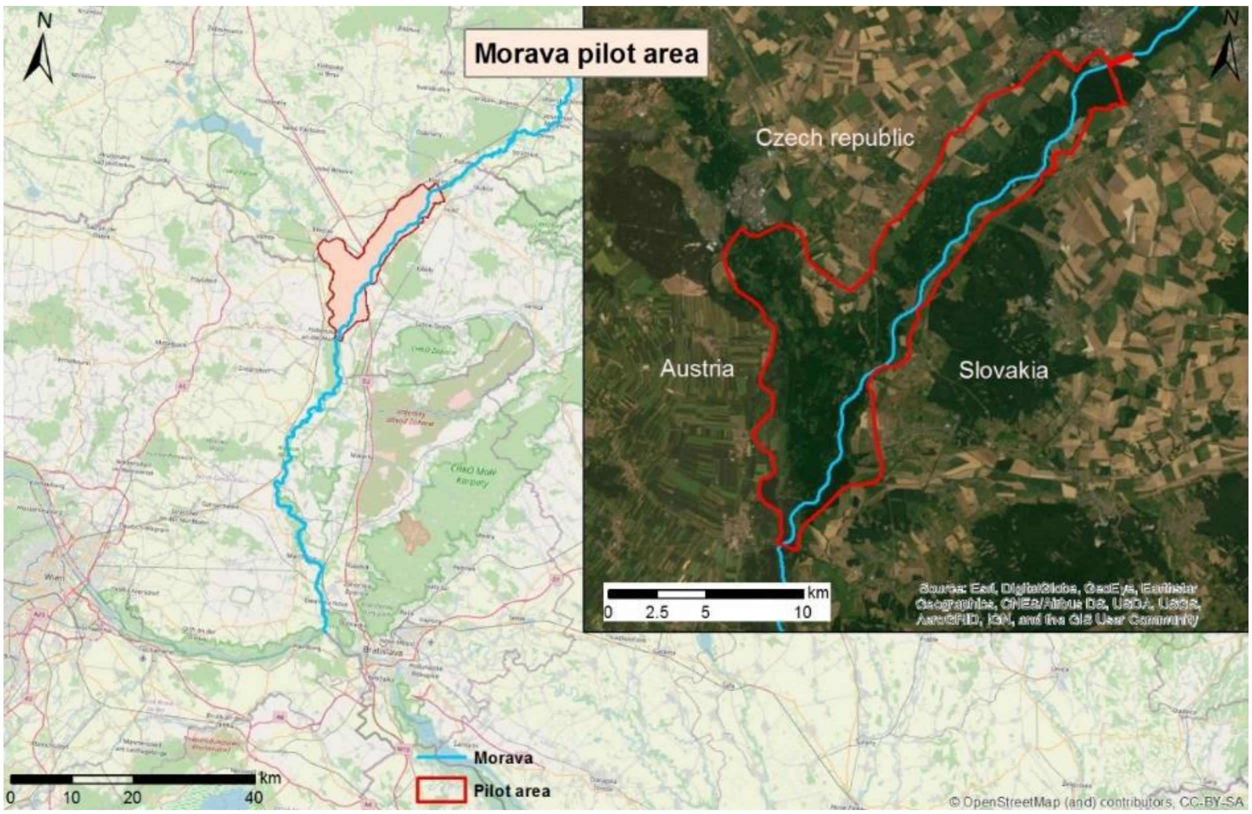


Figure 1: Topographic and aerial map of the Morava pilot area

The Morava River forms the border between the Czech Republic and Slovakia. It should be remembered that the current form of this site was created during the period of the common state, but today it is necessary to proceed on the basis of cross-border cooperation when considering this site. The character of the river floodplain is very different in the two countries. In the Czech Republic, the floodplain is overwhelmingly made up of a mosaic of floodplain forest, in which floodplain meadows, small water bodies and a network of river arms and channels are embedded. Unfortunately, this whole system is cut off from the river by a flood barrier, which is very close to the Morava River. The valley floodplain extends as far as the River Dyje, from which it is again separated by a flood barrier. This creates a huge 'pocket' at the confluence of the Morava and the Dyje, where flood flows can be captured in a controlled manner.

In the Slovak territory, the upper part of the floodplain consists of a cultural landscape, which is again separated from the Morava by a flood barrier. In contrast to the Czech territory, no spillway, even a controlled one, is envisaged in this area. The last active floodplain site on the Morava border stream is located in the lower part of the section in question on the Slovak bank. Although the river is not fenced, it is also a straightened and modified stream in this section.

Cross-border cooperation has already been initiated in recent years to improve the water management and hydromorphological status of the Morava River. These projects, although they have brought many positive results, have not, or even could not, attempt to change the established practice or the overall water management solution. This is only possible on the overall scale of the entire border area, or the entire area of the confluence of the Morava and the Dyje rivers. It is on this scale that this feasibility study addresses this issue.

III.2 Definition of the problem

The water management solution for the area of interest dates back to the 1970s and the solution concept is even much older. It is therefore not surprising that it no longer meets the current requirements or the challenges posed by climate change. The solution strongly accepted the requirements of flood protection and, in the context of the knowledge of the time, also addressed the issue of maintaining minimum flows. The behaviour of the system under normal flows or regularly recurring annual floods, which used to determine the overall character of the area, was not considered in line with the approach taken at the time. The solution did not respect the longitudinal connectivity, the fish migration along the stream was interrupted by the weir cross structures. Lateral connectivity, i. e. the ability of fish to migrate between the river and the alluvial waters in its floodplain, was also fundamentally disrupted. This led to a major degradation of the fish community, where a large number of typical species were linked to the possibility of reproduction in the annually flooded floodplain.

One of the largest floodplain forest complexes in Europe remains in the area behind the dam. This floodplain forest has been completely cut off from the river and the regular floods that have shaped it for centuries. Worst of all, the water regime of this forest has been fundamentally disrupted. The area in question is one of the driest in the whole of the Czech Republic and has the lowest rainfall. The floodplain forest was therefore dependent on precipitation that felt outside of its territory and was brought by the river. This system was completely broken by water management modifications.

In order to maintain a good water regime in the floodplain forest, the water management plans proposed several measures. The water level in the river was raised by a pair of tube weirs. However, the permanently dewatered weirs siltered very quickly and the expected transfer of surface water to groundwater did not occur. Initially, using a network of historic drainage canals for irrigation showed promising results. These structures, which originally diverted excess water from the forest after floods, were instead used to bring water into the forest. However, due to low flow dynamics, even this canal system was soon silted and its effect was not sufficient. Artificial flooding was also used to improve the water regime, whereby an artificial flood wave was created by draining the New Mill reservoirs and this was fed into the floodplain forest through a system of waterworks. The floodplain forests along the Morava River were thus supplied with water from the Dyje River. This system, however, encountered the problem of determining the appropriate term for artificial flooding. Even if a suitable date could be found in some years, it was not possible to get the necessary amount of water into the floodplain forest. Therefore, although there were ways of getting water into the floodplain forest under specific conditions, it was no longer possible to designate the whole area as a classic active floodplain. This was reflected in the gradual loss of biodiversity or its sustainability.

III.3 Goals

The main objectives of the project include improvement of flow conditions in the river floodplains with respect to flood protection and nature protection goals, optimization of water regime in the floodplains, enhancement of conditions for diverse biotopes, which can be found in the area of interest and last but not least improvement of conditions for fish migration and theirs living.

Improvement of flow conditions in the floodplains consists mainly in finding suitable sites that can be connected to the river in full connectivity. This means that these sites should be influenced by the natural hydrological regime of the river, including their spillways, without major restrictions. To enable this, existing dams at these sites should be removed and replaced with new dams in a position more set back from the river. This natural water regime of these sites will optimise the water regime in the floodplains and enhance conditions for diverse biotopes. These changes will not have a major impact on the change of use of these sites the new water regime is fully compatible with the existing floodplain forest culture. As it seems realistic to create a continuous area along the watercourse at least the width of the original meander belt, the next logical step is to try to restore the original route of the Morava watercourse. Thanks to these interventions, lateral connectivity between the river and its floodplain will also be restored in order to improve the conditions for fish migration and their life. It is also necessary to ensure longitudinal connectivity, i.e. the opening of transverse barriers to flow.

III.4 Indicators

Important indicators are the area of floodplain with full active connections to the river, or their areal extent. Another important indicator is the extension of the length of the river, or the length of river sections reconnected to the river. The last major indicator is the number of cross-barriers to migration. The input value of these indicators can be approached in two ways. Either to define their present value and to define their total value as a target value. The second way is to assess only the change in these indicators, that is, the input value is zero for all of them and the target value is only the newly created change in these indicators. In the case of the first method, only the area of the floodplain in the Zahorie SPA between the river and the summer dam represents the input value of this indicator. The input value for the length of the stream is the length of the existing hardened section. For cleared migration barriers the input value is two, already the number of weirs removed in the past. The target value is set as the total potential of these indicators in the solution area, of course the contribution to these indicators can also be evaluated for partial solutions, i.e. solutions for individual sites per partes.

Additional complementary indicators can be proposed to refine the impact assessment of the measures. For example, the number of fish species constituting the fish stock or the number of fish that are able to reproduce naturally in the area could be considered. We can also monitor the dynamics of groundwater levels, or the increase in groundwater reserves, but here it is difficult to set a target value and the course of the levels is very variable and it is difficult to interpret its instantaneous value correctly. On the other hand, this is a very important indicator or change from the point of view of a significant number of stakeholders.

III.5 Target groups

On the Czech side, the list of stakeholders is quite simple. The majority owner of the land in question is Lesy ČR, the state enterprise that manages the forest. The forests of the Czech Republic have also long been developing projects aimed at improving the water regime of the floodplain forest. These projects have mainly focused on the use of the canal network created in the floodplain forest for its irrigation. However, this method gradually reached its limit and gradually lost its effectiveness. The forests of the

Czech Republic are therefore a natural partner to address the radical change in addressing the improvement of the water regime of the forest. There is a similar forest manager in the Slovak Republic, Lesy SK. On the Slovak side, however, most of the forest is located in a military area. A more important partner in the matter of forest management is the administrator of military forests, i.e. Military Forests and Estates of the Slovak Republic.

Another logical partner of the project are the entities exercising the fishing right. A significant part of the fishing grounds in this area are again managed by the Forests of the Czech Republic. However, another stakeholder is also the Moravian Fishermen's Association.

The project addresses a fundamental change in the water management system, therefore we include among the stakeholders the stream managers from both countries concerned, i.e. Povodí Moravy, s.p. (CZ) and the Slovak Water Management Company SVP (SK). In terms of water management, it is the enterprise Povodí Moravy, s.p. that will be most affected by the changes.

On the Czech side, the area of interest falls entirely within the Natura 2000 area, and from this perspective the nature conservation authorities and the Agency for Nature Conservation and Landscape Protection of the Czech Republic are also stakeholders. On the Slovak side, the administration of the Zahorie Protected Landscape Area.

Due to the historical perception of the whole area as a natural floodplain of the river, villages were established beyond the boundary of the floodplain. This situation has not changed to this day and the development of the villages is not directly significantly affected by the Morava River, but it is necessary to include these villages among the important stakeholders. These are the municipalities of Lanžhot, Kostice, Tvrdonice, Týnec, Moravská Nová Ves, Hrušky, Břeclav and Mikulčice. Agricultural entities in these municipalities should also be included among the affected stakeholders.

Due to the scope of the project, both line ministries on both sides of the border should also be included among the stakeholders. These are the Czech and Slovak Ministries of Agriculture and Environment. Due to the border character of the Morava River, the Border Waters Commission and the Border Commission cannot be omitted.

IV. Evaluation of background and environment

IV.1 Introduction of the geographical environment of the area

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 km^2 (Figure 1). 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. Pilot area was investigated by the Czech Morava River Basin Authority (MRBA) and the Water Research Institute of Slovakia (VUVH) within the Interreg Danube Floodplain project.

Figure 2: Morava River basin and the Danube Floodplain pilot reach

Pilot area of the Danube Floodplain project is Morava river reach from rkm 69 to 100 on the border between Czech Republic and Slovakia. The 2D modelling was performed at the area of 147 km^2 (Figure 2). Morava in this section is a typical lowland river, originally strongly meandering (Figure 3). 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.

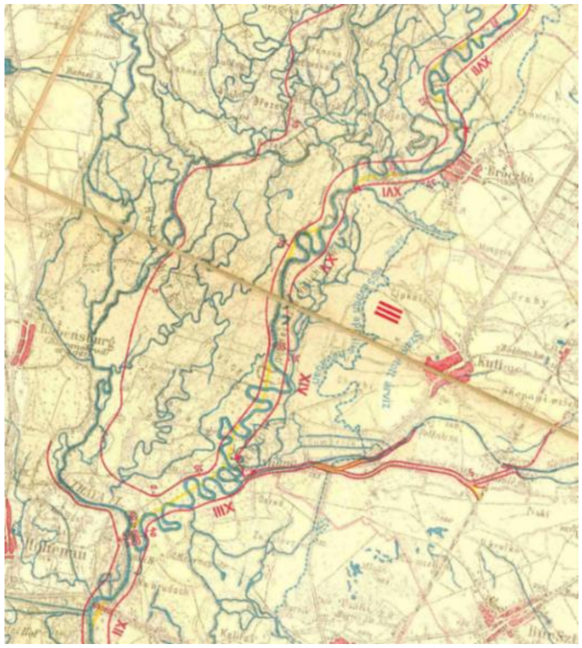


Figure 3: Original Morava river channel on the map from the beginning of 20th century

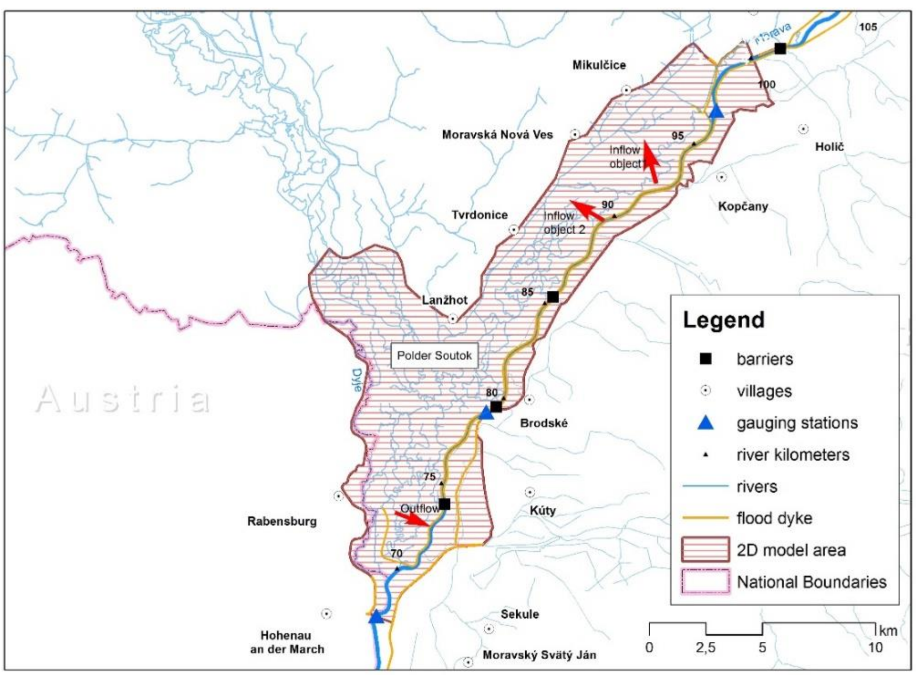


Figure 4: Morava river pilot area evaluated by 2D modelling

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 5: 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 m^3/s. Water is released to the floodplain forest (Natura 2000 site).

Figure 6: Inflow object to the retention area behind the flood protection dyke (Author: VUVH)

There are no settlements directly in the modelled floodplain area.

IV.2 Introduction of the socio-economic environment of the area

From the point of view of the historical development of the area, the noble Liechtenstein family is an important factor. The Soutok area has been part of their estate for centuries. The property held in Moravia (which, however, extended to Slovakia and Austria) was more important for this family than all the property in Liechtenstein's own. In the spirit of Baroque aesthetics, the Lichtensteins transformed this area into a composed landscape, but they always performed these activities with respect for the active floodplain, and the annual floods were perceived as a natural and rather positive phenomenon during their dominion. From the historical source we can also trace their constant resistance to modifications and regulations of rivers. These plans were perceived by the aristocratic family as insensitive and disrespectful interventions in the character of the balanced landscape they had built for generations. The current state of the landscape in the area is therefore to a large extent still influenced by the enlightened policy of this genus.

This method of farming, based on reasonable and from today's point of view sustainable use of the landscape, was located on the area of periodic outflows of the rivers Morava, Dyje and Kyjovka in a wide fan of their confluence. Rather than the confluence of three rivers, it was a complex system of many of their branches, which branched out and intertwined without it being possible to distinguish whether it was the arm of Moravia, Kyjovka or Dyje. The current beds of the Morava and Dyje rivers, which also form the state border, were gradually pushed to the very edge of this area. Therefore, the majority of this river system lies in the Czech Republic, in the territory of Austria and Slovakia we find rather individual outcrops of this system. Significantly, the river floodplain in the territory of Slovakia extends to the lower section, where an important wetland locality of the Zahorie Protected Landscape Area is located on the Slovak bank. From the point of view of the river, it is also necessary to consider the "protrusions" of the floodplain in Slovakia as significant. The Zahorie Protected Landscape Area is then completely comparable in its scope and significance with localities in the Czech territory.
The method of management, or its consistent adaptation to periodic floods, was also reflected in the origin and location of human settlements in this area. No permanent settlement is located directly in the floodplain area. On the Czech side, the villages of Lanžhot, Kostice, Tvrdonice, Týnec, Moravská Nová Ves and Mikulčice are aligned in one line, which exactly respects the flood line from the Morava River. This arrangement also gave a good opportunity to manage the active floodplain, which was and is mostly forested, but some also created municipal meadows, which are located mainly on the outskirts near the villages. In the places where the spilled waters of the Morava and Dyje merged, we can only find floodplain forest. Lanžhot is thus the last inhabited locality, in fact the last place where periodic floods still enabled the establishment of settlements.

On the Slovak side we find the villages of Kopčany, Brodské and Kúty. However, they already lie completely between the confluence cone of the Morava and Dyje rivers. From the point of view of the locals, the landscape is understood as typically floodplain, as an area that has always belonged to the river. Although the water regime of the landscape has been significantly changed by water management modifications, the use of the area is still adapted to the original active periodic flooding, even though it no longer occurs. Due to social changes after the Second World War, the property was expropriated and the era of the Liechtenstein government ended. Nevertheless, the tradition of their approach was maintained for a long time and the territory did not change from the state that was historically built here. The area was spoken of as the Moravian Amazon, and its wild character was reinforced by the fact that only limited access was allowed to the localities along the Austrian border, which at that time divided the world into East and West. In the end, however, megalomaniac water management modifications did not escape this area either. In document from that time we read the sentence: "Due to reckless adjustments in the upper and middle sections of the streams, there was such a fundamental fluctuation of the flow that it is necessary to adjust their lower sections." Thus, in the 1970s, construction machinery bit into the unspoilt landscape of the confluence of the Morava and Dyje rivers. The annual floods were stopped and the area was given a precisely defined water management function. The floodplain forest was enclosed in the dams of the polder, which was to catch up to the biggest catastrophic floods. But most of the time it remains cut off from the life-giving river.

After fifty years, the awareness of the natural spring flooding of floodplain forests is gradually disappearing. The vast majority of farmers have become accustomed to adapting their activities to the rhythm of river floods during the year. This awareness must be restored in the inhabitants of the locality. Reminding them of this old knowledge is one of the tasks of this project. The advantage in this direction is that the overwhelming part of floodplain forests in the Czech Republic is administered by the state organization Forests of the Czech Republic. Thus, there is actually only one important partner in the locality, with whom it is necessary to negotiate the benefits of a new water regime setting, or the restoration of a historically proven management model.

IV.3 Legal and policy background

The basic framework for water management in the Czech Republic is created by the European Water Framework Directive. This will subsequently be reflected in the national water management plan as well as in the plans for individual sub-basins. Within these plans, the Morava River in this section was included among the heavily modified water bodies - the Heavily Modified Water Body (HMWB). This means that we are not obliged to achieve good water status here, but only good potential. However, the process of classifying the stream into the HMWB category was accompanied by a heated discussion. From a comprehensive point of view, the classification as heavily modified can also be considered a kind of "excuse" for an unsatisfactory state of flow. In the case of the solved section of the Morava River, the question is whether the classification among HMWBs was caused by "high demands" for the performance of water management functions of the stream, or just a reckless very technical adjustment of the stream in the past. In the latter case, however, it is possible to change this state. Despite the fact that this is not explicitly required by the Water Framework Directive, it is possible in this case to consider such a type of revitalization measures, thanks to which the Morava will be excluded from HMWB in this section. Even if we continue to consider Morava in the solved section as HMWB, its current parameters are unsatisfactory. The ecological status is at level 3 - medium (Ecological status: 3 moderate) and the hydromorphological status is even at level 4 - poor (Hydromophological quality: 4 - poor). The Morava River thus falls far short of the values required by the Water Framework Directive.

Another important document is the Act No. 254/2001 Coll. (Water Act). In § 44, it defines the natural bed of a watercourse and states that it can also be created by implementing measures to correct interventions caused by human activity. Such a flow can change its direction, longitudinal inclination and transverse profile. In § 45, it further states that the reborn stream may leave its natural riverbed during a flood due to natural forces, thus creating a new riverbed. In § 50 and § 51, it imposes an obligation on landowners to tolerate the natural bed of a watercourse on their land.

This is essential for our project. These provisions say that human intervention can create a natural riverbed from a waterworks (technically modified stream). The Water Act then guarantees the possibility of natural morphological development for natural riverbeds and obliges the owners of coastal lands to tolerate this development. The transfer of today's modified Morava riverbed to the natural bed of the water year would thus be crucial in terms of its further natural development.

Due to the fact that the solved area lies in the area defined in the Natura 2000 system, the Bird and Habitat Directive is also essential for the solution. However, this European regulation is fully integrated into the national law on nature protection, so its reflection in the creation of the project in the Czech Republic is a matter of course.

V. Scenario analysis

V.1 Methodology of the scenario analysis

The solved pilot area is specific in many indicators it is possible to specify it as one complex water management work. Its function is very closely linked to flood protection. Despite the fact, that it is a floodplain along the Morava River (respectively between the Morava and Dyje rivers) it is primarily intended for the transformation of floods coming on the Dyje river. This transformation does not provide flood protection directly in the solved area, the function of the whole area is to slow down the course of floods on the river Dyje so that their effect manifests itself only after the floods on the river Moravia have subsided. This means that the main benefit of this measure is for the section of Moravia below the confluence with the Dyje (Slovakia-Austria border section), which first transfers floods from Moravia and then the flood from the Dyje, so there is no undesirable concurrence of these two flood waves. The effort of the original solution was to preserve the retention space until the last moment until the highest peak flows. The whole area of the floodplain forest is thus, paradoxically, edged to the level of century-old water, and the flood spills into it only through controlled objects. The newly proposed solution does not aim to improve the situation of extreme floods in the section of Moravia below the confluence with the river Dyje, but focuses on flood management directly in the section. For this reason, when assessing the success of the measure, it is necessary to partially exclude the impact of the transformation of the polder and focus on the parameters related to the own flow of Moravia. When choosing the method, it was necessary to proceed from the requirement that the results must be comparable and comparable with other pilot areas and in general with all floodplain localities on the Danube and its tributaries.

Therefore, it was first necessary to identify existing active and potential areas of the floodplain in agreement with other PPs, in our case only localities with a direct link to the river Morava. The methodology for identification of active and potential floodplains on Morava River is based on the experience of others 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.

Despite the fact that, as mentioned earlier, the pilot area of the border stream of Moravia is relatively specific, the FEM method with all PPs was used for further evaluation.

The main objectiveof this activity is the evaluation of active and potencial floodplains along Morava River 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 the historical maps should be used for the identification of the former floodplains. For the identification of the active floodplains, the following conditions should be fulfilled:

- a ratio factor of $width_{floodplain}/width_{river}$ > 2:1;
- a minimum floodplain size of 500 ha on larger and 100 ha on smaller tributaries
- 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
- 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 71: Floodplain Evaluation Matrix - in blue: minimum set, in green: medium set, in yellow: extended set of parameters

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 valuable information for decision makers.

An Activity leader (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 meeting. Here are the results (only for the parameters from the minimum set):

Thresholds ΔQrel		Thresholds Δt		Thresholds Δh	
1	< 1 %	1	< 1 h	1	< 10 cm
3	1 - 2 %	3	1 - 5 h	3	10 - 50 cm
5	> 2 %	5	> 5 h	5	> 50 cm

Thresholds protected species		Connectivity of FP water bodies	
1	< 1	1	< 50 %
3	1 - 20	3	50 % - 80 %
5	> 20	5	> 80 %

Thresholds affected buildings		Thresholds land use	
1	> 5 [n/km²]	1	< 2
3	1 - 5 [n/km²]	3	2 - 4
5	< 1 [n/km²]	5	> 4

Figure 82: Thresholds for the parameters from the minimum set

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

Figure 9: Thresholds for the Ranking of parameters from the minimum set

To determine some indicators of the FEM evaluation, it was necessary to develop a 2D hydraulic model of that area. Of course, this model also served many other purposes.

To quantify and evaluate the river hydrodynamics, hydraulic 2D modelling is a broadly used tool. Although the data requirements and processing is demanding, the clear advantage are the spatially detailed results which can be used for further planning (Stone et al. 2017). 2D hydrodynamic models reveal detailed patterns of flow conditions with a high spatial resolution during flood events and are therefore applicable for analyses of ecological functions (Gibson und Pasternack 2015). The models can reproduce the dynamic interactions between the river and its floodplain. These interactions are an important indicator for regulating ecosystem services such as the flood regulation, but also for provisioning ESS like wood from floodplain forests or fish since the models provide information for habitats (Stone et al. 2017). Furthermore, the 2D results deliver important hazard information (e.g. water depth or velocity maps) for detailed damage estimations (Hattermann et al. 2018).

The application of 2D hydrodynamic models in the pilot area, is an ideal base for the further analysis of the flood prevention effect of floodplain restoration measures, the improvements for habitats and ecosystem services (ESS) as well as the ESS extended CBA.It has to be mentioned that the 2D model results do not generate exact real conditions, but with several simulated scenarios an approximation can be yielded on how the floodplains would react in flood events (Stone et al. 2017).

2D model properties in Morava River pilot area	
2D model developed by	VUVH
2D model type and re-lease	HEC-RAS 5.0.7
2D model size in km²	147.37
Number of nodes	1448241
Nodes per km²	10000
DEM base	2x2m (2010)
Temporal resolution	1 hour

Major tribu-taries in model area are Dyje River, Myjava River and many others small tributaries

To assess the effect of floodplain restoration on different characteristics of flood events, it was decided to apply at least three hydrological scenarios. All scenarios investigated are analyzed with a non-steady input hydrograph, to determine the differences in the flood peak height and the flood wave translation. A frequent flood event (HQ2-5), a medium flood event (HQ10-30) and a 100-year flood event (HQ100) are simulated in pilot area model. The input data for these events is mainly taken from observed past events in the pilot area at nearby gauging stations or up- or downscaled hydrographs of these events to fit to the selected HQ values. The data is provided alsou by national hydrological authoritie. In combination with the three restoration scenarios, nine scenarios are simulated in total .
The transient time series are added as input to the model in hourly time steps at the upper model bound-ary in the main channel. Major tributaries are implemented with a steady runoff value or unsteady ob-served runoff time series, if measured data is available from the according event. Lateral inflow of small magnitude is added punctually at several locations.

The specific socio-economic situation has already been described in previous chapters. A specific approach also requires an evaluation of the improvement of environmental indicators. The solution does not actually aim for a significant increase in these indicators (although even this is not negligible). The main motivational project is to ensure the sustainability of these indicators. As a zero solution, the appropriate benchmark, it would be theoretically necessary to use the state that the whole ecosystem would reach without the implementation of project measures. But that would be a big speculation. Therefore, the current situation is used by default for comparison. However, it must be borne in mind that this is not a sustainable situation. Notwithstanding the specific circumstances mentioned above, the ESS ecosystem services method and the CBA method were used to evaluate these indicators, as in the case of other PPs.

V.2. Preliminary analysis for identification of scenarios

The area addressed is not the subject of consideration to improve the current situation for the first time. On the basis of Czech-Austrian and Czech-Slovak cross-border cooperation and other activities, a large number of conceptual materials were created in the past, which addressed the partial issues of further development of the affected area.

An important milestone was the Phare project "Improving the hydrological situation and the environment of fish in the lower reaches of the Morava and Dyje rivers" developed between 1997 and 2000. This project marked a major breakthrough in the way of thinking about the area and opened up space for further activities. It was the first to comprehensively deal with ensuring not only longitudinal but also lateral connectivity of the Morava River.

This project was followed in 2001 by the first thoughts on the removal of dams and the involvement of decommissioned branches back into the river system. This plan was developed for use in The Global Environment Facility (GEF). It could be said that this concept was ahead of its time and, unfortunately, was not finally implemented under the program.

In 2021, knowledge of the methodology of connecting decommissioned arms was not sufficient and the implemented projects often ended in failure. Therefore, the experience from the project Interreg Czech Republic - Austria "DYJE 2020 / THAYA 2020" (ATCZ7) was used to optimize the design of the connection of decommissioned arms. This project designed and verified in practice the methodology for sustainably connecting the decommissioned branches back to the river system of the river Dyje. This methodology is fully applicable on the river Morava.

It is also necessary to mention the project from the Operational Program of Cross-border Cooperation SR - CR 2007 - 2013 "Joint flood control measures on both banks of Morava". As part of this project, two weirs on the Morava River were removed. This is the first similar implementation in the Czech Republic, which has shown that this type of solution can also be considered in conceptual materials. This project further developed the possibilities of renaturing Moravia's own riverbed within the existing area without the assumption of dam removal.

Figure 10: Removal of the substructure of the original tube weir on the river Morava

These documents never addressed the area comprehensively, but always focused on one of the partial problems. Nevertheless, the concept of revitalization scenarios could follow them and create a comprehensive solution for the pilot area.

Revitalization scenarios were thus created by compiling (merging) older proposals and concepts, which they connected into one cooperating whole. An important impetus for the final determination of the scenarios was also the discussion of the plan with stakeholders. One of the main recommendations from this meeting was to move the dikes - the expansion of the active floodplain in the Slovak Republic. Previous proposals provided only for expansion in the Czech territory. This radical change of perspective has opened up a whole new simplicity for the design of solutions.

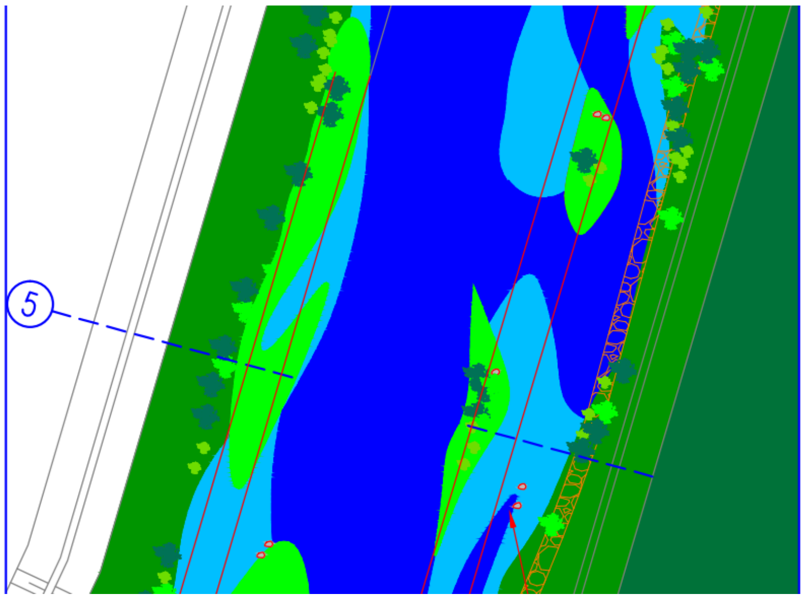


Figure 11: The idea of solving the revitalization of the Morava riverbed in fenced sections

V.3 The case without project

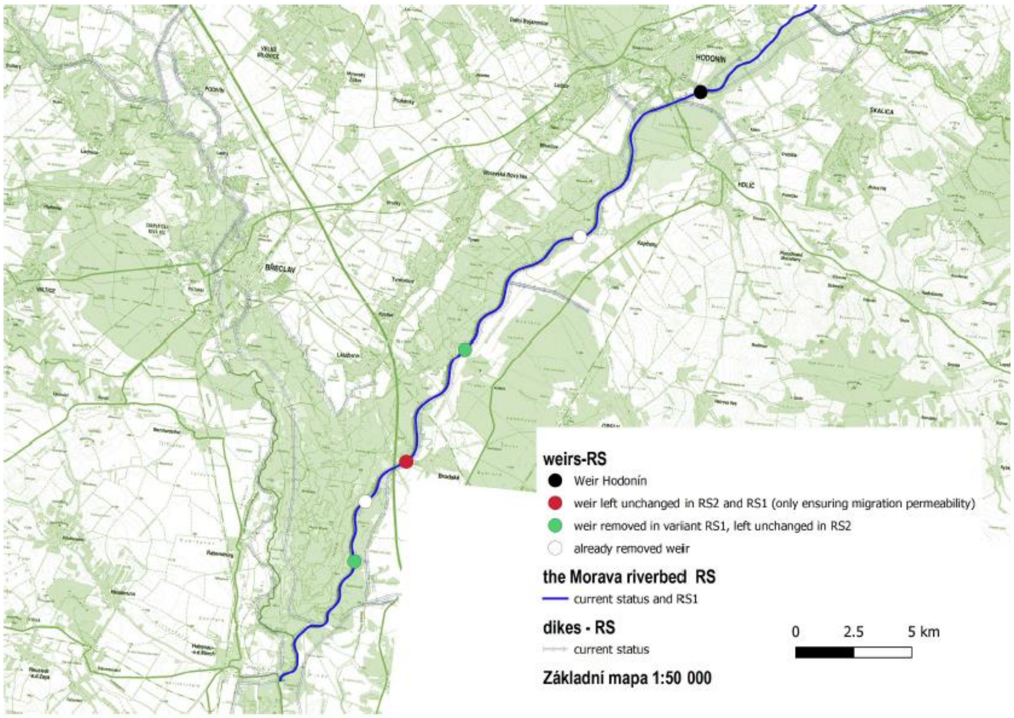


Figure 12: Location of transverse structures in the solved section

As mentioned in previous chapters, the current situation is the result of concepts and solutions from the 1950s and 1970s, respectively. The concept corresponds to the then concept of water management and addressed the priority of extreme peak flows of low recurrence (Q100). The solution also reflected the then idea of the need to navigate the Morava. Despite the fact that the solution was already looking for ways to compensate for the impact on the environment, it dealt almost exclusively with the issue of minimum flows and their distribution. However, these measures have proved ineffective. Experiments carried out in the past have shown that the scope for improving the situation through partial measures is very limited. Even those that seemed promising at first gradually lost their effectiveness. The partial measures could not restore the necessary dynamism and thus cannot be described as sustainable. Despite great inertia, alluvial habitats lose their vitality and water bodies gradually "age", which may lead to their complete extinction. The original diverse system of periodic arms, small bodies of water and wetlands has changed unstoppably towards terrestrial habitats without a significant link to the watercourse.

It is a great advantage that these regime changes did not lead to a change in management in the area of interest. The floodplain of the Morava and Dyje rivers is managed very similarly to the times when the whole area was under the influence of active inundation. But even here it is possible to observe negative changes. Despite the fact that the floodplain forest has great vitality and inertia, ie that it is able to work with the reserves depleted in the past in the poorer years, the deficit caused by the prevention of annual floods is already manifesting itself in it. Unfortunately, repeated attempts at artificial flooding in the past have shown that without a radical solution, ensuring sufficient moisture for the floodplain forest is not sustainable.

Biodiversity has an even stronger link to restoring the natural regime of annual flooding. Floods are an important disturbance for biodiversity, and the current situation thus leads to a gradual, albeit slow, but clear reduction in species diversity and habitat stability.

Without the implementation of the project, the state of the fish stock must also be assessed as unsatisfactory. The fish stock in the Morava is currently completely dependent on artificial restocking. The regulated riverbed does not provide sufficient conditions for natural reproduction or other parts of the fish life cycle. If we add to this the fragmentation of the flow by transverse structures, the situation of the fish stock is unsustainable without further intervention.

V.4 Introduction of project scenarios (A/B)

V.4.1 Scenario A RS1

We also describe the RS1 revitalization scenario as realistic, mainly because other project partners also use a similar designation. In the case of the border section of the Morava, it is rather a scenario based on, respectively integrating and specifying all previously processed plans. For the first time, these intentions are understood in context and actually create a new solution.

The focus of this scenario is to ensure the migratory permeability of the river in the longitudinal direction. It is therefore a question of removing or making transverse structures possible. Two weirs have been removed in the past (tube weir Lanžhot km 76,916 and tube weir Kopčany km 92,720). The other two weirs (Tvrdonice weir km 85,385 and Lanžhot weir km 74,117) are also designed for removal. In the case of the roughened chute Lanžhot, it is proposed to reduce it by 0.6 m and modify its boulder structure so as to provide suitable conditions for fish migration. From the original total height of these five obstacles of 11.05 m, which was completely impenetrable for fish, a reduced height of 2.5 m remains, where, however, full migration permeability will be ensured.

Even in a realistic scenario, we must consider lateral migration, or lateral connection of the river and its floodplain. In this section of the stream, it is not possible to ensure the removal or displacement of protective dikes further from the stream without a solution.

A specific part is the removal of the "summer dam" in the Záhorie Protected Landscape Area. This dam protects the area only to lower flows, during larger floods it is already flooded. It was probably built to simplify forest management. Due to today's territory in the protected landscape area, this dam is no longer needed, or the water regime of the territory negatively affects it.

The realistic scenario of the river does not envisage a change in the current route of the Morava. It only suggests local measures to increase bank diversity and intra-bed morphology in suitable places with sufficient riverbed width. During these measures, sand or trowel benches are inserted into the stream or, on the contrary, ponds or small blind shoulders are dug into the terrain of the existing berm. However, due to the Berm area, these measures are relatively limited. However, they can still bring significant improvements over the current situation. Ensuring the stability of the dam (if it is left in a given section) must also be addressed during these measures. For this reason, dormant fortifications are proposed in critical localities - ie fortifications that are preventively placed in a dug furrow along the boundary line, which the river should not cross.

V.4.1.1 – Technical analysis

With the exception of the reconstruction of the Lanžhot boulder chute into a migratory permeable structure, in the case of this stage it is mainly the removal of unsuitable buildings, or their replacement in a more suitable position. From the point of view of national legislation, however, even in these cases it is a water management work, or the removal of the building is permitted by the same process as its construction. Due to the transboundary nature of the stream, all interventions must also be discussed in the Boundary Waters Commission.

In the case of removal of weir structures, there is already a procedure that was applied during the removal of the first two transverse structures on the river Morava. This procedure will also be used for the remaining two structures designed for removal. Therefore, project documentation for the demolition of buildings will be prepared for these cases, for which it will be necessary to obtain a joint zoning and building permit. It is important that the developed hydraulic model proved that this removal is possible in terms of flow conditions, or that the removal of structures will not jeopardize the stability of the remaining section of the flow.

The reconstruction of the Lanžhot chute into a migratory permeable structure is based on several previously processed conceptual materials. A similar solution has been tested on many other profiles in the past. However, it must be admitted that an obstacle to the flow of the size of the Morava on the border section has never been solved in the Czech Republic. We do not know a similar migration permeable solution from abroad. However, the solution is applicable to such a large river. However, increased emphasis needs to be placed on stability assessment, especially when passing through increased flows. Here it is possible to start from similarly designed constructions, which, however, did not take into account the needs of migration permeability. However, the construction procedures are the same here. In terms of migration solutions, on the other hand, low flow rates are the most problematic. They tend to "get lost" in the boulder structure, or are not able to ensure adequate migration conditions across the entire width of the overflow edge. For this reason, a defined and structurally modified part is proposed in the boulder structure, which serves precisely to ensure suitable conditions for migration in the period of low flows.

In this case, the removal of dams is always supplemented by the replacement of the removed dam in a position moved further away from the stream. These sub-parts should always be performed at the same time, ie the material from the removed dam will be used immediately for the construction of the indented dam. It is necessary to assume that it will not be possible to use all the material obtained from the removed dam to build a new dam. Part of the material will be so rooted in vegetation (grass) that it will not meet the parameters and requirements for material suitable for protective dikes. However, this material should also be preferentially used at the construction site, for example for the construction of elevated localities-lumps, used to hide game during floods, or just to create the necessary diversity of habitats. In the event of a lack of material for dams, local material (similar to the construction of the original dams) originating from the earthworks should be used again, where new small water bodies or wetlands will be created.

Local modifications to the original Morava riverbed can be made in two ways. Either as a water management structure that would change the character of the current riverbed, but it would still be a waterworks. In terms of discussion, this option is significantly simpler. However, in terms of morphological flow quality, the second variant is more advantageous. In the second case, the measures would be implemented as the implementation of measures to correct interventions caused by human activity, which according to § 44 of Act No. 254/2001 Coll. (Water Act) a natural riverbed is created. Such a flow can change its direction, longitudinal slope and transverse profile. In § 45, the law further states that the natural flow may leave its natural riverbed during a flood due to natural forces, thus creating a new riverbed. With this solution, the flow adjustment would completely disappear and only the protective dams would remain. Therefore, only these dams would continue to be considered as construction, together with measures (sleeping fortifications) ensuring that the newly created natural riverbed does not disturb their stability.

V.4.1.2 – Effects

The realistic scenario is actually a compromise between generally accepted solutions and trying to find a new solution for the border section of the Morava River. This is actually from the basis of the possibility of achieving the desired effects. It can be stated that it sufficiently solves the provision of migration permeability of the river in the longitudinal direction. Thanks to the displacement of some sections of dams, lateral migration permeability is also ensured and the newly interconnected areas of the floodplain create important habitats for the natural reproduction of fish, typical for this type of lowland flow. Without the proposed measures, river habitats would be missing.

Although the proposed local modifications of the regulated riverbed will bring a partial improvement of the situation, they can significantly reduce the space that this variant frees up for the river. Even in this variant, it is possible to theoretically consider defining the resulting riverbed as a natural riverbed. Although such a flow may change its bed, in this variant a large number of boundary conditions remain (for example, existing or even displaced dams) that in practice the development of the riverbed would have to be limited as often. It is therefore not very led that this option would fully restore morphological processes. The fact that the floodplain is released asymmetrically only towards the Czech bank also contributes to this, which does not correspond to the natural morphological pattern that the river would create spontaneously in this section.

In this variant, therefore, the revitalization intervention does not restore the natural forcing of the flow and its spontaneous creation is very unlikely. On the other hand, the preserved remains of the original riverbeds in the connected floodplain get into the form of alluvial waters, where at increased flows at least the morphological processes associated with the interaction of alluvial waters and flood flows will be restored.

Thus, it is possible to say that the scenario brings an improvement in the morphological diversity and diversity of habitats and often returns some morphological processes to this section. However, it is probably not possible to restore the trough-forming processes, which in the long run makes it impossible for the proposed measures to be sustainable. However, if we understand this scenario as a stage in the solution, its benefits are unquestionable. The advantage is that basically all proposed measures can be incorporated into the optimistic variant in the future, respectively this scenario may follow on from the implemented measures.

In this scenario, it is also not proposed to change the water regime of the majority of the floodplain, which, despite the proposed measures, still remains behind the protection of the dam, without direct contact with the river.

The feasibility study has shown that this realistic scenario is possible, has its undeniable benefits, but its impact is limited. Its greatest advantage is that it can function to a significant extent as a stage in solving an optimistic scenario.

V.4.1.3 – Economic & financial cost estimation

For the economic and financial evaluation of the realistic scenario, it is necessary to provide an expert estimate of the costs of the measure. At the feasibility study level, we used two different approaches.
The first is to look for suitable analogous implementations or rather more similar implementations. Based on this, we are able to determine the estimated price, but it is possible to implement specific measures in this scenario. This was the case in the case of weir removal and in the case of migratory-favorable treatment of the stone chute. To determine the price of the weir, we used mainly the already removed removal of the lower structures of the bag weirs on this section of the Morava River, but also other

removal of transverse structures implemented in the Morava river basin. For the reconstruction of the stone chute, it was possible to use a large number of implementations of migratory permeable boulder structures, as well as the implementation of boulder slides without emphasis on migration permeability.

In the case of removing or building dams, we proceeded differently. Here, too, of course, we have a wide range of projects that are just removing or even building dams. However, dams in these projects have very different parameters, whether it is the length or height of the dam. Based on the experience from these projects, we were able to determine the cost per 1 m^2 of removed or newly placed dam material. From there, it was easy to work on determining the cost per 1 m (section one meter long) of the dam. For the needs of the budget, such a meter is referred to as a common meter, in Czech "a common meter (bm)". For some simplification, which was necessary in the scale of the feasibility study, we identified two basic dimensional types of dams, smaller with a cross-sectional area of 9 m2 and larger / or higher) with a cross-sectional area of 28 m^2. Only the "summer" dam on the territory of the protected landscape area Zahoří, which is removed without compensation, falls into a smaller category. All other dams fall into the "big" category. It follows that even dams newly built in a remote position are considered as large dams for the needs of the budget.

The price per common meter was determined on the basis of budget items currently valid for 2021. The basic assumption of the set price is that all material obtained by removing dams will be fully used in building new dams, or that any surplus or unsuitable material will be used at the construction site. From the point of view of economy, this is by far the most advantageous procedure.

Restoration measures	Unit	Number of Units	Price per Unit	Costs/expediture (Eur)
Removal of weirs	weir	2	1 400 000,00	2 800 000,00
Adjustment of selected barriers (migration permeability)	weir	1	800 000,00	800 000,00
removal of the existing levees small one (area of cross section 9 m2)	bm	4 800	144,00	691 200,00
removal of the existing levees big one (area of cross section 28 m2)	bm	15 750	448,00	7 056 000,00
Relocation of flood dykes/ building of levees big one (area of cross section 28 m2)	bm	14 650	168,00	2 461 200,00
TOTAL				13 808 400,00
Area of new active floodplain	ha	750,00		
Area of new active floodplain (only CZ)	ha	485,00		

Figure 13: An overview of draft measures and financial costs in scenario A (RS1)

The total cost of implementing the realistic RS1 scenario is € 13,808,400 based on the above procedure. This amount does not include project preparation costs or land purchase costs. In this case, it is possible to assume that the majority of land that will be affected by the transfer of the dam is owned by the Czech Republic (reported on them by Lesy ČR), so it will most likely be a gratuitous transfer. For better comparability of variants in this case, we include an amount for the purchase of land in the amount of 10% of the implementation costs (this ratio is based on experience from similar projects and rules and experience of European and national subsidy programs aimed at revitalizing the landscape). 3% of implementation costs are considered for project preparation for the needs of the budget. After taking these costs into account, we receive the final total amount of EUR 15,603,492.

We can use several methods to determine the effectiveness of this amount. The first is a comparison of this amount with the amount determined according to the methodology of costs of usual measures used by the Operational Program Environment, which is the most important financial instrument for landscape revitalization in the Czech Republic. This program sets the usual amount for the revitalization of a watercourse 40 Euro per m2 of area of the revitalized stream, in the case of revitalization of the stream including the floodplain the amount is slightly smaller and is 34 Euro per m2 of area. If we use this lower amount and include only the area of the newly connected floodplain in the Czech Republic, we still get an amount more than ten times higher than the expected costs of the measure.

The second method is to use the costs of previously implemented similar actions. If we determine the average amount of the costs of the action, which focused precisely on the revitalization of the stream and its floodplain, we get the amount of 51,700 Euros per one ha of solved area. With this method we get comparable costs of 25 million Euros, including only the area of the floodplain in the Czech Republic, and 38.8 million Euros, including the entire revitalized area of the floodplain. Even with this method, the set costs of the measures are therefore two to three times cheaper.

The proposed measure is effective both against the marginal costs set by the subsidy rules and against the costs of comparable measures.

V.4.2 Scenario B RS2,

The RS2 revitalization scenario is described as optimistic, again mainly because other project partners also use a similar designation. In the case of the border section of Moravia, it is rather a scenario supplementing the solutions considered so far with procedures that are based on current knowledge and create a concept that corresponds to current trends and is able to respond comprehensively to the challenges of global change and provide sustainable solutions. In a significant part, the scenario follows the measures of the RS1 scenario and further develops them.

Like the realistic RS1 scenario, the optimistic RS2 scenario addresses the migration of the river in the longitudinal direction. In the case of the roughened Lanžhot slide, it is again proposed to reduce it by 0.6 m and modify its boulder structure so as to provide suitable conditions for fish migration. In this scenario, however, the removal of two weirs is not proposed (Tvrdonice weir km 85,385 and Lanžhot weir km 74,117). These weirs are used in the proposal to restore the original route of the Morava riverbed (in more detail in the description of this activity).

In the optimistic scenario, we must, of course, consider lateral migration, or rather the lateral connection of the river and its floodplain. Compared to the realistic scenario, a significantly longer length of dams is removed. Based on the comments from the stakeholder discussion, the active floodplain is not only expanding in the Czech Republic, but the substantial floodplain area will now also be connected to the river in Slovakia. The area of the new active floodplain is almost four times higher than in the realistic scenario. We consider the identification of the possibilities to extend the active areas to both banks of Moravia to be one of the most important results of this scenario.

A specific part is the removal of the "summer dam" in the Zahorie Protected Landscape Area, which is described in a realistic scenario. In the optimistic scenario, however, the removal of the right-bank flood dam on the upper section of the Morava River is increasing. In this case, however, it is not a shift of the flood line and the dam is removed without compensation, increasing the frequency of spills in this section should favorably affect the dynamics of the water regime of the entire polder, or improve the water balance of the floodplain forest.

A fundamental change from the optimistic scenario to the realistic one is the restoration of the original route of the Morava River. Back to the river system, arms in the Czech and Slovak territory are involved. Local measures in the area of the current rivers are therefore necessary to implement only on sections where the section of the original Morava riverbed is not connected. Due to the fact that even in the localities where the connection takes place, the original riverbed is preserved in some form, the measures that would be implemented in these sections within the partial phases of the solution (RS1 scenario), which still restore the original routes did not address.

As mentioned, the current riverbed is always preserved, but a distribution object is always inserted into it, which directs most of the flow to the newly connected original Morava riverbed. For this purpose, two existing weirs will be used (weir Tvrdonice km 85,385 and weir Lanžhot km 74,117), which therefore does not need to be removed in this scenario. The migration route through these transverse obstacles leads through newly connected branches. These measures will lead to the dynamic development not only of the newly connected branches, but also of the left sections of the current riverbed. In some cases, the original riverbed will function as a parallel arm, in most cases their development may lead to spontaneous extinction, transformation into a blind arm or periodically flooded habitats.

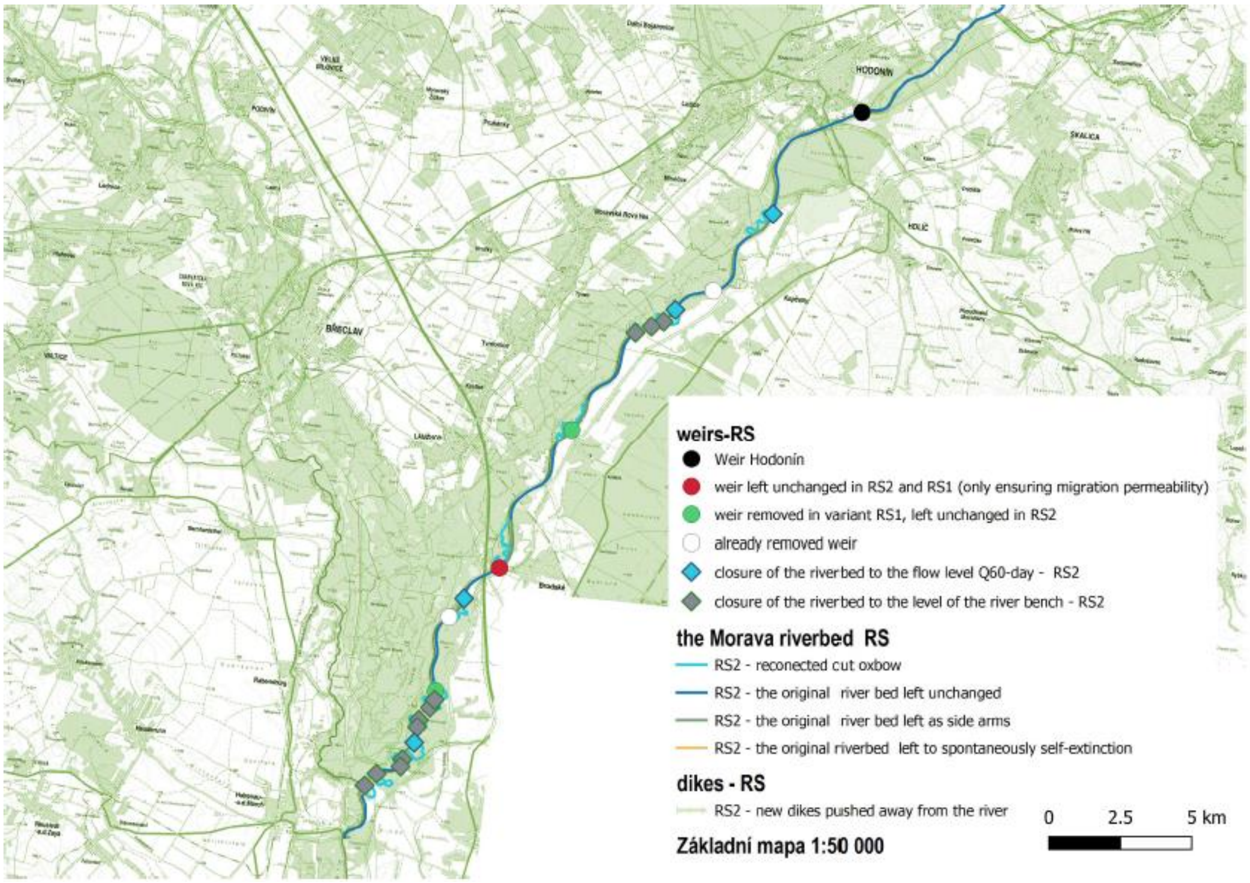


Figure 14: Location of transverse structures in the solved section

V.4.2.1 – Technical analysis

In this stage, all objects designed for removal by the realistic stage are deleted. The only exception is the removal of two weirs on the Morava River. However, this stage proposes to remove many other objects. At the same time, many buildings are also being built at this stage.

From the point of view of national legislation, even in cases of removal of a building, it is a water management work, or the removal of a building is permitted by the same process as its construction. Due to the transboundary nature of the stream, all interventions must also be discussed in the Boundary Waters Commission.

The reconstruction of the Lanžhot chute into a migratory permeable structure is based on many older conceptual materials and previously implemented implementation projects. This procedure is described in detail in the technical analysis of the realistic stage.

In this scenario, the removal of dams is carried out on Czech territory to the same extent as in the realistic scenario. In addition, extensive dam removal is also proposed in the Slovak territory, where it is always supplemented by replacing the removed dam in a position further away from the stream. In contrast to the realistic scenario, dam removal is also carried out in the Czech territory without compensation. As already mentioned in the realistic scenario, it is always necessary to carry out the removal and rebuilding of the dams in the offset position at the same time, ie that the material from the removed dam will be used immediately for the construction of the offset dam. It is necessary to assume that it will not be possible to use all the material obtained from the removed dam to build a new dam. Part of the material will be so rooted in vegetation (grass) that it will not meet the parameters and requirements for material suitable for protective dikes. However, this material should also be used preferentially at the construction site. In the Slovak territory, it is more difficult to find space for the construction of elevated localities-lumps, used to hide game during floods. In this case, the amount of material from the disturbed dams is better taken into account in the designed dam profile. Due to the nature of the area, it is possible to consider dams in the form of earthen ramparts with a gradual slope. In the peripheral parts of these earthen ramparts, it is possible to use material with worse parameters, which would preclude its use in a classical earthen dam. In case of lack of material for dams, local material (similarly to the construction of the original dams) coming from the earthworks should be used again, in the place of which new small water areas or wetlands will be created.

A special case is the removal of a dam without compensation on Czech territory. In this case, there is no newly built object where the material could be used. This, with the complete removal of the dam, would lead to a large surplus of material and complicate and, in particular, increase the cost of implementing this measure. Fortunately, the purpose of this measure is not to connect part of the floodplain back to the river, but to allow water to flow into part of the polder left in the dam. In this case, it will not be a complete removal of dams, but rather only its local excavations, which will significantly reduce the excess material. This material can then be used for local landscaping.

Local modifications to the original Morava riverbed can be made in two ways. Either as a water management structure that would change the character of the current riverbed, but it would still be a waterworks. In terms of discussion, this option is significantly simpler. However, in terms of morphological flow quality, the second variant is more advantageous. In the second case, the measures would be implemented as an implementation of measures to remedy interventions caused by human activity, which according to § 44 of Act No. 254/2001 Coll. (Water Law) a natural bed of a watercourse is created. Such a stream can change its direction, longitudinal slope and transverse profile. In § 45, the law further states that the natural flow may leave its natural riverbed during a flood due to natural forces, thus creating a new riverbed. With this solution, the flow adjustment would completely disappear and only protective dikes would remain. Therefore, only these dams would continue to be considered as construction, together with measures (dormant fortifications) ensuring that the newly created natural riverbed does not disturb their stability. Of course, it is expedient to carry out these modifications in localities where the removal of dams and the restoration of the original riverbed is not expected. Of course, even where the modified riverbed remains only as a side arm, such a measure increases its morphological value (for example, if they were implemented in the previous stage of the solution. Given that the optimistic scenario envisages the restoration of the original river winding, even the left sections of the apartment have been converted into a natural riverbed, ie rather through the implementation of measures to remedy human-caused interventions.

A crucial part of the optimistic scenario is the restoration of the original winding of the Morava River. This consists in connecting the individual branches, which were cut off from the river during modifications in the 1970s. These arms remained in the floodplain in the form of weaned arms. The same assignment has already been solved in recent years on the river Dyje and it is possible to take over it in full for the river Moravia. Unlike the river Dyje, however, it is conditioned by the removal of flood dikes beyond the decommissioned branches, as described in the previous paragraphs. As part of the Dyje 2020 project, the entire methodological procedure for connecting similar branches on the border stream was described in detail, which greatly facilitated the design of the solution on the Moravia River.

On the one hand, the solution consists in removing the material that was placed in the arms during water management modifications and closes the arms mostly at their upper and lower ends, ie the existing preserved water areas will be connected to the Morava riverbed itself. This connection must be made to the full profile of the original riverbed. In similar projects, the extracted material is usually used to backfill the modified riverbed so that the river returns to its original riverbed and the modified riverbed disappears completely. However, this solution is not possible on the border flow, because the modified flow leads to the state border in its center and the project must not cause its change. On the other hand, it is necessary to partially direct the flows to the parked arm. It has already been shown in the past that the variant where only both ends of the arms are opened does not bring good results, and in most cases the connected arms are quickly grounded. The same problem was solved on the river Dyje. For the above reasons, the principle of "ecological" integration was proposed, where the puncture is maintained and is only partially dammed by the object directing the required part of the flow into the arm. Based on a study of historical maps (1st and 2nd military mapping), we found that this method probably corresponds to the original morphological form, where in many places there was just branching of the riverbed.

The original pierces will therefore be preserved and only the objects that divide the water into the restored arms in a ratio that will not cause a change of boundaries will be dammed. The distribution object has a unique structure, it consists of a low boulder stage with a wide crown, which ensures the division of especially low flows, and a two-sided narrowing of the flow (aptly marked "šli"), which in turn ensures the direction of flood flows. In addition to connecting the branches, the project may include the creation of a wetland communicating at increased flows with the river and lumps of excess soil, which serve as a game hiding during floods. In the case of the Morava River, the dam will be carried out on two different levels. In most cases, the entire kyneta will be blocked up to the level of the existing berm. In this case, the modified riverbed will be left to spontaneous development, which may lead to its extinction. According to the experience from the river Dyje, however, there will only be a significant morphological development, when the original monotonous modified riverbed will change into a morphologically very diverse riverbed with a relatively high fluctuation of flows. Morphological elements (benches, islands, etc.) protrude from the riverbed, which are flooded only periodically and are important river habitats and habitats. In some cases, the flow into the arm will increase around the flows exceeded after 30 to 60 days a year. In this case, there will be two almost equivalent parallel belts. Both building stages will be used for this solution, which will not need to be removed. The distribution object has a unique structure, it consists of a low boulder stage with a wide crown, which ensures the division of especially low flows, and a two-sided narrowing of the flow (aptly marked "šli"), which in turn ensures the direction of flood flows.

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Figure 15: Restoring the orig. forcing of the riverbed - connection of the decommissioned arm on the border stream

Figure 16: Partition object and example of changes of the riverbed left to spontaneous morphological development

V.4.2.2 – Effects

The optimistic scenario represents a comprehensive solution for the border section of the Morava River. It is not burdened by stereotypes of older solutions. Not only does it ensure the migratory permeability of the river in the longitudinal direction, but it also fully ensures the lateral migratory permeability, and the newly interconnected floodplains create important habitats for natural fish reproduction, typical of this type of lowland flow. Without the proposed measures, these habitats would be significantly missing from the river.

The proposed local modifications of the regulated riverbed bring a partial improvement of the situation, but they are to a large extent limited by the space between the dikes. However, where dams are left in their current position, their influence is important. In this variant, it is necessary to consider defining the resulting riverbed as a natural watercourse bed in these plants as well.

An important element of this scenario is the restoration of the original winding of the riverbed, which will be achieved by moving the dams and connecting the decommissioned branches. In this case, it is quite clear that a natural watercourse will form. By law, this flow can change its channels. In this variant, the number of boundary conditions is significantly reduced (for example, the lines of existing or even displaced dams) so that the need to limit the development of the riverbed will be so low, or between these limits the flow will have enough space to fully restore morphological processes.

The scenario therefore not only improves the morphological diversity and diversity of habitats, but also fully addresses the morphological processes in this area, which ensure the sustainability of the solution. The advantage is that basically all the proposed measures of the realistic scenario can be incorporated into this optimistic variant in the future, respectively this scenario can follow the implemented measures. This allows this very drastic intervention to be carried out in feasible stages.

In this scenario, it also addresses the change in the water regime of the majority of the floodplain, which, despite the proposed measures, still remains behind the protection of the dam, without direct contact with the river. Thanks to the partial removal of dams without compensation, the dynamic periodic flooding of this site will be restored without significantly reducing the existing flood protection function. Respectively, in the extent of lower floods, this function will be strengthened and a sufficient transformation of catastrophic floods will be achieved.

The feasibility study has shown that this optimistic scenario is possible and has major benefits. It brings a comprehensive sustainable solution, makes full use of the morphological activities of the river to achieve the set goal and it is possible to implement it in proportionate stages.

With this optimistic scenario, the Morava River and its active floodplain will be shifted to the form we can observe on its tributary, the Dyje River, or to the form that will arise on this river after the completion of current revitalization projects. In any case, experience, surveys and observations from the Dyje River show that this model represents an optimal balance between the requirements for the morphological value of the river, adaptation to climate change and the management of flood flows.

Its economic efficiency is very good (see the following chapter) and its cost-benefit ratio is more advantageous than in the realistic variant.

V.4.2.3 – Economic & financial cost estimation

For the economic and financial evaluation of the optimistic scenario, it was necessary to establish an expert estimate of the costs of the planned measures. At the level of the feasibility study, we used two different approaches, as in the realistic scenario.

The first is to find a suitable analogous implementation or rather more similar implementations. Based on the similarities, we are able to determine the estimated price at which it is possible to implement specific measures in this scenario. This was the case in the case of connecting the decommissioned arms and in the case of a migration-favorable adjustment of the stone chute. For the reconstruction of the stone chute, it was possible to use a large number of implementations of migratory permeable boulder structures, as well as the implementation of boulder slides without emphasis on migration permeability. Experience and knowledge of costs from already implemented connections of decommissioned arms on the river Dyje were used to evaluate the connection of decommissioned arms back to the stream (including the construction of the necessary distribution facility).

In the case of removing or building dams, we proceeded differently. Here, too, of course, we have a wide range of projects that address the removal or construction of dams. However, dams in these projects have very different parameters, whether it is the length or height of the dam. Based on the experience from these projects, we were able to determine the cost per m2 of removed or newly placed dam material. From there, it was easy to work on determining the cost per meter (a section one meter long) of the dam. Such a meter is called a common meter for the needs of the budget, in Czech "common meter" (bm). For some simplification, which was necessary in the scale of the feasibility study, we determined two basic dimensional types of dams, smaller with a cross-sectional area of 9 m2 and larger (or higher) with a cross-sectional area of 28 m2. Only the "summer" dam on the territory of the protected landscape area Zahoří, which is removed without compensation, falls into a smaller category. All other dams fall into the "big" category. It follows that even dams newly built in a remote position are considered as large dams for the needs of the budget.
The fact that the dams were not removed in full was taken into account when valuing the removal of dams without compensation.

The price per common meter was determined on the basis of budget items currently valid for 2021. The basic assumption of the set price is that all material obtained by removing dams will be fully used in building new dams, or any surpluses or unsuitable material will be used at the construction site. From the point of view of economy, this is by far the most advantageous procedure.

Restoration measures	Unit	Number of Units	Price per Unit	Costs/expediture (Eur)
Removal of weirs	weir	0		0,00
Adjustment of selected barriers (migration permeability)	weir	1	800 000,00	800 000,00
removal of the existing levees small one (area of cross section 9 m2)	bm	4 800	144,00	691 200,00
removal of the existing levees big one (area of cross section 28 m2)	bm	37 550	448,00	16 822 400,00
removal of the existing levees without compensation	bm	8 250	224,00	1 848 000,00
Relocation of flood dykes/ building of levees big one (area of cross section 28 m2)	bm	40 090	168,00	6 735 120,00
Relocation of flood dykes/ building of levees small one (area of cross section 9 m2)	bm	16 000	54,00	864 000,00
closure of the riverbed to the level of the river bench	Closure + connected arm	3	1 000 000,00	3 000 000,00
closure of the riverbed to the flow level Q60-day	Closure + connected arm	11	1 400 000,00	15 400 000,00
TOTAL				46 160 720,00
Length of river prolongation	m	24 200		
Area of new active floodplain	ha	2 950,00		

Figure 17: An overview of draft measures and financial costs in scenario B (RS2)

The total cost of implementing the optimistic RS2 scenario amounts to EUR 46,160,720 based on the above procedure. This amount does not include project preparation costs or land purchase costs. In this case, as in the realistic scenario, it can be assumed that the majority of land in the Czech Republic, which will be affected by the transfer of the dam is owned by the Czech Republic (reported on them by Lesy ČR), so it will most likely be a gratuitous transfer. On the Slovak territory, however, the land will already be subject to purchase. Therefore, in this case, we include the amount for the purchase of land in the amount of 10% of the implementation costs (this ratio is based on experience from similar projects and the rules and experience of European and national grant programs aimed at revitalizing the landscape). 3% of implementation costs are considered for project preparation for the needs of the budget. After taking into account these costs, we receive the final total amount of 52,161,614 Euros.

As in the realistic scenario, several methods can be used to determine the effectiveness of this amount. The first is a comparison of this amount with the amount determined according to the methodology of usual measures used by the Operational Program Environment, which is the most important financial instrument for landscape revitalization in the Czech Republic. This program sets the usual amount for the revitalization of a watercourse 40 Euro per m2 of area of the revitalized stream, in the case of revitalization of the stream, including the floodplain, the amount is slightly smaller and is 34 Euro per m2 of area. If we use this lower amount and include the entire area of the newly connected floodplain, we get an amount almost twenty times higher than the expected costs of the measure. Given that the amounts insured vary by an order of magnitude, we will try to determine the cost of the usual measures in yet another way. Thanks to this scenario, it is connected back to the stream, or the stream will be extended by 24.2 km. If we calculate the average width of the connected sections of the river (including accompanying vegetation) of about 70 m, we get an area of 169.4 ha. If we only multiply this area by the usual amount for revitalizing the watercourse, we get costs higher than 67 million Euros. So the usual costs, even if only this partial benefit is taken into account, exceed the expected costs according to the feasibility study.

The second method is, to use the costs of previously implemented similar actions. If we determine the average amount of the costs of the action, which focused on the law and revitalization of the stream and its floodplain, we get the amount of 51,700 Euros per hectare of area addressed. With this method, we get comparable costs greater than 152 million Euros, including the entire revitalized area of the floodplain. Even with this method, the set costs of the measures are therefore three times cheaper.

Total costs represent a significant amount that goes beyond the scope of current projects. However, it is necessary to realize that the benefits of this scenario are also on a completely unprecedented scale, both in terms of the extent of the revitalized floodplain and the length of the riverbed returned to the Morava watercourse. The proposed measure is very effective both against the limit costs set by the subsidy rules and against the costs of comparable measures. When using any of the methods, the costs are also more efficient than when evaluating a realistic scenario.

V.5. Evaluation of the scenarios and selection of the chosen/proposed scenario

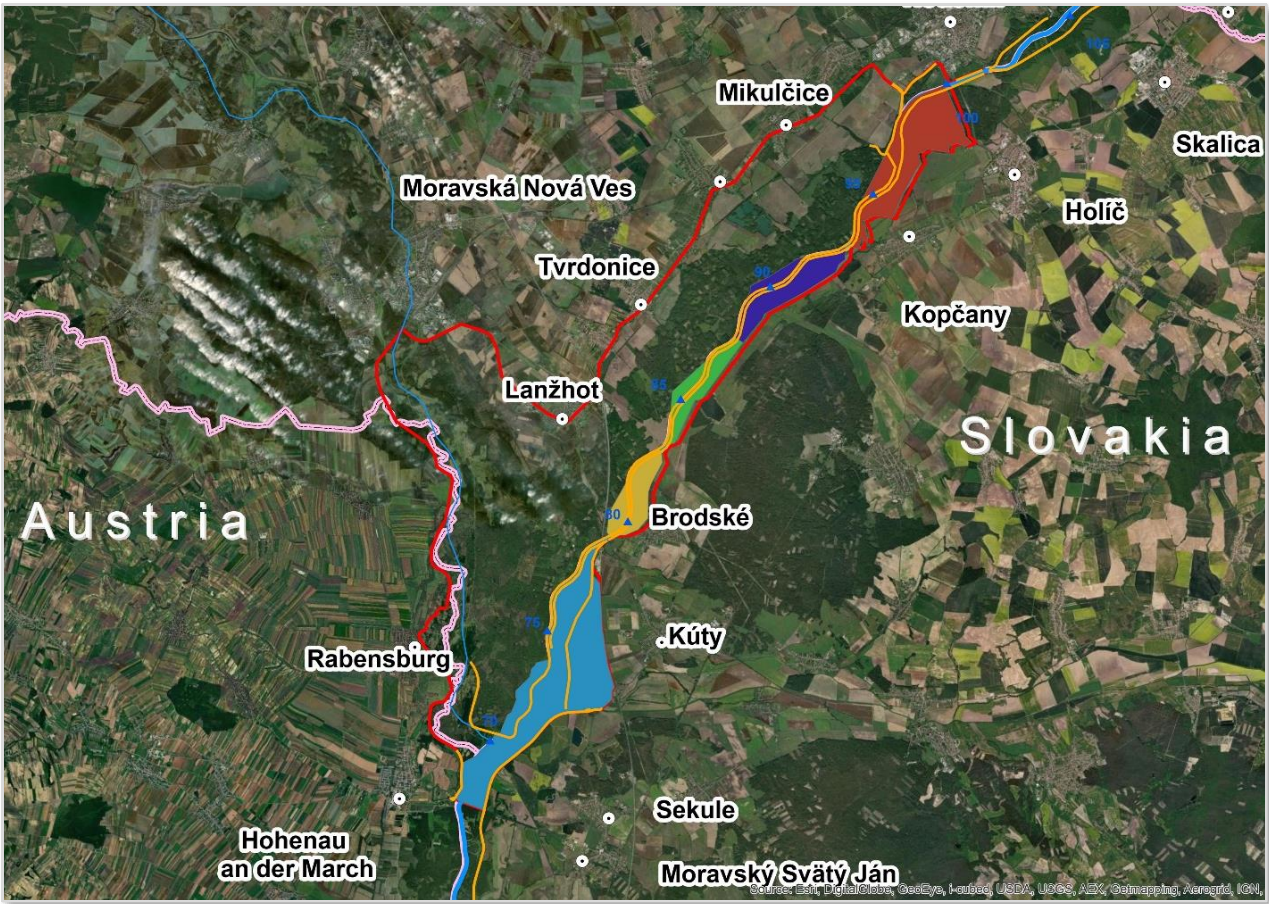


Figure 18: An overview of draft measures

Finally restoration measures in the Morava river differ a lot between R1 and R2. R2 includes several measures concerning the river channel itself and the extent of the floodplains, whereas in R1 only floodplain expansions are implemented. Thus, the effects of ΔQ and Δt are variable. Additionally special tributary conditions have to be considered in the Morava model area. It is important to also investigate the lateral inflows from the tributaries as the discharge conditions of the tributaries and the Morava can differ and shift the results. For example, the restoration measures do not seem effective by the means of the flood wave translation for HQ5 and HQ100, but effective for a HQ10. However, when analyzing the results subjected to the discharge of the Morava main channel and the discharge of the Dyje tributary, it is noted that for the HQ5 and HQ100 the share of discharge of the Dyje is rather high and the effect of the upstream restoration measures is attenuated at the confluence. Thus, the importance to consider local conditions during the evaluation of the effectiveness of restoration measures is once more confirmed.

Overall the largest reduction of the peak discharge (ΔQ) of the investigated flood waves is obtained for the Morava pilot area in an R2 scenario with about 10% (Figure 19). In the other pilot areas a peak reduction of maximum 2% in the R1 and up to 4% in the R2 scenario is simulated. Many scenarios do not show a notable impact on the peak value (e.g. Begečka Jama and Bistret), however this can be explained by the restoration measures. Morava is the only pilot area that investigated a modification of the river course (meandering). Yet, special tributary conditions have to be considered when interpreting results of the Morava pilot area. Some scenarios show even a slight increase of the peak discharge by less than 1% (Morava HQ_5), which can be again explained by the discharges of the tributaries. The HQ_{2-5} event simulation show smaller percentage values in peak reduction than the HQ_{10-30} and HQ_{100} events, explained by the fact that the main river channel is often able to discharge smaller flood magnitudes, without activation of the implemented restoration measures.

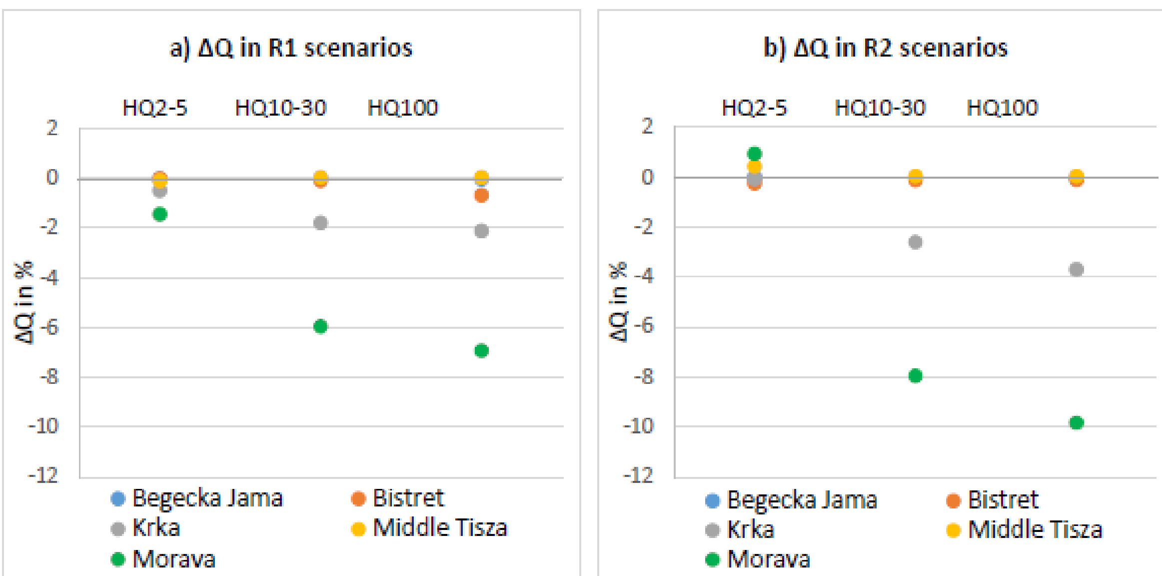


Figure 19: Flood peak reduction (ΔQ) in % compared to the CS in all pilot areas in a) the R1 and b) the R2 scenario

Looking at the ΔQ values of all scenarios in the pilot areas compared with the percentage change in the flooded area, it can be concluded that if measures are implemented in the river channel itself (deepening and widening of the riverbed) a larger increase in the flooded area does not correlate with a reduction in ΔQ, but a decrease of the flooded area correlates with a flood peak reduction. Yet, this is only confirmed if restoration measures on the river channel are implemented. Thus it is crucial to not only consider a single restoration measure but a combination of multiple measures and the joint effectiveness.

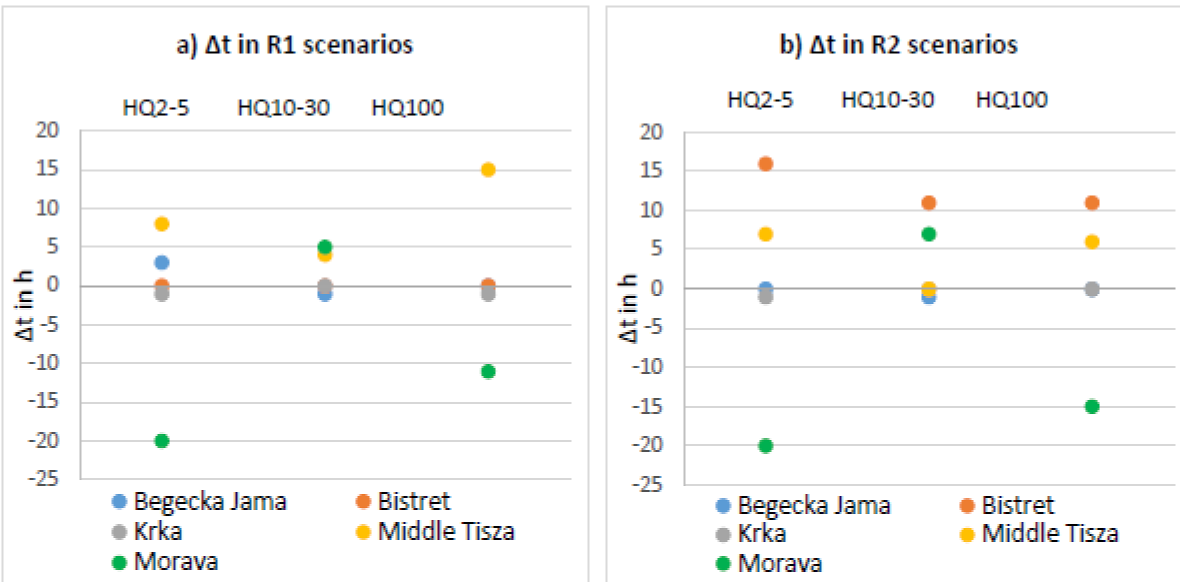


Figure 20: Flood wave translation (Δt) in hours compared to the CS in all pilot areas in a) the R1 and b) the R2 scenario

Regarding the effect of the time to flood peak, the difference in hours (Δt) between the flood peaks is compared with CS. It is visible that both, an earlier or a later approach of the flood peak is generated with the two scenarios (Figure 20). In the Morava pilot area the earlier flood peak is caused by the interaction of the Dyje tributary flood wave which discharges into Morava just upstream of the lower model border. So for a further analysis of the impact of only the restoration measures, a simulation without discharge from Dyje is a possibility to assess the Morava River restoration effects. However, the situation would be unrealistic and rather restoration measures also affecting the Dyje discharge should be determines and assessed in an integrated way.

An increase in the flooded area through restoration measures mostly generates a later approach of the flood peak. The larger the expansion of the floodplain the more considerable the effectiveness of the measure for flood wave translation. However, the effect on the maximum discharge value is not that distinct by the extension of floodplain area but more by a combination of restoration measures, concerning the river channel, the floodplain extent and the character of the floodplain (natural conditions) as in the Morava R2 scenario.

			REDUCTIO	/AVE TRANSL	ATER LEVEL	/ITY OF FP WA	OF PROTECTI	LAND USE	ALLY AFFECTED BI
			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
MORAVA	SK_MR_AFP_01	860,941	-0,42	-6	-1,79	57	187	4,69	0
	SK_MR_PFP_01	1483,79	-0,94	-9	-2,32	100	187	4,24	0
	SK_MR_PFP_02	289,942	> -1	-2	-2,66	81	59	4,25	0
	SK_MR_PFP_03	270,412	> -1	-1	-2,37	84	66	3,71	0
	SK_MR_PFP_04	411,883	> -1	-1	-2,34	83	62	3,82	0
	SK_MR_PFP_05	744,738	-3,52	-17	-1,92	84	62	4,59	0

Figure 23: Results of FEM Floodplain Evaluation of AFP and PFP of the Morava river with the parameters values

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

VI. Detailed evaluation of the chosen scenario

A detailed evaluation took place for both proposed scenarios within the evaluation of solution variants. During the evaluation, all measures considered were assessed:

- 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.

VI. 1 Description of the technical background of the chosen scenario

It is already described in chapter V.4.2.1 - Technical analysis

VI. 2 Institutional, operational analysis:

All measures must be properly negotiated as waterworks. Therefore, their permit will not take place according to the building law, but the water law. In the permitting process, it is necessary to respect several specifics, typical for the addressed area. The first is the existence of a state border, which in most of the affected routes of the Morava River runs through the middle of its flow. All measures are therefore subject to discussion in the Joint Czech-Slovak Boundary Waters Commission. The activities of this commission are governed by the "Agreement between the Government of the Czech Republic and the Government of the Slovak Republic on Cooperation in Border Waters, Communication No. 7/2000 Coll." The Minister of the Environment of the Czech Republic is entrusted with the implementation of contracts and agreements on the Czech side in accordance with the relevant government resolutions. Operational and professional matters and the fulfillment of tasks within the Commission and standing committees are provided by the Department of Water Protection of the Ministry of the Environment (OOV MŽP). This covers the issue of water management on the border stream.

However, the state border also represents an administrative border. This issue is the responsibility of the Ministry of the Interior of the Czech Republic, which manages the state border through the Standing Czech-Slovak Border Commission. State border administration means the performance of state administration in the determination, demarcation and demarcation of state borders, their control, maintenance, geodetic support and maintaining the clarity of their course, as well as in the management of border documentary work. This commission also assesses which intervention may affect the course of the state border.

In the case of a border flow, the permitting authority for constructions permitted under the Water Act is the regional authority, in our case the Regional Authority of the South Moravian Region. This office is also competent for EIA management. In the case of solved constructions, the vast majority fall at least into the category of EIA investigation procedure. The majority of the territory belongs to the Natura 2000 system. Therefore, it is necessary to obtain an opinion on the impact of the proposed measures on this system, or the exclusion of their negative impact. This statement is issued again by the regional authority.

VI. 3 Summary of the environmental effects and achieving the sustainable development goals

The Morava pilot area is located at the confluence of the Thaya and Morava River at the border between Slovakia and Czech Republic. Naturally, the Morava has been an actively meandering river with extensive oxbows and backwaters created by the morphodynamics of this river. This geomorphological origin has created an extremely complex floodplain terrain which is still visible in today's topography. Figure 23 shows a hillshade of a digital elevation model highlighting the complex terrain. This topography still influences the pattern of floodplain habitats today even if a channelization and the construction of dykes have disconnected the river from the floodplain.

In the current state, the total area hydrologically connected (but not flooded) during the HQ2-5 flood event is already more than 4000 ha. It is obvious that the activation of the floodplain is driven only by the old channel structures still abundant in the terrain. The majority of this area is covered by mixed riparian forest, the habitat type we can expect from flood duration and water depth.

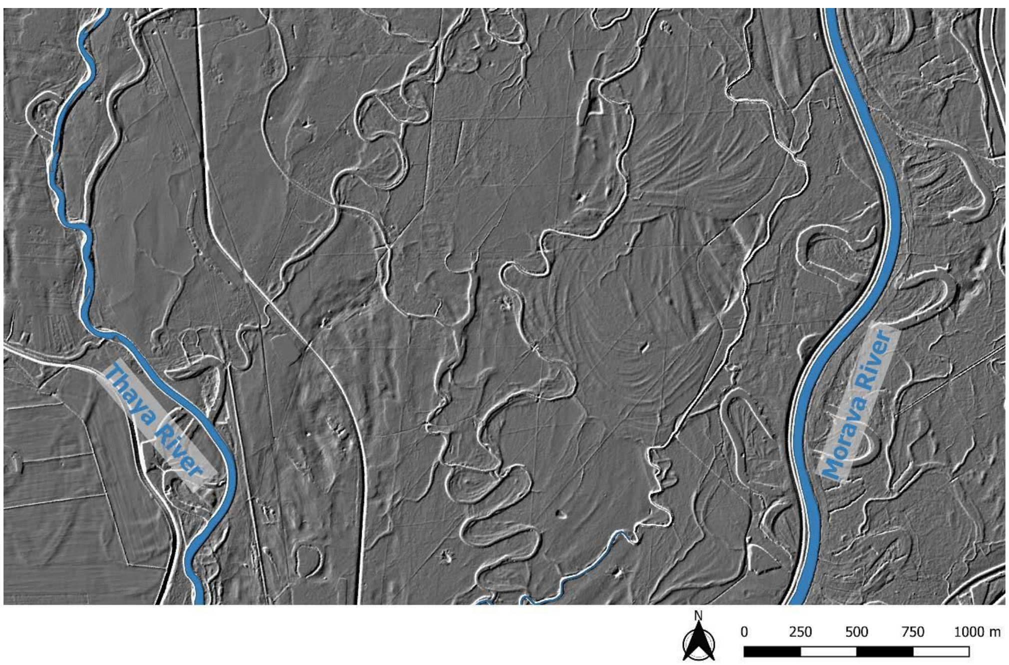


Figure 23: Hillshade of the floodplain topography of the Morava pilot area

Also backwaters exist in the current state. They concentrate in the area at the confluence of the Thaya and Morava River and develop in the depressions of the historic floodplain terrain.

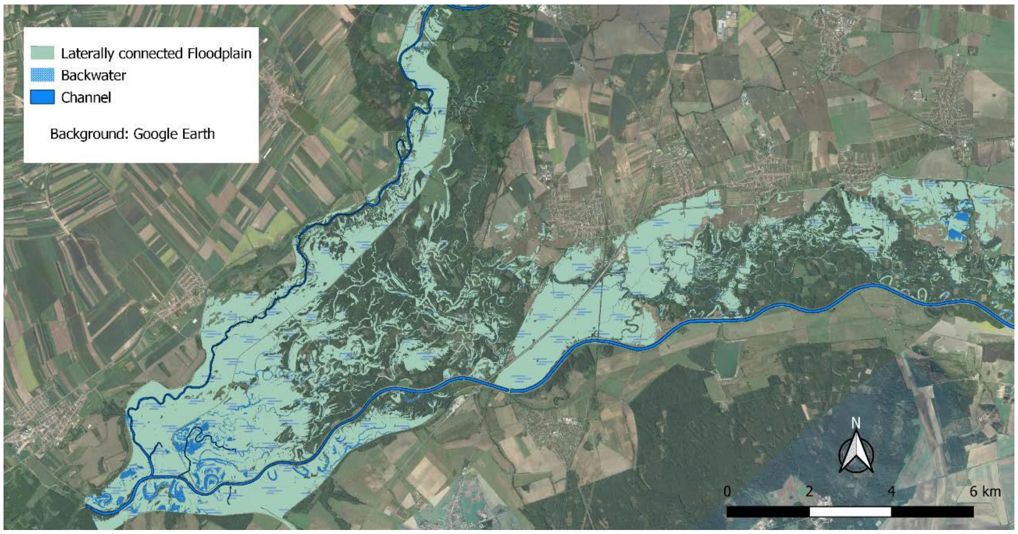


Figure 24: Meso-habitats of the Morava pilot areas in the current state

These backwaters provide habitat for amphibians like Bombina bombina and also stagnophilic fish species like Misgurnus fossilis. The limitations of connectivity reduce the habitat suitability for fish species migrating between main channel and backwater systems.

In the realistic restoration scenario, dyke relocation is intended to re-connect oxbows and parts of the floodplain to channel. Figure 25 shows an example of the effect of dyke relocation on the formation of backwaters.

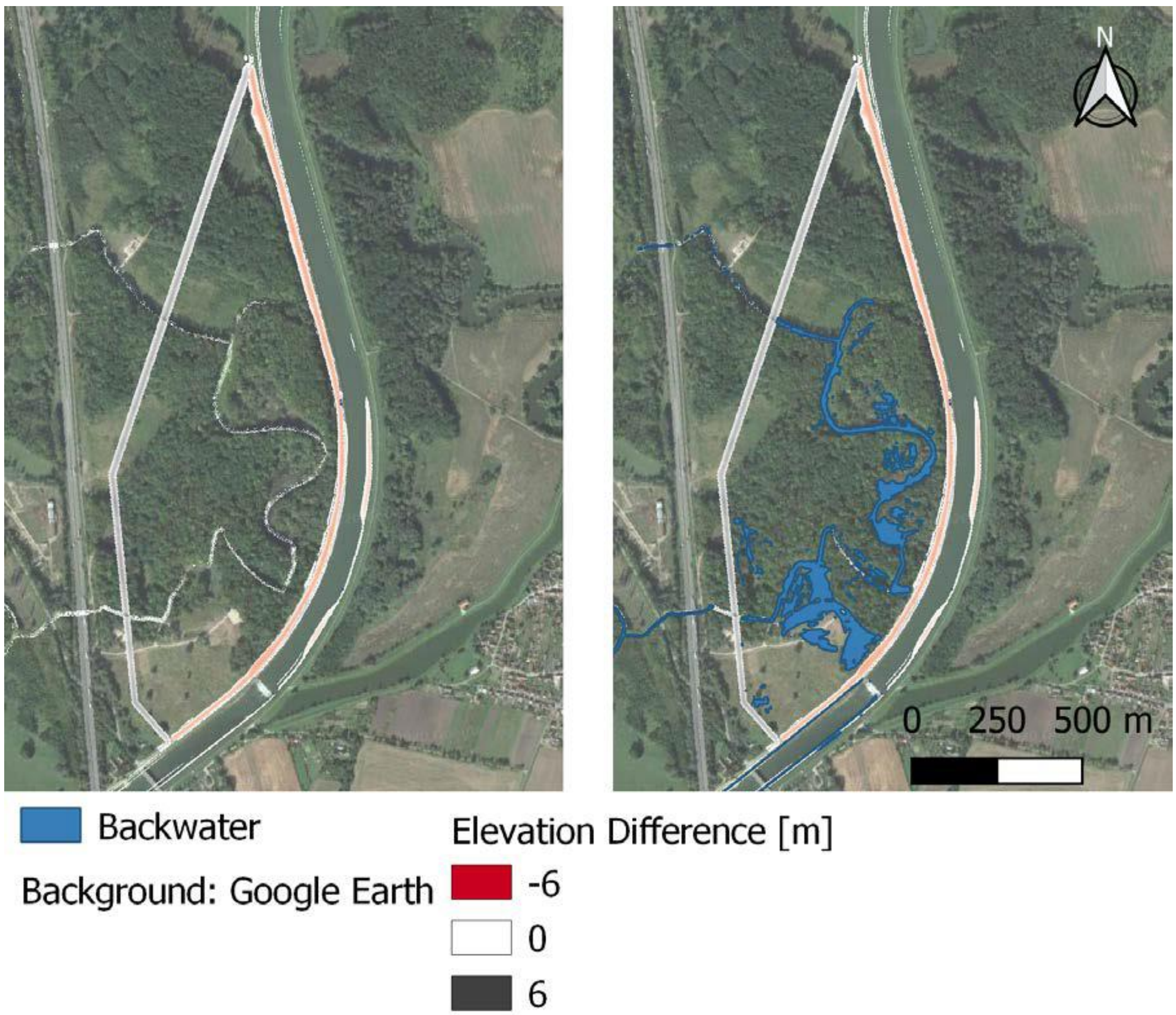


Figure 25: Example of oxbow reconnection by dyke re-location. Left side is the current state, right side the realistic restoration scenario. The elevation difference shows the intended dyke relocation

Such reconnection of oxbows creates valuable habitat for fish species migrating between channel and backwater such as Gymnocephalus spp. Within the realistic scenario, all in all 7 dyke relocations are planned increasing the number of connected oxbows and thus backwater area. While most of dyke relocations seem to have the expected effect of oxbow re-connection, there are also oxbows where the connectivity is not fully restored by dyke relocation alone. Here, further measures like a deepening of the oxbow might be necessary. The effect of dyke relocation on the increase of connected floodplain area and on the development of further backwaters like e.g. ponds is still unclear due to the complex terrain. Here, further calibration and validation work is required to give reliable results.

In the optimistic restoration scenario, changes in the channel planform are intended. This is a particularity compared to all other restoration scenarios where the focus has entirely been on the modification of lateral connectivity by means of dyke relocation or establishment of connection didges. It is intended to re-establish meanders in the channelized river especially in the river section close to the confluence with the Thaya River (Fig. 22). The planned meanders increase the area belonging to the channel habitat from 256 ha in the current state to 283 ha in the optimistic state. In addition, the flow velocity during an HQ2.5 flood event is reduced from above 1 m/s to approximately 0.7-1 m/s. This increases the habitat suitability for lowland river fish species like Gobio albipinnatus which depend on moderate flow conditions.

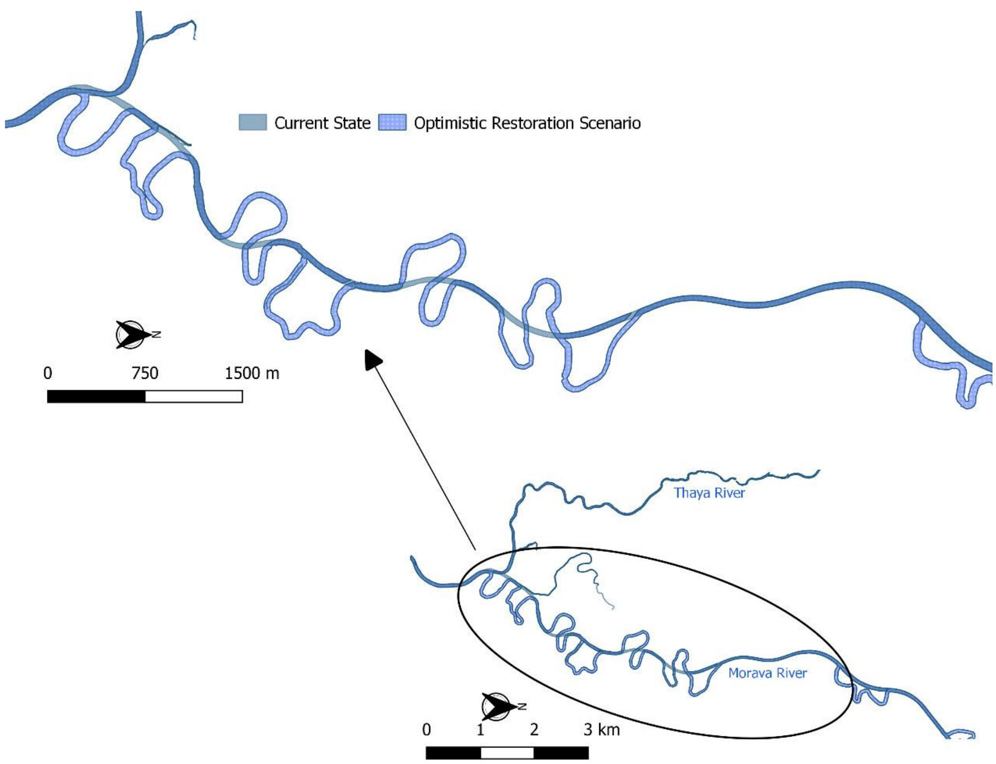


Figure 26: Channel planform modification in the optimistic restoration state by re-introduction of meanders

Due to the changes in flow conditions and the general modification of the river structure also the area of backwater habitats is significantly increased by this restoration measure. These backwaters partly are predicted in the form of connected oxbows but also as stagnant ponds forming in depressions on the floodplain. These pond-like backwaters are highly relevant habitats for amphibians having only a minor benefit from oxbows being re-connected to the channel. In an overall evaluation, the restoration by restoring the original river planform and removing barriers of lateral connectivity allows to re-establish natural dynamics of the river system. These dynamics will form a small-scale mosaic of habitat patches as it becomes already obvious from the meso-scale habitat model. Due to the complexity of the floodplain topography of the Morava area and the complex hydrological reaction of this terrain further, more detailed investigation is recommended for a final evaluation.

VI. 4 Financial sustainability of the project and cost-benefit analysis

The chapter presents the results of including the estimation of ecosystem services in a standard cost-benefit analysis (CBA), resulting in an “extended cost-benefit analysis”. We show the results of six ecosystem services (ESS) types, estimated by applying the Toolkit for Ecosystem Service Site-based Assessment (TESSA) and complementary methodologies (e.g., stakeholder engagement). The ESS estimations were used to include (in monetary values and discounted) the co-benefits of floodplain restoration measures into CBA analyses. Herein, we present the outcomes of four pilot area of the Danube Floodplain Project. The total annual added value of the ESS benefits of the “realistic” floodplain restoration measures, was estimated at approximately 0.7 million USD_{2019}/yr in Morava. For “optimistic” restoration measures, the total annual added value of the ESS benefits was estimated at approximately 3.1 million USD(2019)/yr in Morava. Considering the costs of the measures and the discounting of the ESS added values, the extended CBA results are promising. In Morava at least one restoration measure (realistic or optimistic) lead to a benefits-costs-ratio (BCR) approximately equal or higher than 1, when using an extended CBA. The standard BCR shows instead results smaller than one and closer to zero for both restoration scenarios (between 0 and 0.4).

Results of Global Climate Regulation

The results of carbon storage are presented in Figure 27. For all four pilot areas and all scenarios, the largest carbon stock is represented by soil organic matter and the smallest by either below-ground or litter and dead wood carbon. As a result of forest- or grass-dominated area conversion in alternative to crop-dominated areas, the general response of the floodplain restoration measures is the carbon stocks increase.

In RS1, carbon storage would not change in Morava, In RS2, carbon storage would increase by 1.8%, for the, Morava, and Bistret areas respectively. This would lead to a gain of stock monetary value in the area of 0.4 for Moravamillion USD2020 as a total static value (not annual).

The monetary values are the result of multiplying the stored carbon and the GHGs flux in CO2 equivalents times the values of the CO2 emissions taxation systems documented in the report of the World Bank (World Bank, 2020), i.e. 19 USD2020 per metric tons of carbon dioxide equivalent (tCO2e) (World Bank, 2020).

Carbon stocks	Begecka Jama			Bistret			Krka			Morava		
	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2
AGB [ton C]	7334	7917	10608	529,651	528,197	530,129	151883	155343	155175	491909	491909	530,037
BGB [ton C]	1985	2029	2220	96,056	95,965	96,276	47471	46520	46467	154727	154727	165,638
LB + DWB [ton C]	2806	2866	3132	133,139	133,067	133,450	18708	19782	19762	122896	122896	131,320
SOC [ton C]	37417	37676	39769	1,637,108	1,632,641	1,637,469	337059	344286	343898	1217660	1217660	1,218,105
Total Carbon Stocks [ton C]	49541	50489	55730	2,395,955	2,389,870	2,397,324	555121	565932	565302	1987192	1987192	2,045,100
Total Carbon Stocks [USD2020]	3,451,356	3,517,400	3,882,523	166,918,176	166,494,256	167,013,556	38,673,443	39,426,596	39,382,706	138,441,043	138,441,043	142,475,306
RS1-CS [ton C]		948			-6,085			10,811			0	
RS2-CS [ton C]		6,189			1,369			10,181			57,908	
ES value of the RS1 [USD2020]		**66,044**			**-423,920**			**753,153**			**0**	
ES value of the RS2 [USD2020]		**431,167**			**95,380**			**709,263**			**4,034,264**	

Figure 27: Carbon storage results for the pilot areas, where the total carbon stocks are calculated as the sum of above-ground biomass (ABG), below-ground biomass (BGB), litter biomass (LB), dead wood biomass (DWB), and soil organic carbon (SOC).

Figure 28 shows the net GHGs fluxes in the current and restoration scenarios, where the negative values represent equivalent CO_2 emissions and positive values represent equivalent CO_2 sequestration. The results are dominated by CO_2 emissions due to the carbon stock losses, if the tree-dominated areas would be considered to be harvested or affected by other disturbances. Emissions of N_2O and CH_4 also show some (substantial in Morava) effects on the overall GHGs balance in all pilot areas and scenarios.

In the Morava area, the sequestration of equivalent CO_2 increases by 8.0% for the RS2 due to an increase of carbon stock and a decrease in methane emissions. RS1 in Morava shows no effect in terms of GHGs flux.

GHG flux	Begecka Jama			Bistret			Krka			Morava		
	CS	RS1	RS2	CS	RS1	RS2	CS_v2	RS1	RS2	CS	RS1	RS2_v2
Carbon Stock Increment [ton CO2/yr]	5,104	4,957	4,237	69,942	70,763	70,558	32,259	30,620	30,584	104,985	104,985	113,219
Carbon Stock Losses [ton CO2/yr]	-45,577	-38,694	-38,694	-432,846	-432,846	-432,846	-786,634	-786,636	-786,636	-107,853	-107,853	-107,853
CO2 Em. [ton CO2/yr]	0	0	0	0	0	0	0	0	-221	-6,966	-6,966	-6,731
CH4 Em. [ton CO2/yr]	-9	-9	-9	-1	-1	-1	-437	-424	-423	-1,127,132	1,127,132	-1,027,194
N2O Em. [ton CO2/yr]	-9	-9	-9	-8,551	-8,508	-8,529	1,013	-990	-989	-5,715	5,715	-5,252
GHGs flux [ton CO2/yr]	-40,493	-33,755	-34,477	-371,458	-370,592	-370,820	-755,826	-742,096	-757,683	-1,142,681	-1,142,681	-1,051,802
RS1-CS [ton CO2/yr]		6,738			865			13,730			0	
RS2-CS [ton CO2/yr]		6,016			638			-1,857			90,879	
ESS value of the RS1 [USD2020/yr]		**128,022**			**16,443**			**260,869**			**0**	
ESS value of the RS2 [USD2020/yr]		**114,304**			**12,124**			**-35,284**			**1,726,694**	

Figure 28: Greenhouse gases flux results for the pilot areas (negative net values indicate equivalent CO2 emissions; positive net values indicate equivalent CO2 sequestration).

Water-related services: Flood mitigation

In terms of flood mitigation, the scenarios tested in the pilot areas show inhomogeneous results.

The modeled flood risk benefits of flood storage resulting from floodplain restorations in Morava are instead positive (respectively by 47.19% to 43.67%), though merely affected by the small difference in water level. The floodplain's ESS flood mitigation is shown in terms of the expected annual flood-caused damage, i.e. not in terms of ESS benefits.

Flood risk reduction		Expected annual flood-caused damage [EUR2019/yr]	CS - RS1 [EUR2019/yr]	CS - RS2 [EUR2019/yr]	percentage CS - RS1	percentage CS - RS2
Begecka Jama	CS	1,660,519	-306	-1,099	-0.02%	-0.07%
	RS1	1,660,825				
	RS2	1,661,618				
Bistret	CS	6,664,491	-30,702	-3,010,876	-0.46%	-45.18%
	RS1	6,695,193				
	RS2	9,675,367				
Krka	CS	3,824,913	50,645	82,634	1.32%	2.16%
	RS1	3,774,268				
	RS2	3,742,279				
Morava	CS	1,276,834	602,559	557,580	47.19%	43.67%
	RS1	674,274				
	RS2	719,254				

Figure 29: Results of flood risk estimation for the pilot areas

Water-related services: Nutrients retention

The results on the ESS value of total nitrogen (TN) retention (Figure 30) depend on the amount of filtered volume and the flooded area size.The flooded area is decreasing in Morava with the restoration measure and its corresponding ESS value decreases by 28.2% in RS1 and by 8.0% in RS2.

Nutrients retention	Begecka Jama			Bistret			Krka			Morava		
	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2
Retained and filtered water volume [m³]	14,864,416	14,897,355	15,694,581	168,651,209	180,037,266	369,155,727	5,371,641	5,397,090	5,364,732	15,504,891	12,667,543	15,664,573
Flooded area (tree-, grass-, and wetland-dominated) [ha]	106.15	100.84	106.81	728.05	935.57	4619.21	252.64	276.78	277.41	1,475.67	1,296.58	1,343.49
ESS value [USD2019/yr]	1,974	1,879	2,097	153,594	210,696	2,133,031	1,698	1,869	1,862	28,620	20,545	26,325
RS1-CS [USD2019/yr]		-95			57,102			171			-8,075	
RS2-CS [USD2019/yr]		123			1,979,437			164			-2,295	

Figure 30: Results of nutrients retention ESS value for the four pilot areas. The retained and filtered water volume was extracted according to the description presented in Deliverable D 4.3.2.

Cultivated goods

The results of cultivated goods' provisioning ESS value for crops, livestock, and aquaculture are reported in Figure 31. In Morava, the RS1 does not bring any change in the cultivated goods ESS value. For RS2 instead, the tree-dominated areas would increase and would cause a lower presence of livestock with its consequent lower revenue (2.9%) for the pilot area's cultivated goods ESS value.

Cultivated good	Begecka Jama			Bistret			Krka			Morava		
	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]	CS [USD2017/y]	RS1 [USD2017/y]	RS2 [USD2017/y]
Crops	0	0	0	2,044,251	2,036,531	2,036,770	203,577	203,571	201,686	373,192	373,192	356,923
Livestock	16,305	15,838	13,637	10,275,688	10,259,072	10,275,688	1,617,430	1,615,233	1,613,937	15,283,932	15,283,932	14,827,595
Aquaculture	0	0	0	1,433,214	1,970,669	2,149,821	3,398	3,008	3,398	110,248	110,248	124,546
SUM	16,305	15,838	13,637	13,753,153	14,266,272	14,462,279	1,824,405	1,821,812	1,819,021	15,767,372	15,767,372	15,309,064
RS1-CS		-467			513,119			-2,593			0	
RS2-CS		-2,668			709,126			-5,384			-458,309	

Figure 31: Results of cultivated goods provisioning ESS value for the four pilot areas (for the unit prices used, please refer to Deliverable D 4.3.2)

Nature-based recreation

The sample size of quantitative studies was calculated as suggested by TESSA (Peh et al., 2017). The precision level is approximately 55% for Morava (taking the mean and standard deviation of the results of the first ten surveys). This corresponds to sample sizes of 50 for Morava. Based on the interviews for the census of visitors to the area, we used as number of visitors per year to each pilot area of 100,000 for Morava (median of three values). According to NARW, the increase in visits would be much higher than what was assumed from the results of the survey. Figure 32 shows the corresponding results. All four pilot areas show an increase of the recreational ESS value in case the NBS would take place for both restoration scenarios, besides for RS1 I Morava. The ESS value increases because the visit numbers would increase. In RS2, the benefits from recreation would increase by 20% for Morava.

	Begecka Jama			Bistret			Krka			Morava		
Consumers surplus [EUR2019/visit]	122.70			77.18			128.09			55.27		
	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2	CS	RS1	RS2
Nature based recreation [EUR2019/yr]	1,227,040	2,178,571	2,478,123	7,718	28,605	29,573	3,202,233	3,863,188	3,367,349	5,527,168	5,527,168	6,630,320
Area [ha]	393.86			38,304.01			4,114.80			17,067.63		
Nature based recreation per unit [EUR2019/ha·yr]	3115.42	5531.33	6291.89	0.20	0.75	0.77	778.22	938.85	818.35	323.84	323.84	388.47
RS1-CS [EUR2019/yr]	951,530			20,886			660,954			0		
RS2-CS [EUR2019/yr]	1,251,083			21,855			165,115			1,103,152		

Figure 32: Results of nature-based recreation ESS value for the four pilot areas

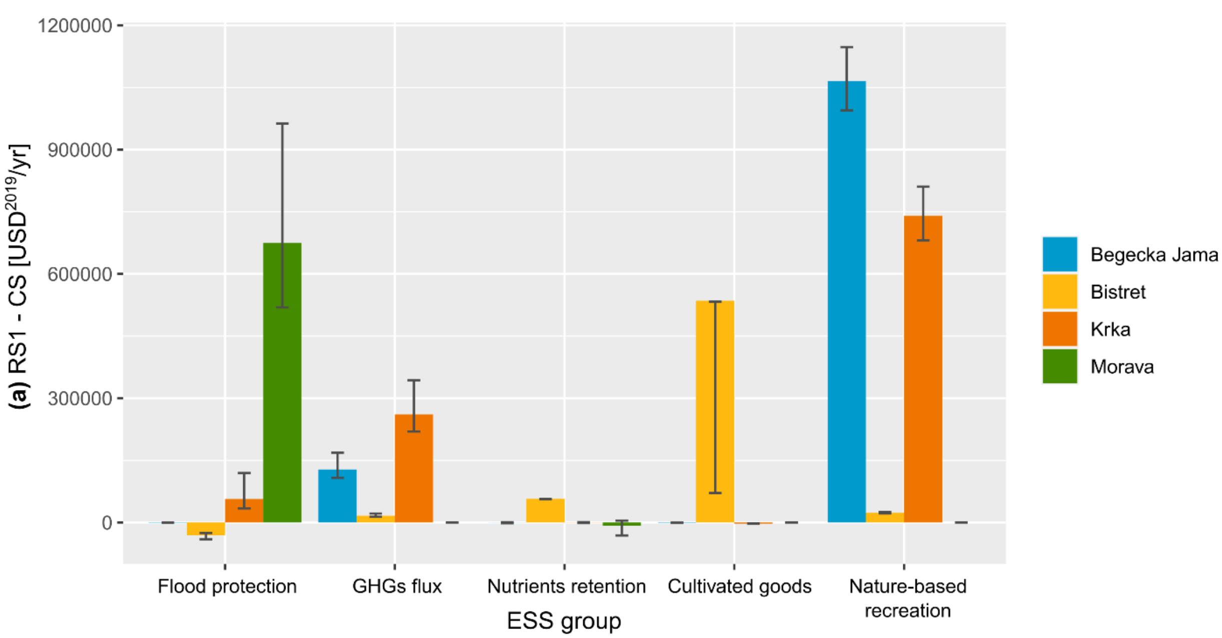
As seen in Figure 33, the total absolute value of the ESS benefits of the realistic floodplain restoration measures, i.e. RS1, without considering the gains in carbon stocks, was estimated at approximately 0.7 million USD2019/yr in Morava. For RS2, the total absolute value of the ESS benefits was estimated at approximately 3.1 million USD(2019)/yr in Morava.

However, the total added value of the NBS in terms of ESS is not homogeneously distributed among the ESS types. Figure 32 and Figure 33 display the annually added ESS values of the floodplain restoration for all pilot areas according to ESS type, where we can observe how ESS types contribute in terms of annual monetary values in the pilot areas. While the most affecting ESS types are not constant among pilot areas, nutrients retention is constantly the least contributing ESS to the sum of benefits for Morava.

Figure 30 to Figure 33 show for the pilot areas the resulting maps of added ESS value, as a direct impact of the hypothetical restoration measures, where carbon storage values were excluded here as well. From all eight maps, we observe that the regions with the highest increase in ESS value per unit area are the ones directly affected by the floodplain restoration.

	Begecka Jama		Bistret		Krka		Morava	
	RS1 - CS	RS2 - CS	RS1 - CS	RS2 - CS	RS1 - CS	RS2 - CS	RS1 - CS	RS2 - CS
Carbon storage [USD2020]	66,044 [55,616; 86,900]	431,167 [363,088; 567,325]	-423,920 [-557,789;-356,985]	95,380 [80,320;125,500]	753,153 [634,234;990,991]	709,263 [597,274; 933,241]	0 [0;0]	4,034,264 [3,397,275; 5,308,241]
GHGs flux [USD2020/yr]	128,022 [107808;168450]	114,304 [96256;150400]	16,443 [13,846;21,635]	12,124 [10,210;15,953]	260,869 [219679;343249]	-35,284 [-46426;-29713]	0 [0;0]	1,726,694 [1454058; 2271965]
Flood mitigation [USD2019/yr]	-343 [-542;-253]	-1231 [-2205;-857]	-30,702 [-40,533; -25,292]	-3,010,876 [-5,935,315; -2,026,662]	56,714 [34126;119259]	92,535 [59409;181015]	674,759 [519266;962987]	624,390 [480462;891081]
Nutrients retention [USD2019/yr]	-95 [-1787;592]	123 [44;320]	57,103 [55,654;57,103]	1,979,437 [1,960,579;1,979,437]	171 [-1096;712]	164 [61;412]	-8075 [-31290;4474]	-2295 [-4931;-902]
Cultivated goods [USD2019/yr]	-487 [-786;-368]	-2783 [-4494;-2104]	535,180 [71,284;533,195]	739,613 [120,322;738,961]	-2705 [-2978;-2466]	-5615 [-5845;-4823]	0 [0;0]	-478,013 [-496348;-465927]
Nature-Based Recreation [USD2020/yr]	1,065,543 [994551;1147450]	1,400,989 [1307647;1508680]	23,389 [21,657;25,423]	24,473 [22,661;26,601]	740,150 [680974;810590]	184,899 [170116;202496]	0 [0;0]	1,235,333 [1180181;1295892]
SUM [USD2019-20/yr]	1,192,641 [1,099,244; 1,315,871]	1,511,402 [1,397,248; 1,656,439]	601,412 [121,908;612,063]	-255,228 [-3,821,543;734,291]	1,055,199 [930,706; 1,271,344]	236,699 [177,315; 349,387]	666,683 [487,976; 967,462]	3,106,108 [2,613,422; 3,992,110]

Figure 33: Summary of the ESS values results shown in the previous tables and their sum, i.e. added ESS value of the floodplain restoration scenarios RS1 (a) and RS2 (b) in comparison to the current state (CS) homogenized to USD2019/yr in all four pilot areas



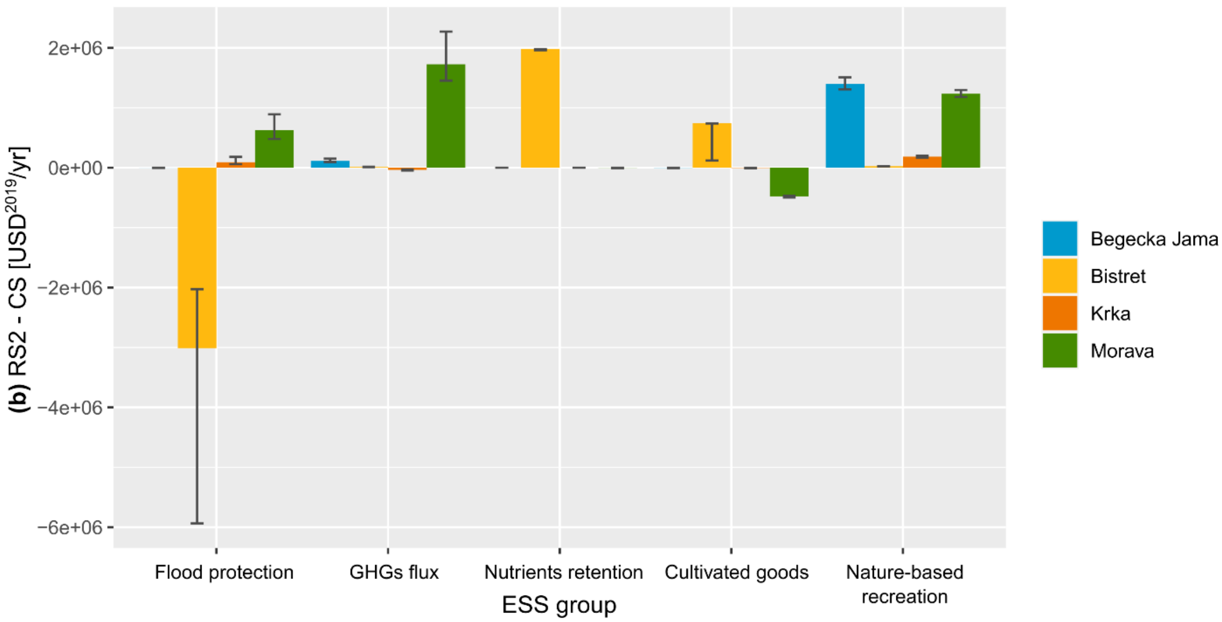
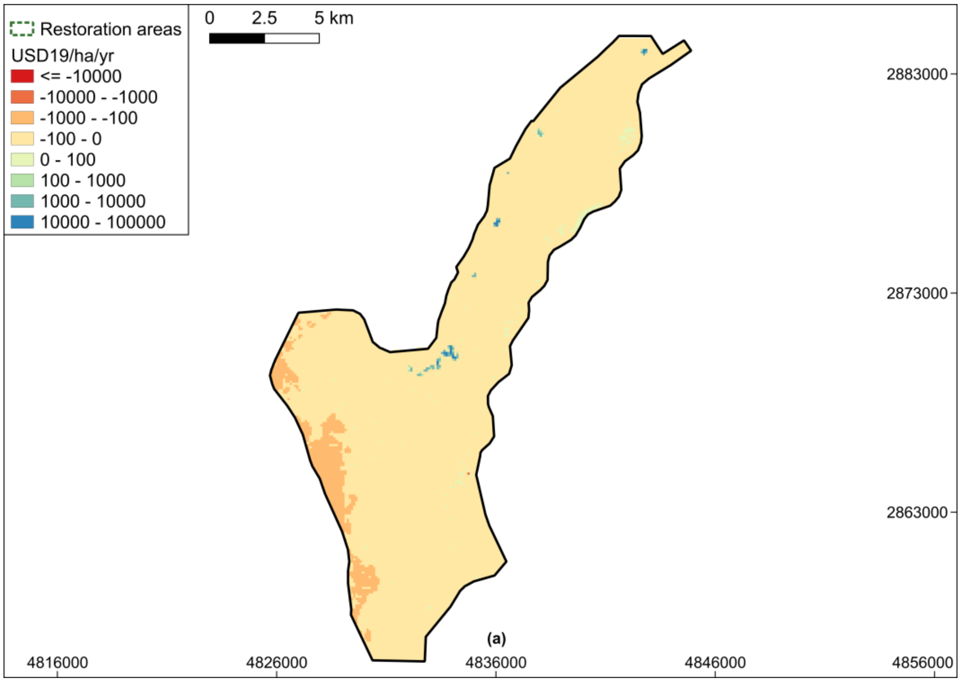


Figure 34: Added ESS value of the floodplain restoration scenarios RS1 (a) and RS2 (b) in comparison to the current state (CS) homogenized to USD2019/yr in all four pilot areas


Restoration areas
USD19/ha/yr
<= -10000
-10000 - -1000
-1000 - -100
-100 - 0
0 - 100
100 - 1000
1000 - 10000
10000 - 100000
0
2.5
5 km
2883000
2873000
2863000
4816000
4826000
4836000
4846000
4856000
(a)

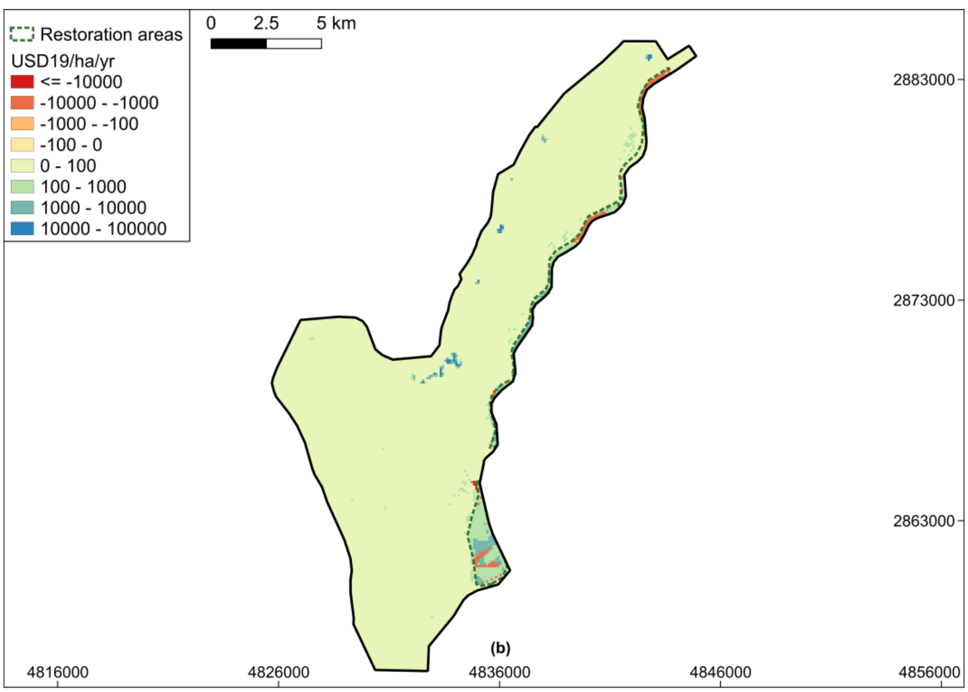

Restoration areas
USD19/ha/yr
<= -10000
-10000 - -1000
-1000 - -100
-100 - 0
0 - 100
100 - 1000
1000 - 10000
10000 - 100000
0
2.5
5 km
2883000
2873000
2863000
4816000
4826000
4836000
4846000
4856000
(b)

Figure 35: Map of the sum of ESS added value (excluding carbon storage) of the floodplain restoration measure by unit area (homogenized to USD2019/ha/yr) in Morava for RS1 (a) and RS2 (b) restoration scenarios. Adapted from Perosa et al. (2021b).

To finalize the cost-benefits analysis (CBA), the benefits and the costs were compared with each other for all pilot areas. Before comparing them, benefits and costs were discounted, assuming the discounting parameters. r = 0.04 N = 50

The costs of the restoration measures were provided by the pilot areas responsible partners are discounted and shown in Figure 36.

	Costs [USD2019] (discounted)		
	CS	RS1	RS2
Begecka Jama	0	1,468,645	33,843,628
Bistret	2,965,530	33,109,297	40,919,918
Krka	1,650,730	4,439,600	6,225,913
Morava	1,482,765	57,134,067	67,492,409

Figure 36: Costs of the restoration measures as communicated by the pilot area responsible partners and then discounted

In Morava, the RS1 estimations show a similar result (around -41 million USD2019), whether the benefits-costs difference was estimated with standard or the extended CBA. The RS2 instead shows higher benefits than costs (by 716,000 USD2019) when applying the extended CBA methodology.

In Morava, the only BCR higher than the threshold (1) corresponds to the scenario RS2 calculated with the extended CBA method. All other configurations show a BCR between 0.2 and 0.3.

In Morava, when considering the extended CBA, the preferable scenario tends to be RS2, according to its BCR (>1), its maximum annual added value (3.1 million USD_{2019}/yr). If we only considered the benefits derived from avoided risk, RS1 is the preferable restoration measure, although it would not be profitable (BCR<1 and BC-difference < 0).

VI.5 Risk evaluation of the chosen scenario and risk management strategy

The preferred optimistic scenario provides a comprehensive sustainable solution for the area being addressed. It will significantly improve its ability to adapt to climate change. At the same time, however, it is a drastic intervention that fundamentally changes current approaches and established practices and customs. If we look at the estimated design costs of about 1.5 million euros, it is clear that the feasibility study could only make a very indicative solution and define all the obstacles to the solution, or all issues that will need to be addressed during detailed project preparation. However, we can divide the probable risks of the project into several groups.

Ownership structure

The objects on the stream and the actual watercourse are owned by the stream administrator, ie Povodí Moravy, s.p., or the Slovak Water Management Company (SVP). The administrators of the stream also owned some land under the decommissioned branches, which remained in the floodplain behind the dikes, even in the grounded parts of these branches. But this is not the rule. From the point of view of ownership, the most problematic is the transfer of the dikes to the relocated position, in which case the construction will always be carried out on foreign land. In the Czech Republic, the situation is significantly simpler, in addition to the flow manager, the vast part of the land is owned (the right to manage) the company Lesy ČR, with which it is possible to transfer the land in a free manner. The majority of the area is also located in the cadastral area of Lanžhot, where complex land readjustments are currently underway. As part of these adjustments, it is necessary, at least within the scope of the former river branches, to transfer the complete holding of the land to the stream manager. The flow manager develops all necessary activities in this direction. A significantly larger number of owners is affected in the Slovak territory, but a detailed solution of these relations can only be done in the next stages of the project documentation. Due to the nature of the event, it is also possible to proceed here by announcing the measures as public benefit. This requires their inclusion in the spatial planning documentation. Therefore, it is possible to proceed with expropriation in these plots.

Habitat damage and collisions with nature protection areas

Impact of the habitat or collision with nature protection areas is possible especially when building dams in a remote position. This may also occur in part in the case of the connection of decommissioned branches, where valuable habitats may have formed over time. Due to the age of the shoulders and the experience of similar localities on the river Dyje, this collision is not very likely. Likewise, the impact of these conflicts is not to be expected when the dams are moved on Slovak territory. The situation is therefore the most complicated in the Czech territory, where the new dams are led directly in the existing floodplain forest, where it is necessary to carry out with maximum sensitivity to the growing trees and also a possible network of forest canals and branches. Fortunately, the small protected area is not located in the area affected by the movement of dams, subject to the Skařiny nature reserve at arm D22 on cadastral area Mikulčice. Even in this case, it is probably possible to find a route that does not touch this area.

Protected landscape area and national park

Large protected areas are currently located only in Slovakia. This is the Zahorie Protected Landscape Area. However, the intention is not in conflict with the interests and concept of this protected area; on the contrary, the measures are aimed at improving the water regime of this area and in some cases directly reflect the requirements of the PLA administration. The issue of large-scale protection of this area is currently reopening in the Czech territory in the form of a protected landscape area or national park. If we start from the conceptual documents that were previously processed in this direction, the selected optimistic scenario is fully in line with the purpose and focus of this large protected area. The requirements and intentions of the selected scenario will also be applied in the process of declaring this new protected area, which will ensure the compliance of these activities and the reflection of the target state in emerging documents, such as the management plan for the future protected area.

Water way

The route of the planned Danube-Odra-Elbe waterway passes through the solved locality. However, according to the current government statement, this idea is perhaps definitely abandoned. For this reason, we no longer anticipate a conflict with this intention.

Soil balance

The economic balance sheet of the project is based on a balanced balance of mined and stored materials. In particular, it is not possible to allow a significant surplus of material that would have to be disposed of outside the project. Such a fact would lead to a multiple increase in costs, so it is necessary to insist on this principle in the next stages of preparation.

VI.6 Implementation of the project and timeline

The chosen optimistic scenario is unique in its approach and scope. However, the complexity of project preparation also corresponds to this. Obviously, it is not realistic or instructive to carry out the whole scenario as a whole, but it will be more advantageous to divide it into several stages. One of the possibilities is the partial realization of a realistic scenario as a stage of the solution. However, this option does not seem advantageous after evaluation. The realistic scenario would run into similar problems as the optimistic one, and its solution is significantly more focused on the Czech territory, so it would actually completely ignore the issue of cross-border cooperation. Advantageous are in some cases not even possible to solve them separately some of the types of measures. Exceptions are the migratory access to the Lanžhot boulder slide and the removal of the summer dam. These two objects represent a separate solution and can be implemented separately. These objects form the first stage of the solution. In addition to this implementation, a search study that selects suitable sites for the second stage should be included in the first stage. The subject of the second stage should be a pilot solution for moving the dikes and connecting the decommissioned arms back to the watercourse. Work procedures and experience from a similar solution on the river Dyje will be used for this solution.

On the river Dyje, only the connection of the branches was carried out, so on the river Moravia the problem of moving the dikes is increasing and also the conditions on the river Moravia are partially different from the conditions of the river Dyje. A pilot solution is therefore necessary to verify and optimize the entire workflow before massively deploying these procedures. For the pilot solution, it is appropriate to optimally select the location where the removal and connection of the arms takes place on the Czech and Slovak banks, or, conversely, the location where the need for removal is low (in the lower section and area of the Zahorie Protected Landscape Area). However, this question should be answered only by the above-mentioned search study. In the third stage, the remaining parts of the scenario should be completed based on the experience of the pilot solution.

VI.7 Communication and publicity

For publicity and promotion of the event, it is possible to use similar realizations on the river Dyje, where it is possible to show the "target" state directly in the field. Due to the scope of the project, it will probably be necessary to hire a professional company to set a promotional strategy, create promotional materials (spots, videos, publications, etc.) and run promotional campaigns.

VI.8 Monitoring requirements

Monitoring can be divided into biotic and abiotic components. For biotic monitoring, the monitoring of fish stock is essential, as it is at the top of the food chain and therefore an excellent reflection of the state of the river ecosystem. In this monitoring it is necessary to monitor not only adults but also juveniles, in particular yearling fry, which represent the natural reproductive capacity of the species. In addition, it is a good idea to select another group of organisms that represent transitional habitats between aquatic and terrestrial environments. For example, dragonflies have proved to be successful in this respect in the past. It is of course possible to monitor the occurrence of species protected by law, but this area cannot be systematically covered in its entirety.

Abiotic monitoring mainly monitors the morphological development of the watercourse, i.e. how the river reacts to our measures and how successful the initiation of natural morphological processes has been. In order to monitor these phenomena, it is necessary to create a set of transverse profiles in which periodic focusing of their typology and evaluation of the present morphological elements will be carried out. These profiles should be designed not only on the reconnected sections of the decommissioned arms, but also on the original river bed in the sections intended for spontaneous development, but also outside them, since a certain degree of morphological development can be expected throughout the river section. For these profiles it is necessary to determine the status before the start of the revitalisation works, after their completion and then subsequently at fixed time intervals (1/2 or 1 year) and then operationally in the event of the passage of significant hydrological events.

VII. Appendixes

- Deliverable 4.1.1. Report on the technical realization scenarios taken into consideration for modelling, the implementation in a 2D model and assessment of the impact (Danube Floodplain, 2020a)
- Deliverable 4.2.1. Report about the stakeholder analysis, their interests and their benefits from the floodplains in the pilot areas resulting from the workshops (Danube Floodplain, 2019)
- Deliverable 4.2.2. Report, database and maps of ESS analysis of the pilot areas including a list, description, assessment, and ranking concerning the demands and supplies (Danube Floodplain, 2020b)
- Deliverable D 4.2.3. Report on the assessment of biodiversity in the pilot areas including a database and maps of pilot areas' biodiversity and habitat modeling as input for 4.4.1 and part of output 4.1 (Danube Floodplain, 2020c)
- Deliverable 4.3.1. Report on assessment results of the CBA applied to the pre-selected pilot areas including ESS, stakeholders and biodiversity as input for D 4.4.1 and therefore part of the feasibility studies in output 4.1 (Danube Floodplain, 2021a)
- Deliverable 4.3.2. Method documentation describing the implementation of ESS and biodiversity to traditional CBA as input for D 4.3.4 and therefore of output 5.1 (Danube Floodplain, 2021b)

Literature

The list refers to the literature stated in the Preamble (WWF HU).

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