Activity 3.3

Floodplain assessment on selected tributaries

Yantra River

Bulgaria

D 3.3.2 - List of floodplains, their characteristics, restoration/preservation potential and associated measures

D 3.3.3. - Recommendations for floodplain assessment on tributaries including the description of implemented methods and classification criteria.

Report

Part 1 – Methodology

April, 2020

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LIST OF ABBREVIATIONS

APSFR	**A**reas of **P**otentially **S**ignificant **F**lood **R**isk
BDA	**Bi**o**d**iversity **A**ct of the Republic of Bulgaria
DEM	**D**igital **E**levation **M**odel
DOM	**D**igital **O**rthophoto **M**ap
EEA	**E**xecutive **E**nvironmental **A**gency of the Republic of Bulgaria
FEM	**F**loodplain **E**valuation **M**atrix
IACS	**I**ntegrated **A**dministration and **C**ontrol **S**ystem
GIS	**G**eographic **I**nformation **S**ystem
MAFF	**M**inistry of **A**griculture, **F**ood and **F**orestry
LPIS	**L**and **P**arcel **I**dentification **S**ystem
PAA	**P**rotected **A**reas **A**ct of the Republic of Bulgaria

INTRODUCTION

The Danube Floodplain project is aimed to improving transnational water management, providing an approach for coordination of measures to reduce flood risk without conflicting WFD. The floodplains are important tool for flood risk reduction while maximizing benefits for biodiversity conservation and thus contributing to the achievement of the goals of both Floods Directive and WFD.

The identification of existing and potentially restorable floodplains and the assessment of their efficiency is a precondition for their restoration and preservation, so under the project, an approach for floodplains delineation and assessment was agreed and applied. The analytical approach is based on the Floodplain Evaluation Matrix (FEM), which defines the main evaluation criteria, organised in four main groups - hydrological, hydraulic, environmental and socio-economic.

Besides the floodplains on the Danube, the project activities include also assessment of floodplains on selected Danube tributaries. The assessemnt of the floodplains on the tributaries is using the concept and FEM, applied for the Danube River, considering the specifics of the selected river and national conditions.

The activities on delineatieon and assessment of the floodplains on the BG Danube tribytary – Yantra river were contacted as external service and were performed by the team of Bulgarian company "Geopolymorphic Ltd".

This document presents the methodology applied for the identification and evaluation of the floodplains along the main river course of Yantra River. The results of the implementation of the methodology are presented in a separate document (Part 2 of the Report)

The methodology is based on the methodology and FEM concept, agreed under the project, further developed according to the river characteristics and national conditions and data. Given the fact that the Bulgarian knowledge and experience on floodplain management is very limited, this document is intendend to serve as a basis for the development of a national methodology for floodplains' assessment. The floodplains on the Yantra River are highly diverse in terms of landforms and degree of anthropogenization. The purpose of examining all floodplains is to study a larger set of conditions for their formation in Bulgaria. It should be noted that due to the diverse terrain conditions (relief) in the country, to create methodologies that reflect all local conditions, the study should include other specific catchments.

Methodology for Identification of Floodplains

The methodology for identification of floodplains is designed to identify two main types of floodplains - active and potential. The active floodplains are those which have a hydraulic connectivity to the main river bed and the extent of the flooding depends on the water quantity and the relief forms. Potential floodplains include hydrotechnical structures that limit flooding. In the past, before the construction of these facilities, they functioned as active floodplains.

The identification of the floodplains is based on the use of three criteria:

- Coefficient of the ratio between the width of the floodplain and the width of the water mirror of the river;
- Minimum size of the floodplains;
- Hydraulic connectivity of the identificated floodplains - only used to determine the active floodplains.

Coefficient of the ratio between the width of the floodplain and the width of the water mirror of the river

The purpose of this criterion is to determine the start and end points of floodplains. A floodplain begins and ends when its width is equal to or greater than the width of the river, ie. the ratio is greater than or equal to one. In the case of islands, the largest river channel shall be measured and the widths of islands and river sidearms shall not be taken into account.

An active floodplain can extend on both sides of the river. Its width is measured separately for the area to the left and right of the main course. The total width is not calculated. In order to fulfill the criterion for the ratio of floodplain / river width, it is sufficient that the width on one side of the main stream alone is greater than or equal to the width of the river

In the case of dykes, the active floodplain is limited to the distance from the shoreline to the heel of the dyke by the river.

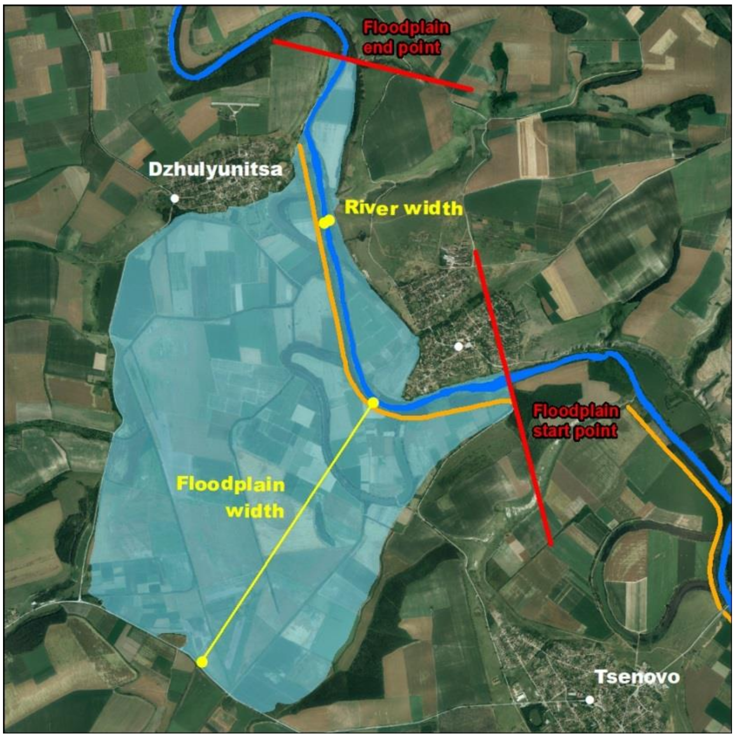


Figure 1: Potential floodplain along the Yantra River between the villages of Tsenovo and Dzhulunitsa

Minimum size of the active floodplains

The purpose of this criterion is to prevent the identification of too many small floodplains. However, using the same size of floodplain for territories with radically different landscapes is pointless. The size must be adapted to the local conditions, including according to the character of the relief (mountainous, hilly, flat).

Hydraulic connectivity of the identificated floodplains - only used to determine the active floodplains

The purpose of this criterion is to trace and not disturb the natural path of the water when identifying floodplains. Areas that do not have hydraulic connectivity (direct flow) to the main river should not be included in the floodplain.

In determining the active floodplains, all three criteria must be met simultaneously, and in the case of potential floodplains - only the first two.

Methodological approach in identification of floodplains

The identification of floodplains (active and potential) is done in the same way, and existing differences will be identified. The work is done in 3 stages:

1. Preliminary evaluation of floodplains;
2. Refinement of floodplain boundaries;
3. Classification of floodplains by their size.

Preliminary assessment of floodplains

The preliminary evaluation of floodplains should be carried out on the basis of available and readily accesible data at the time of implementation of the analyses. These data should include medium to high precision DEMs, GIS layers for available hydrotechnical structures (including dikes), hydrographic data (rivers and standing water bodies) and cadastral data. Hydrological and hydraulic calculations can be performed by approximate methods using available archival data.

The preliminary evaluation of floodplains shall be carried out in the following order:

1. Defining the study area

The purpose of this step is to quickly and accurately identify the area with direct runoff to the study river. This can be done through the DEM-based catchment generation approach. The catchment area should include all subcatchments that have a direct flow to the study river or are estuary of another river that flows into it.

2. Data collection

The purpose of this step is to collect data that will allow the identification of the floodplains of the entire study stream. The scope of this data should be consistent with the study area defined in step 1. The data must include:

- DEM with medium or high accuracy;
- Floodplains corresponding to a probability of 1% for the active ones and 0.1% for potential ones if flood hazard maps were prepared for the studied river flow under the Flood Directive or other hydraulic modeling was performed with the same probbility;
- GIS layers with hyrotechnical facilities (dikes and others). The data should be on a scale of 1:25 000 or larger and it is recommended that it be no smaller than 1: 5 000;
- Large-scale topographic maps at 1: 5,000 scale;
- GIS layers with hydrographic data - rivers, standing water bodies, canals;
- Climate and water quantities data;
- Cadastral data;
- Aerial photos or satellite images with high and very high spatial resolution. They will provide information about the current extent of the water mirror of the study stream, as well as the

presence of islands, bridges, etc.;

- Geological maps, but only for places with presence of alluvial formations and Holocene floodplain terraces. The use of this resource is recommended;
- Soil maps, but only for territory with Fluvisols, Colluvisols and Gleysols. The scale of the maps should be 1:25 000 or larger. Using this resource is recommended.
- Archive satellite images that represent extreme past floods or river currents 30 or more years ago, especially valuable are those taken before river corrections were made in the middle and second half of last century.

3. Identification of geomorphological floodplain

The purpose of this step is to identificate the geomorphologic floodplain of the study river course. The identification can be done in two ways, depending on whether or not the river section is part of an Area of potentially significant flood risk (APSFR), delineated accordinfg to the Floods directive.

In case an APSFR is designated and flood maps exist:

In this case it is acceptable to omit the identification of the geomorphologic floodplain. The available information in the existing flood hazard maps should be used directly. For the delineation of the active floodplains, the areas flooded with a probability of 1% should be used. and for potential floodplains - those with 0.1%. When using this information, the following should be considered:

- To review the data on the water quantities used in the calculation of the water level at the given probability - data quality, relevance, scope;
- To review models used in hydraulics calculation;
- To review the hydrotechnical facilities used in the modeling;
- To review the DEMs used in hydraulic models;
- Depending on the correctness and completeness of the above factors, make an assessment of the accuracy of the calculated floodplain and the need to correct and modify it.

In case there is no APSFR / no flood hazard maps available:

In the absence of APSFR, for the identification of the geomorphological floodplain, it is recommended to prepare the geometric classification of the terrain. The accuracy of its determination depends on the DEM used. For this purpose, medium or high precision DEM should be used as indicated in step 2.

The identification of the geomorphologic floodplain by the geometric classification of the terrain can be done by any of the following methods:

- Slope-based analyzes: site-specific depending on the concrete terrain and local conditions;
- Use of topographic indices to determine potential floodplains: TWI, Euclidean, Cost Distance Allocation, etc.;
- Use of ready-made scripts, such as ArcGIS Riparian Topography Toolbox, Floodplain Mapper Toolbox, Hydrology Toolset.

The limitations of applying this approach are related to the accuracy of the DEM. Therefore, it is imperative that the created geomorphologic floodplain be validated and corrected with additional data, such as large-scale 1: 5 000 scale maps, geological and soil maps, aerophoto or high-resolution satellite images, archive satellite images. The last ones can, on the one hand, provide information about flooded areas in the event of extreme flooding. On the other hand, they show changes in river flow over a longer period of time. Especially those showing the situation before the river corrections.

4. Hydraulic modeling

This step is taken when there is no previous hydraulic modeling data with 1% probability for active and 0.1% for potential. The purpose is to make it on the basis of an approximate hydrological analysis, realized with the available archival data, from which to determine the water quantities with the corresponding probability. Hydraulic calculations can be performed in one of the following ways:

- Approximate hydraulic methods - using the equation for steady motion;
- Approximate hydraulic methods - using the uneven movement equation;
- 1D or 2D hydraulic model on steady-state assumption using available topographic information without modeling of facilities.

In the presence of dykes, at this stage of the study it may be assumed, that the top of the dyke is located at an elevation close to the water level when passing a high wave at a 1% probability.

In the absence of data on water quantities, hydraulic modeling cannot be done and the geomorphological floodplain remains unchanged.

5. Adjustments to the extent of floodplains depending on land use

The purpose of this step is to exclude urban and industrial areas from the floodplains defined in step 6. In this step, cadastral data should be used. All cadastral properties that have an land use type connected to urbanized and industrial territories must be excluded from the floodplain. An up-to-date aerial photo or high resolution satellite images should be used.

The result of this stage is a polygon layer with all floodplains within the studied river.

6. Defining the water mirror of the river

The purpose of this step is to determine the current extent of the water mirror of the studied river. It also includes river islands.

7. Defining the beginning and the end of the floodplains

The purpose of this step is to identify specific floodplains. This is done through the created geomorphological floodplain of the entire study stream (steps 3 and 4) and the polygon layer of the water mirror (step 6).

The accepted criterion for determining the beginning and end of the floodplain is the ratio of the width of the floodplain to the width of the water mirror of the river to be greater than 1. In the presence of islands, the river channel with the greatest width is used and the widths of islands and side sleeves are not taken into account.

A floodplain can extend on both sides of the river. Its width is measured separately for the area to the left and right of the main river course. The total width is not calculated. In order to fulfill the criterion for the ratio of floodplain / river width it is sufficient that the width on one side of the main stream alone is greater than or equal to the width of the river.

In the presence of dykes, the active floodplain is limited to the distance from the shoreline to the heel of the dyke by the river.

Refinement of floodplain boundaries

The purpose of this stage is to specify the extent of the floodplains defined in the first assessent. Very high precision DEMs, detailed hydrological studies using the 1D approaches and hydraulic testing described in (Methodology for determining adjacent lands and floodplain areas in Bulgaria, 2012) must be prepared for each of them, or 2D model if necessary. When designing hydraulic models, consideration should be given to all facilities located in or near the riverbed - bridges, drains, dikes, road and railway embankments, etc., which could have a serious impact on the hydraulic characteristics.

The end result of this stage is a refined polygon layer with all floodplains within the studied river.

Classification of floodplains according to their size

At this stage, the floodplains defined in the previous stage should be re-examined in view of their area. The goal is to identificate and remove small floodplains that are not particularly important for lowering the peak of high waves.

Different thresholds are used depending on which part of the river course the floodplain is located - upper, middle or lower. This approach is related to the differences in the complexity of the relief. The upper courses of the rivers are characterized by V-shaped valleys, the presence of rapids, gorges. The water course is at high speed and predominates the destructive and transport activity of the water. The floodplains in the upper courses are small in size and not typical in general. The middle courses are characterized by wider river valleys, rivers meander and lakes. Floodplains are more common and larger in size. The lower river sourses are characterized by wide flat-bottomed valleys, extensive floodplains, low water velocity. Floodplains are common and larger than others.

The following thresholds are accepted for the size of floodplains on Yantra River:

Table 1: Minimum size of river floodplains

Type of river course	Minimum size of floodplain in ha
Upper course	20
Middle course	50
Lower course	100

The work at this stage consists of:

1. Determining the location of each floodplain in the river course – on upper, middle or lower part of the river;
2. Exclusion of floodplains whose area is below the thresholds specified in Table 1;
3. Numbering of the floodplains.

The area of each floodplain must be calculated in ha. Thereafter, a comparison with Table 1 should be made and those floodplains having an area smaller than the threshold, should be dropped.

Each floodplain must have a unique identification number. For this purpose, the floodplains are numbered according to the following algorithm:

Country Code_ River Code_ Floodplain Type _ Serial number of the floodplain

For example **BG_YN_AFP_001**, where

- BG – Bulgaria
- YN – Yantra
- AFP/PFP – active or potential floodplain.

Final result after identification of floodplains

The final result of the identification of floodplains (active and potential) according to the prepared methodology consists of 4 products:

1. Polygon layer of floodplains with mandatory fields in the attribute table for unique identification number, location in the river course (upper, middle or lower) and area (in ha);
2. GIS database with data used to identificate the floodplains;
3. Document describing how floodplains are identificated, following the steps outlined in the methodological approach;
4. Passport of floodplains completed.

The floodplain passport provides brief information, organized into 4 main categories:

- Location;
- Physical characteristics;
- Technical characteristics;
- Affiliation to a special status region/area, measures to be implemented within the floodplain under the Bulgarian law.

Table 2 represents a floodplain passport template.

Table 2: Floodplain passport template

LOCATION		
Unique Identification Code	*BG_YN_**PFP**_001*	
Watershed	*Name of watershed (for example Yantra)*	
Type of floodplain	*Active / potential*	
Starting and ending point	Starting point	*Decimal degrees*
	Ending point	*Decimal degrees*
Populated place, municipality, district	district	
	municipality	
	populated place	*name (EKATTE)*
PHYSICALL CHARACTERISTICS		
Area of the floodplain	Total area (ha)	
	Area of the open water (ha)	
	Area of the active floodplain (ha)	
	Area of the potential floodplain (ha)	
River width (m)		
Maximum width of the floodplain (m)		
Minimum width of floodplain (m)		
Average width of floodplain (m)		
Elevation (m)	Average elevation for the floodplain	
	Elevation in the starting point	

	Elevation in the ending point		
Corrections of the main river	*Yes / No*		
Presence of islands	*Yes / No*		
The presence of side sleeves	*Yes / No*		
Pesence of standing water bodies	*Yes / No*		
Presence of traces of old river beds	*Yes / No*		
Presence of wetlands	*Yes / No*		
TECHNICAL CHARACTERISTICS			
Presence of dykes	*Yes / No*		
Location of the dykes	*Left / right shore*		
Dyke type			
Condition of the dykes			
Presence of breaks in the conductivity of the main river (including barrage, hydroelectric power station, waterfall, water intake, etc.)	*Yes / No*	*Description*	
Presence of bridges	*Yes / No*	*Description*	
Presence of channels	*Yes / No*	*Description*	
BELONG TO			
ASPFR	*Yes / No*		
Natura 2000 or protected areas	*Yes / No*	*SCI BG0000610 – Yantra River*	
protected area under the Protected Areas Act	*Yes / No*		

Methodology for evaluating the effectiveness of floodplains

The evaluation of the effectiveness of floodplains (active and potential) is made with a view to take future actions to protect their conservation/preservation and to prevent from future flood risk. This assessment requires the examination of floodplains in various aspects which in turn can be limited to four main groups – hydrological, hydraulic, ecological and socio-economic. Different parameters are defined in order to objectively characterize the groups. Additionally, the selected parameters must be easily calculated with accessible, free to use and country-wide data.

All parameters used in the current methodology for evaluating the effectiveness of floodplains are presented in Table 3.

Table 3: Parameters for evaluating the effectiveness of floodplains

Hydrological parameters	**Hydraulic parameters**	**Ecological parameters**	**Socio-economic parameters**
Flood peak reduction	Water level	Connectivity of floodplain water bodies	Potentially affected buildings
Flood wave translation	Flow velocity	Existence of protected species	Land use
Effect in case of extreme discharge		Existence of protected habitats	
		Vegetation naturalness	
Simple hydro-morphological evaluation *		Potential for typical habitats	
		Biocorridor, "stepping stone" *	

*) Parameters, identified and used at national level – not included in the ptroject's FEM

HYDROLOGICAL PARAMETERS

Parameter "Flood peak reduction"

Description

The indicator takes into account the effect of the floodplain on the reduction of the peak of the flood wave hydrograph. In order to determine the effect, a comparison is made between the peak of the hydrograph on the upstream of the studied area and the output hydrograph at the end of the floodplain. A floodwave with probabilty of exceedance 1% is used as a reference for the active floodplans, and floodwave with probability of exceedance of 0.1% for the potential floodplains. The evaluation of the retention effect of the floodplain is carried out based on a comparison of the difference between the peak of the input and output hydrograph ΔQ with the maximum input discharge Q_{max}. The obtained results are relative and allow comparison between floodplains of different size. If the size of the floodplains is very different, an approach where the flood peak reduction per unit area is used as a criterion can be applied.

Data source

The results of an unsteady two-dimensional hydraulic model or measurements of water discharges in nearby hydrological stations should be used as a basis for the study. If the available information is not sufficient for two-dimensional models, or its quality is not adequate, the use of unsteady one-dimensional numerical hydraulic model is allowed. In this case, special attention should be paid to the modeling of the floodplain in order to represent its hydraulic action as accurately as possible, as the classic approach most commonly used in one-dimensional hydraulic modeling is not appropriate in this particular case.

Workflow

Step 1:

Hydrological parameter. From hydrological point of view, the use of records of real floodwave hydrographs, which peaks are close to the relevant discharge with probability of exceedance 1% for active and 0.1% for potential floodplains is most appropriate. If records with different peaks are available, they can be used too if scaled properly.

Due to the specifics of the hydrological network in Bulgaria and the lack of public data of recorded past floods hydrographs, an alternative approach is needed to obtain the upstream hydrographs of each studied floodplain. It uses a synthetic hydrograph, obtained using the methodology created by prof. Gerassimov (Gerassimov, 1980). The peak of the hydrograph is equal to the maximum discharge with probability of exceedance 1%, which is this particular case is obtained by implementation of regional relations. If all the needed hydrological information is missing, the maximal discharge with specific probablilty of exceedance can be obtained using a synthetic hydrograph, developed by other methodology of prof. Gerassimov.

Step 2:

Calculation of the output hydrograph at the end of the floodplain. An unsteady 2D model should be used for the purpose. If the available information is not sufficient, the use of unsteady one-dimensional numerical hydraulic model is allowed. In this case, special attention should be paid to the modeling of the floodplain in order to represent its hydraulic action as accurately as possible. The minimum set of input data includes:

- Geometry of the river bed, floodplains, embankments and all other structures;
- Ladcover, resp. spatial distribution of the roughness coefficient;
- Upstream and downstream boundary conditions.

If tributarias are present in the studied river reach, the inflow from the tributary should be taken into account too. In the common case, the mean discharge is used, but in case the tributary and its watershed cannot be considered independent from the main river, also a hydrograph from the tributary should be calculated.

Due to the specifics of Bulgarian rivers, it is not appropriate to evaluate the retention of the riverbed itself and it can be neglected.

Step 3:

Calculating ΔQ and ΔQ_{rel}. The retention of the floodplain can be obtained by the difference between the input and output hydrographs - ΔQ.

$$\Delta Q = Q_{max}^{input} - Q_{max}^{output} \quad [\mathrm{m^3/s}] \qquad (1)$$

The relative retention should be calculated too, where ΔQ should be divided by the Q_{max} multiplied by 100 to make a comparison of different river reaches possible. This allows the comparisson between different floodplains.

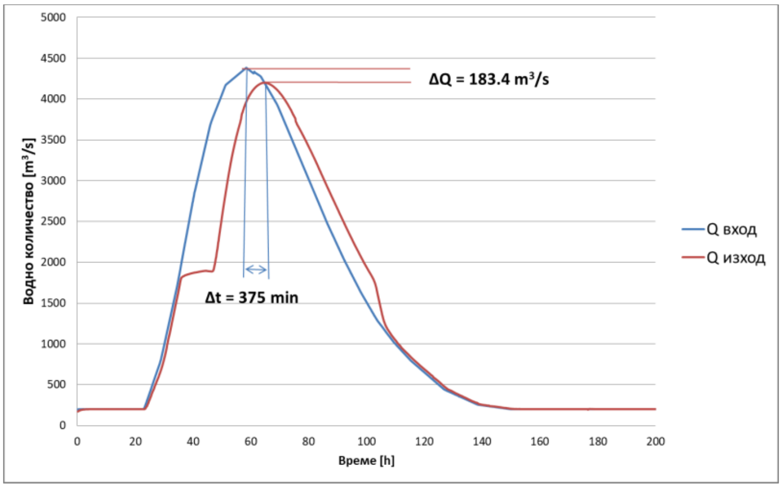
$$\Delta Q_{rel} = \frac{\Delta Q}{Q_{max}^{input}} \times 100 \quad [\%] \qquad (2)$$

Example

In order to illstrate the above described approach, a potential floodplain of Yantra river is used –

BG_YN_PFP_002.

The input hydrograph is synthetic, obtained using the methodology of prof. Gerassimov. The study is carried out using the 2D numerical model SRH-2D. A DEM with spatial resolution of 8 m is used as a background, while the embankments are build using data from topographic maps and geodetic surveys, where available. The roughness coefficients are obtained using data for the lancover and landuse from the land parcel identification system (LPIS), provided by Ministry of Agriculture, Food and Forestry (MAFF) of the Republic of Bulgaria.



ΔQ [m³/s]	183.4 [m³/s]
ΔQ_{rel} [%]	4.18 %

Figure 2: Flood retention in BG_YN_PFP_002 floodplain (probability of exceedance 0.1%)

Parameter "Flood wave translation"

Description

This parameter allows to study the flood wave attenuation in the floodplain. In order to obtain it, the time difference between the times of occurance of the flood peaks for both input and output hydrographs is calculated. The reference hydrographs have a probability of exceedance of 1% for active and 0.1 % for potential floodplains. To allow the comparisson between different floodplains, the relative time difference should be calculated too.

Data source

The time difference is calculated by the same models, used for calculation of the flood peak reduction.

Workflow

The approach is similar to the one used for estiamation of the flood peak reduction.

Step 1:

Estimation of Δt and $\Delta t_{rel.}$ The time difference between the occurance of the peak discharge of the input and output hydrographs should be calculated using.

$$\Delta t = t_{max}^{input} - t_{max}^{output} \quad [\text{min}] \qquad (3)$$

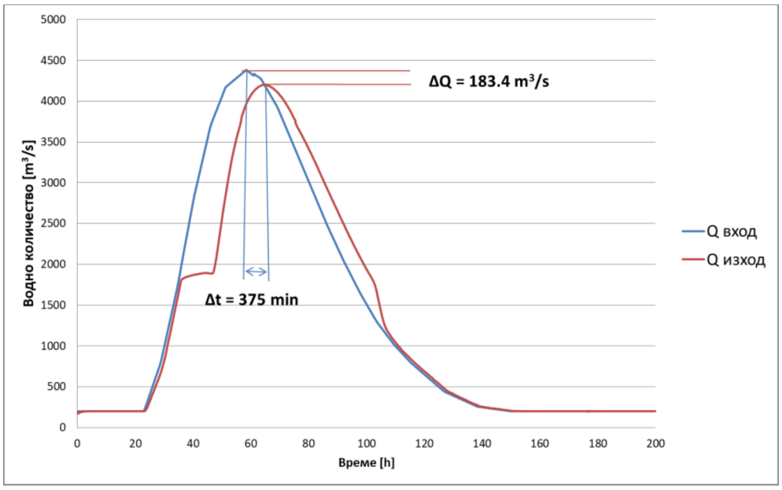
Step 2:

Calculation of the relative time Δt_{rel}, dividing the time difference Δt by the floodwave duration.

$$\Delta t_{rel} = \frac{\Delta t}{t_{flood}} \text{ x } 100 \quad [\%] \qquad (4)$$

<u>*Example*</u>

For illustration of the above described approach, a potential floodplain of Yantra river is used – BG_YN_PFP_002.



Δt [m³/s]	375 [min]
Δt_{rel} [%]	4.8 %

Figure 3: Floodwave peak attenuation for floodplain BG_YN_PFP_002 (probability of exceedance 0.1%)

<u>Parameter "Effect in case of extreme discharge"</u>

<u>*Description*</u>

It shows the effects on hydrological/hydraulic parameters of the flow for scenarios of floodwaves with probability of exceedance (0.1%) lower than the design hydrograph. The model results may show possibility for additional capacity of the floodplains or increased flood risk for the settlements behind the embankments. The parameter consideres the flood peak reduction or its attenuation, compared with the ones of the design discharge.

<u>*Data source*</u>

The hydraulic model, used for calculation of the 1% floodwave should be used.

During the study should be clarified if any urban areas are affected and if so, the flood risk should be estimated.

Workflow

The workflow is the same as the one, described for the previous parameters.

Step 1:

Calculation of ΔQ_{extr} and $\Delta Q_{rel.,\ extr.}$ The retention of the floodplain can be obtained by the difference between the input and output hydrographs – $\Delta Q_{extreme}$

$$\Delta Q_{extr} = Q_{max,extr}^{input} - Q_{max,extr}^{output} \qquad [m^3/s] \qquad (5)$$

The relative retention should be calculated too, where ΔQextr should be divided by the Qmax, extr multiplied by 100 to make a comparison of different river reaches possible. This allows the comparisson between different floodplains.

$$\Delta Q_{rel,extr} = \frac{\Delta Q_{extr}}{Q_{max,extr}^{вход}} \text{ x } 100 \qquad [\%] \qquad (6)$$

Step 2:

Calculation of Δt_{extr} and $\Delta t_{rel.,\ extr.}$ The time difference between the occurance of the peak discharge of the input and output hydrographs should be calculated.

$$\Delta t_{extr} = t_{max,extr}^{\text{input}} - t_{max,extr}^{\text{output}} \qquad [min] \qquad (7)$$

Calculation of the relative time Δt_{rel}, dividing the time difference Δt by the floodwave duration should be carried out after that.

$$\Delta t_{rel,extr} = \frac{\Delta t_{extr}}{t_{flood,extr}} \text{ x } 100 \qquad [\%] \qquad (8)$$

Step 3:

$\Delta Q_{rel.}$, and $\Delta Q_{rel.,\ extr}$ as well as $\Delta t_{rel.}$, and $\Delta t_{rel.,\ extr.}$ should be compared, where the ratios between $\Delta Q_{rel.}$ and $\Delta Q_{rel.,\ extr.}$

$$\Delta Q_{comp} = \frac{\Delta Q_{rel}}{\Delta Q_{rel,extr}} \text{ x } 100 \qquad [\%] \qquad (9)$$

And between $\Delta t_{rel.}$, and $\Delta t_{rel.,\ extr}$ are calculated

$$\Delta t_{comp} = \frac{\Delta t_{rel}}{\Delta t_{rel,extr}} \text{ x } 100 \qquad [\%] \qquad (10)$$

Example

To illustrate the above described approach, a potential floodplain of Yantra river is used – BG_YN_PFP_002.

ΔQ [m³/s]	**463 [m³/s]**	**ΔQextr [m³/s]**	**183.4 [m³/s]**
ΔQ_{rel} [%]	27.67 %	$\Delta Q_{rel,\ extr}$ [%]	4.18 %
Δt [m³/s]	840 [min]	Δt_{extr} [m3/s]	375 [min]
Δt_{rel} [%]	11.67 %	$\Delta t_{rel,\ extr}$ [%]	4.8 %
Δt_{comp} [%]	245 %	ΔQ_{comp} [%]	411 %

Parameter "Simple hydro-morphological evaluation"

Description

The hydromorphological status of the adjacent river section is used to evaluate the effectiveness of floodplains. The degree of anthropogenic pressure and the change in hydromorphological characteristics are analyzed. The estimation is simplified and is performed by the parameter of curvature of the river bed. The main advantages of this parameter are:

- Relatively high sensitivity to general hydromorphological status;
- Possibility of express evaluation based on remote methods;
- Use of quantitative data and comparability of results.

The curvature of a river bed is most often described by the curvature coefficient, defined by the ratio of the length of a river stretch to the length of the river valley. The curvature coefficient for a given river stretch is relatively constant. When a meander breaks off as a result of riverbed processes, the river becomes shorter and a temporary unstable state is created. The system is stabilized by forming a new meander. As a consequence, the temporarily reduced value of the curvature coefficient is restored to its original value.

When corrections of the rivers are made separating the floodplains unstable conditions are created. In the absence or inappropriate shoreline, the river begins to recover its curvature. This results in compromising dikes and other hydrotechnical facilities, which in turn is associated with an increased risk of flooding. In many cases, moving the dyke or reactivating the floodplain is a measure to limit the damage caused by river corridor migration processes. As a general rule, the more heavily modified a river stretch is, the greater will be the effect of restoring the floodplain on the stability of the river corridor.

For the purposes of the evaluation, the hydromorphological status is determined by the degree of shortening of the river bed as a result of anthropogenic pressure (corrections of rivers, detachment of floodplains, etc.). It is expressed by the following equation:

$$S = \frac{S_c}{S_n} \qquad (11)$$

where:

S - River bed shortening index;

Sn - Length of river bed before corrections are made;

Sc - Length of river bed after corrections of river bed.

The projected correction parameters should be used when measuring corrected river sections. Changes occurring after the correction should be considered as temporary disturbances and should not be taken into account.

Hydromorphological changes are considered significant when, as a result of the shortening of the river bed or the change in the curvature coefficient, the river has changed to another hydromorphological class. Rosgen's stream classification at level - I (Rosgen, 1996) was used as a reference. (Rosgen, 1996).

Data source

Large-scale topographic maps or archive satellite images and / or aerial photographs could be used to establish the status of the river bed in the past.

Satellite images and / or aerial photographs taken no later than the last 5 years must be used to determine the present state of the river.

Method of calculation

Step 1:

Measurement of the length of the new river bed adjacent to the estimated floodplain. The length of the new river bed is defined by:

- "New starting point" - the first point at which a new river bed enters (intersects) or touches the estimated floodplain;
- "New end point" - the last point at which the new river bed leaves the floodplain, or the last point at which they touch.

Step 2:

Measuring the length of the old river bed adjacent to the estimated floodplain. The length of the old river bed is defined by:

- "Old starting point" - this is the point from the old river bed that is closest to the corresponding "new starting point" (see step one);
- "Old end point" - this is the point from the old river bed that is closest to the corresponding "new end point" (see step one).

Under this definition:

- When the river bed is not corrected or displaced, the new start (or end) point and the old start (or end point) will coincide.
- When two floodplains have a common boundary, the new endpoint of the higher floodplain plane coincides with the new start point of the next and respectively the old endpoint of one

plane coincide with the old start point of the next plane.

- If the shape of the floodplain and the river are such that they intersect at more than two points, the intermediate points of intersection are not taken into account.

Step 3:

Calculation of the river bed shortening index by equation (11).

Example

Active floodplain at the mouth of the Yantra River with code BG_YN_AFP_001.

The length of the old river bed before the correction of the river is 9 828 m. After correction the length of the river is shortened to 4 944 m. The index of river bed shortening, calculated by equation (11) is 1.99.

HYDRAULIC PARAMETERS

Parameter "Water level change"

Description

The purpouse of the study is to obtain the influence of the change of floodplain geometry (I.e. through removement of embankments) on the water levels (Δh). The comparison of the values should be performed in the same cross section in the middle of the floodplain or in the nearest settlement. This parameter will show the effect of total exclusion of the floodplain and the effect of hypothetical removement of embankments for better floodplain connectivity.

The scenario with complete exclusion of the floodplain should be performed in all cases, while the scenario for removement of embankments only for the potential ones.

Data source

An unsteady 2D model should be used for the purpose. If the available information is not sufficient, the use of unsteady one-dimensional numerical hydraulic model is allowed.

Workflow

Step 1:

Estitmation of h_{tot} for floodwave with probability of exceedance 1% for active floodplains and floodwave with probability of exceedance of 0.1% for the potential floodplains. These are the results, obtained from the models for calculation of ΔQ and Δt.

Step 2:

Calculation of hriverbed for scenario with complete exclusion of the floodplain for floodwave with probability of exceedance 1% for active floodplains and floodwave with probability of exceedance of 0.1% for the potential floodplains. In this case, a new hydraulic model should be developed, with changed geometry, where the areas outside of the riverbed are isolated (with hypothetical embankments or with calculation network elements exclusion). The water level should be obtained in the same point, where in the previous step.

Step 3:

Calculation of $h_{emb.}$ for scenario with complete exclusion of the floodplain for floodwave with probability of exceedance 1% for active floodplains and floodwave with probability of exceedance of 0.1% for the potential floodplains.

Step 4:

Calculation of Δh.

$$\Delta h_{riverBed} = h_{riverBed} - h_{tot} \quad [\mathrm{m}] \tag{12}$$

or

$$\Delta h_{emb} = h_{emb} - h_{tot} \quad [\mathrm{m}] \tag{13}$$

Example

For illustration of the approach, a potential floodplain of Yantra river is used – BG_YN_PFP_002.

Three main scenarios are considered – current state, total exclusion of the floodplain and removal of the embankments.

BG_YN_PFP_002 – Q 0.1%			
$h_{riverBed}$	39.52 [m]	$\Delta h_{riverBed}$	9.84 m
h_{tot}	29.68 [m]	Δh_{emb}	- 0.64 m
h_{emb}	29.04 [m]		

Parameter "Flow velocity"

Description

The purpouse of the study is to obtain the influence of the change of floodplain geometry (I.e. through removement of embankments) on flow velocities (Δv). The comparison of the values should be performed in the same cross section in the middle of the floodplain or in the nearest settlement. This parameter will show the effect of total exclusion of the floodplain and the effect of hypothetical removement of embankments for better floodplain connectivity.

The scenario with complete exclusion of the floodplain should be performed in all cases, while the scenario for removement of embankments only for the potential ones.

Data source

An unsteady 2D model should be used for the purpose. If the available information is not sufficient, the use of unsteady one-dimensional numerical hydraulic model is allowed.

Workflow

Step 1:

Estitmation of vtot for floodwave with probability of exceedance 1% for active floodplains and floodwave with probability of exceedance of 0.1% for the potential floodplains. These are the results, obtained from the models for calculation of ΔQ and Δt..

Step 2:

Calculation of $v_{riverBed}$ for scenario with complete exclusion of the floodplain for floodwave with probability of exceedance 1% for active floodplains and floodwave with probability of exceedance of 0.1% for the potential floodplains. In this case, a new hydraulic model should be developed, with changed geometry, where the areas outside of the riverbed are isolated (with hypothetical embankments or with calculation network elements exclusion). The water level should be obtained in the same point, where in the previous step. It is recommended to choose the comparison point in the deepest area of the river channel.

Step 3:

Calculation of v_{emb} for scenario with complete exclusion of the floodplain for floodwave with probability of exceedance 1% for active floodplains and floodwave with probability of exceedance of 0.1% for the potential floodplains.

Step 4:

<u>Calculation of Δv</u> Determine Δv as a difference between the flow velocities with and without floodplain.

$$\Delta v_{riverBed} = v_{riverBed} - v_{tot} \quad [\mathrm{m}] \tag{14}$$

or

$$\Delta v_{emb} = v_{emb} - v_{tot} \quad [\mathrm{m}] \tag{15}$$

<u>Example</u>

For illustration of the approach, a potential floodplain of Yantra river is used – BG_YN_PFP_002.

Three main scenarios are considered – current state, total exclusion of the floodplain and removal of the embankments.

BG_YN_PFP_002 – Q 1%			
$v_{riverBed}$	1.69 [m/s]	$\Delta v_{riverBed}$	0.68 m/s
v_{tot}	1.01 [m/s]	Δv_{emb}	-0.83 m/s
v_{emb}	0.18 [m/s]		

ECOLOGICAL PARAMETERS

<u>Parameter "Connectivity of floodplain water bodies"</u>

<u>Description</u>

This indicator assesses the degree of the river connectivity of target natural disconnected surface water bodies.

The assesment is done using the folloing scenarios:

- Connectivity at mean water level;
- Connectivity at high water level with probability of exceedance of 5%,
- Connectivity at extreme water level with probability of exceedance of 1%,,
- Connectivity at extreme water level with a probability exceedance less than of 1%

The assessment values for each scenario are presented in Appendix 1, Table 1. For the sections where no disconnected water bodies are available, the assessment value is is beeing set to "5".

For the final assessment under the project, only the scenarios based assessment and the values listed in Appendix 1, Table 1 are used. The generalized final assessment of the lateral connectivity of water bodies is obtained using the scale in Table 6.

Besides, a more detail approach is proposed to be used for the assessment of the parameter "Connectvity of floodplain water bodies" only at national level.The proposed national approach is aimed to the evaluation of the potential benefit of the floodplain restoration and considers additional factors, that could limit the lateral connectivity.

The addiional factors, used for the evaluation, are:

- Distance between the wetland and the river;
- Availability of infrastructure or urbanized territories in the area between the river and the wetland;
- Internal fragmentation within the estimated wetland barriers;
- Vertical connectivity.

The connectivity is defined by the following equation:

$$L = KF_1 F_2F_3F_4 \qquad (16)$$

where:

L – Lateral connectivity of water bodies;

K – Connectivity scenario (see Appendix 1, table 1);

F_1 – Factor distance between wetland and river (see Appendix 1, table 2);

F_2 – Factor presence of infrastructure or urban areas in the area between the river and the wetland;

F_3 – Factor internal fragmentation within the boundaries of the evaluated important zone;

F_4 – Factor vertical connectivity.

The possible values of the factors F1-F4 are listed in Appendix1, Table 2

Data source

Recent satellite images and/or aerial photography (from the last 10 years) made in different seasons of at least two different years. Recent field surveys conducted in the last 10 years.

Parameter "Existence of protected species"

Description

Using protected species as a parameter to assess the restoration potential of floodplains has two major challenges:

- Clarification on the expected impact of floodplain restoration on a species;
- Availability of representative and comparable data.

The impact on a specific species is often not straightforward and depends on its biology, floodplain features, restoration design, etc.

The availability of field data on registered protected species depends mainly on the extent to which the area has been researched. This is especially true of highly mobile groups of species such as birds, bats, fish, etc., which are often the largest protected species. The extent to which the different floodplains are being examined is not the same and the data are not comparable. Direct registrations can only be used for benchmarking if they are collected on a targeted basis throughout the basin where the estimated floodplains are located.

Taking into account these limitations, for the purposes of the evaluation, the Protected Species parameter is based on the potential habitats of 14 indicator species included in Appendix 2 of the Biodiversity Act of the Republic of Bulgaria (BDA) (see Appendix 1, table 3). Indicator species meet the following guiding conditions:

- Species where floodplain restoration will have a uniquely positive impact;
- Species for which area models of potential habitats have been developed at national level.

The assessment is an analysis of the aggregate representativeness of the indicator species listed in Appendix 1, table 3, by model of their potential habitats for a given floodplain. The estimate is relevant for floodplains within a single river basin. It is defined by the following equations:

$$Sm = \frac{S}{Sa} \times 100 \tag{17}$$

$$S = \frac{\sum_{i=1}^{14} Pi}{Pfp} \tag{18}$$

$$Sa = \frac{\sum_{i=1}^{n} Si}{n} \tag{19}$$

where:

Sm – assessment of the criterion of protected species in percentage;

S – area representation of the indicator species in the estimated floodplain;

Sa – average surface representation of indicator species in all floodplains in the valley that have to be evaluated;

Pi – area of potential habitats for each of the 14 indicator species for the territory of the estimated floodplain;

Pfp – area of the estimated floodplain;

Si – area representation of the indicator species for each of the floodplains in the valley that have to be evaluated;

n – number of floodplains in the estimated valley.

Data sources

Geographic Information System for Natura 2000, available at the following link below: http://natura2000.moew.government.bg/.

Method of calculation

Step 1:

Calculation of the area of potential habitats for each of the 14 indicator species for the area of the estimated floodplain (Pi).

Step 2:

Calculation of the area representation of the indicator species in the estimated floodplain (S) by equation (18).

Step 3:

Calculation of the mean area representation of the indicator species in all floodplains in the estimated valley (Sa) by equation (19).

Step 4:

Calculation of the criterion of the protected species in percentage (Sm) by equation (17). and transform the result by the scale in Table 6..

Example

Active floodplain BG_YN_AFP_004 on the Yantra River.

The areas of potential habitats for each of the 14 indicator species for the territory of the estimated floodplain (Pi) are as follows:

Species	Pi [m^2]
Lutra lutra	2301518
Emys orbicularis	5686638
Mauremys rivulata	0
Triturus cristatus	0
Triturus dobrogicus	5679880
Triturus karelinii	0
Bombina bombina	5689733

Bombina variegata	0
Coenagrion ornatum	2964118
Ophiogomphus cecilia	4461544
Leucorrhinia pectoralis	0
Lycaena dispar	4118094
Euphydryas aurinia	0
Hypodryas maturna	0

The estimated floodplain area (Pfp) is 5 689 735 sq.m.

The area representation of the indicator species in the estimated floodplain (S) is 5.43.

The average area representation of the indicator species in all floodplains in the estimated valley (Sa) is 3.48. This value was calculated on the basis of data not included in this example from all 20 floodplains identified along the Yantra River.

The value of the indicator (Sm) in percent is 156.25%. which according to

Table 6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters

corresponds a generalized final assessment of 4.

Parameter "Existence of protected habitats"

Description

This indicator examines the presence of territories included in the national network of protected territories under the Law of the Protected Areas of the Republic of Bulgaria (PAA) and protected areas of the Natura 2000 network under the Law of Biological Diversity of the Republic of Bulgaria. The national network of protected areas includes the following categories:

- National park;
- Nature Park;
- Reserve;
- Managed reserve;
- Protected site;
- Natural monument.

Protected zones within NATURA 2000 are:

- Protected zones under the Birds Directive, Directive 2009/147/EU;
- Protected zones under the Habitats Directive, Directive 92/43/EEC.

In general, the existence of territories protected by the PAA and the BDA is an argument in favor of restoring floodplains. An exception is the case of contradictions between the subject of conservation in the protected areas and zones and floodplain restoration activities.

The degree of formal protection is expressed by a cumulative assessment of the areas of each protected areas and zone within the floodplain:

$$Hm = \frac{\sum_{i=1}^{8} Hi}{Pfp} \times 100 \qquad (20)$$

where:

Hm – first interim evaluation of the cumulative coverage of protected areas and zone in percentage;

Hi – area of each of the eight categories of protected areas and zones within the estimated floodplain;

Pfp – area of the estimated floodplain.

For a large number of territories there is an overlap of different modes and the value of Hm can be much greater than 100%.

An additional criterion for the assessment is the type and number of protected areas under the PAA.

Data source

Output information in digital form is available in the register of protected areas and zones of the EEA: http://eea.government.bg/zpo/bg/

Method of calculation

Step 1:

In this stage areas of all categories of protected territories and areas within the estimated floodplain are being calculated.

Step 2:

Calculation of the first interim evalution by equation (20).

Step 3:

Converting the first interim evalution into a second one using the scale in

Table 6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters

. The second interim evaluation may have values from 1 to 5.

Step 4:

Laying down of the final assessment. The value of the final evaluation is obtained by adding to the value of the second interim evaluation the following:

- one level of valuation for each protected area of the categories: nature park, protected site and natural monument;
- two levels of valuation for each protected area of the categories: national park, nature reserve and managed reserve.

The maximum value of the final valuation could be 5. If values greater than 5 are obtained when applying the fourth step, then the final generalized value of the “Existence of protected habitats” indicator to be taken is 5.

Example:

Potential floodplain BG_YN_PFP_009, located in the lower Yantra River.

The Dzholungyol protected area of 191 027 sq.m is part of the protected area of Yantra River (BG0000610) with 8 883 347 sq.m. The area of the floodplain is 149 40 617 sq.m. The value of the first interim evaluation calculated by equation (20), is 60.74%.

Table 6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters

Parameter “Vegetation naturalness”

Description

This parameter assesses the extent to which the existing natural habitats are similar to those typical of the floodplain.

Primary natural habitats in the floodplains in Bulgaria are not preserved. Historically, all riparian natural habitats have been modified, some of which have been re-established in a manner close to that of the site. The concept of natural habitats can be viewed contigently below. For the purpose of the evaluation, natural habitats are divided into three categories:

- Natural;
- Semi-natural;
- Highly modified.

The parameter vegetation naturalness shall be calculated using the following equation:

$$Nm = \frac{\sum_{i=1}^{40} PiFi}{Pfp} \times 100 \qquad (21)$$

where:

Nm – evaluation of the naturalness of the land cover in percentage;

Pi – area of the relevant land cover category;

Fi – naturalness factor of the corresponding land cover category (its value is 1, 0.5 or 0);

Pfp – area of the estimated floodplain.

Data Source

For calculating the parameter an LPIS land cover/land use layer is used.

Method of calculation

Step 1:

The first step includes an analysis of the land cover in each floodplain. Areas for all 40 land cover categories are calculated according to Appendix 1, table 4. When verifying the results, the sum of the areas for all land cover categories should be equal to the area of the estimated floodplain.

Step 2:

Summing up separately the areas in the natural and semi-natural habitats categories. The vegetation naturalness parameter (see Appendix 1, table 4) for semi-natural habitats is 0.5 and they account for half of their actual area in the valuation. For highly modified habitats, the naturalness parameter is 0 and they are excluded from the assessment.

Example

Active floodplain BG_YN_AFP_001, located at the mouth of the Yantra River.

In the first and second stages, the total area of land cover natural types was estimated to be 5 440 436 square meters, and of the semi-natural ones - 180 353 square meters. By reducing the value of semi-land cover natural types by half (factor 0.5) and estimating their total percentage coverage with comparison to the floodplain area (5 689 735 square meters), a value of 97.20% is obtained. This is the estimate of the naturalness of the earth's cover in percent (**Nm**).

Parameter "Potential for typical habitats"

Description

The potential for typical natural habitats is a comprehensive analysis of the presence of key natural habitats and the naturalness of the land cover.

The assessment is based on 22 types of natural habitats, which are typical for the river corridors (see Appendix 1, table 5). They are included in the Natura 2000 and (Appendix 1 of the Biodiversity Act of the Republic of Bulgaria).

The presence of typical natural habitats in a floodplain is a prerequisite for future expansion of the area with typical natural habitats. Currently, the greater the number of typical natural habitats and the larger their area, the greater the potential for complete development of typical vegetation in the future. For the purpose of this evaluation, a four-level scale has been adopted to determine the contribution of each habitat types:

Table 4: Scale for determining the contribution of each habitat types

Representation of the natural habitat in a floodplain [%]	Contribution
Not defined	0
0 ≤ p ≤ 1	1
1 < p ≤ 5	2
p > 5	3

Neighboring territories are also involved in the restoration process of natural vegetation in a given place. The presence of typical natural habitats near the investigated floodplain is an important prerequisite for its potential. Therefore, the assessment of this indicator considers not only the floodplain given, but also the buffer areas around it.

The second major factor in the assessment is the naturalness of the land cover. It is assumed that the higher the degree of the land cover naturalness, the faster the floodplain typical habitats will be formed in the future.

The interaction of the two main factors in the evaluation is shown in the following equations:

$$Tm = \frac{T}{Ta} \times 100 \tag{22}$$

$$T = \left(\sum_{i=1}^{22} Tfi + \frac{1}{2} \sum_{i=1}^{22} Tbi \right) \sqrt[2]{\frac{N}{100}} \tag{23}$$

$$Ta = \frac{\sum_{i=1}^{n} Ti}{n} \tag{24}$$

where:

Tm – interim evaluation of the indicator potential for typical natural habitats in percentage;

T – representation of the typical habitats in the estimated floodplain and its adjacent buffer territory;

Ta – average representation of the typical habitats in all floodplains and their adjacent buffer territories in the estimated river basin;

Tfi – contribution of each of the 22 typical natural habitats for the estimated floodplain;

Tbi – contribution of each of the 22 typical natural habitats for the buffer territory of the estimated floodplain;

N – final valuation of the natural habitat indicator, expressed in percentage;

Ti – representation of the typical habitats for each of the floodplains and their buffer territories in the estimated river basin;

n – number of floodplains in the estimated river basin.

Data source

Geographic Information System for Natura 2000, available at the following link below: http://natura2000.moew.government.bg/

Method of calculation

Step 1:

Definition of the boundaries and the buffer territories area around the estimated floodplain. The buffer covers points located within 2 km of the estimated floodplain boundary.

Step 2:

Area calculation of each 22 typical natural habitats (see Appendix 1, table 5) in the estimated floodplain and separately in its buffer territory.

Step 3:

Calculation of the percentage representation of each of the 22 typical natural habitats within the estimated floodplain. The percentage representation is calculated from the area of the estimated floodplain.

Step 4:

Calculation of the percentage representation of each of the 22 typical natural habitats falling within the estimated floodplain buffer territory. The percentage representation is calculated from the area of the buffer territory.

Step 5:

The percentage representation of the previous two stages forms the contribution in Table 4. This step is performed separately for the estimated floodplain (Tf) and its buffer area (Tb). The contribution value is "0" when the habitat is not represented. When the relevant habitat is present, depending on its area, the value of this parameter may be 1, 2 or 3.

Step 6:

Calculation of the representation of the typical habitats in the estimated floodplain and adjacent buffer territory (**T**) using equation (23).

Step 7:

Calculation of the average representation of the typical habitats in all floodplains and their adjacent buffer territories in the estimated river basin (**Ta**) by equation (24);

Step 8:

Calculation of the interim valuation of the criterion potential for typical natural habitats in percentage

(**Tm**), using equation (22).

Example

Active floodplain BG_YN_AFP_001 at the mouth of the Yantra River.

The results of the first five steps are summarized in the following table:

Habitat Code	Habitat Area [m^2]		Percentage Contributon [%]		Weight Contribution	
	Floodplain	Buffer territory	Floodplain	Buffer territory	Floodplain Tf	Buffer territory Tb
1530	0	25252	0,00	0,02	0	1
3150	172271	351522	3,03	0,33	2	1
3260	105349	2279572	1,85	2,16	2	2
3270	2862	2246051	0,05	2,13	1	2
6240	436	0	0,01	0,00	1	0
91E0	322554	1466060	5,67	1,39	3	2
91F0	0	1791433	0,00	1,70	0	2

There are 5 typical habitats found in the investigated floodplain, and 6 in its buffer territory, 4 of which are common. With the lowest representation is Habitat 1530 - Pannonian salt-steppes and the salt marshes. It occurs only in the buffer territory. It has an area of 25,252 sq.m and a contribution percentage of 0.02%, which corresponds to the weight of contribution "1". For the floodplain considered, the habitat 91E0 - Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Pandion, Alnion incanae, Salicion albae), with value "3", have the highest gravity.

The total weight of the typical habitats in the floodplain is "9" and for the buffer area "10".

The **N** value is taken from the final valuation of the parameter "Vegetation naturalness" and is 97.20% for that specific case.

The **T** value calculated by equation (23) is 13.80. The **Ta** value calculated by equation (24) is 6.60. This value was calculated from data not included in this example from all 20 designated floodplains along the Yantra River.

The percentage valuation of the parameter "Potential for typical habitats" (**Tm**) is 209.17%.

Parameter "Biocorridor, "stepping stone""

Description

The evaluation of the complex biocorridor potential of a given floodplain is carried out by evaluating the following three biocorridor types:

Type 1 – All units of the biocorridor are riparian forest habitats. This biocorridor type depends on:

- Size and fragmentedness of the areas covered by riparian forest habitats;
- State of the vegetation in the riparian forest habitats;
- Size of the evaluated floodplain.
- The size is relative and is comparable only for objects within river courses that are similar in scale. For example, a riparian forest that has the same size will not have the same value in river courses that are different in scale.

A biocorridor of this type can be formed between two or three adjoining floodplains. In the long term, every outermost unit of the biocorridor can function as a connection to new riparian forest habitats. For this reason, the evaluated floodplain has a comparable biocorridor value when it is a connecting unit and when it is an outermost unit.

Type 2 – The outermost units in the biocorridor are forest habitats outside the floodplains and the connecting units are riparian forest habitats located in the evaluated floodplain. This biocorridor type depends on:

- Size and fragmentation of the forest habitats outside the floodplains;
- Size and status of the riparian forest habitats in the floodplains.

For this biocorridor type the considered floodplain is evaluated only in terms of its function as a connection unit.

Type 3 – The units in the biocorridor are the river and the riparian wetlands. The defining factors for this biocorridor type are:

- Characteristics and status of the wetlands;
- Number and relative size;
- Connection to the main river course;
- Presence of migration barriers in the main river course.

The river or another medium can form functional connections between any two riparian wetlands independent of other wetlands, so the term connecting unit is conditional to a large extent. Distance is not a decisive factor and an interaction between the wetlands can take place both when they are located close to each other (within one floodplain or in adjoining floodplains) and when they are located in parts of the river course that are relatively distant from each other, including neighbouring river courses. The structure of this biocorridor type is more of a network than a linear structure. That is why the contribution of the evaluated floodplain to this biocorridor type is evaluated by the quantity and quality of the target wetlands in it and does not directly take into account its location in the river course.

Between the three biocorridor types there is a synergic connection and they complement each other. In this system the role of the riparian forest habitats is essential. They are a common element of the first two biocorridor types and complement the third type because they contribute to the status of the river and the riparian wetlands. A positive connection also exists in the opposite direction. The presence of riparian wetlands favours the formation of tree vegetation and if there is no systematic deforestation, complexes of these habitats are formed with various transitions between them. An example of such transition are alluvial forests as well as aquatic reed belts and other tall heliophytes (habitat C3.2 according to EUNIS, Davies & al. 2004). The latter habitat, although it is not a forest one, has biocorridor significance also for many typical „forest" animal species.

The indicated cumulative effect is the basis for the evaluation of the complex biocorridor potential of a given floodplain. It is measured by the sum of the three considered biocorridor types.

$$Bm = \sum_{i=1}^{3} Mi\ Bi\ (Ai + Pi) \qquad (25)$$

where:

Bm – first level valuation of the biocorridor potential of the considered floodplain;

Mi – presence and status of habitats outside the considered floodplain that are object to connecting to the according biocorridor type;

Bi – presence of migration barriers for the according biocorridor type;

Ai – current status of key habitats in the considered river floodplain, through which the corresponding type of bio-corridor is formed;

Pi – potential for restoration or extension of key habitats in the considered floodplain.

Data source

The main information sources for performing the evaluation are:

- Recent satellite images (from the past 10 years) in different seasons from at least two different years;
- Cadastral data;
- River basin management plans;
- Data from field studies from the last 10 years – if necessary.

Method of calculation

Step1: Identifying the presence of target habitats

1. *Forest habitats - Type 1 and Type 2 biocorridors*

It is carried out by means of recent satellite images. To be identified are:

- Riparian forest habitats in the evaluated floodplain;
- Riparian forest habitats in the two adjoining floodplains;
- Forest habitats outside forest floodplains that are adjoining or close to the evaluated floodplain.

For the purposes of the evaluation the term riparian forest habitats is applied in a broader sense and covers all types of forest habitats that are located in the floodplain. Characteristic, and often the only ones preserved in the floodplain, are the natural forest habitats located directly by the river:

- 91E0 Alluvial forests with *Alnus glutinosa и Fraxinus excelsior* (*Alno-Pandion*, *Alnion incanae*, *Salicion albae*);
- 91F0 Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*);
- 92A0 *Salix alba* and *Populus alba*;
- 92C0 Forests of *Platanus orientalis*;
- 92D0 Southern riparian galleries and shrubs (*Nerio-Tamaricetea и Securinegion tinctoriae*).

In the periphery of the floodplains the forests are too varied and are mostly similar or identical to the ones on adjoining slopes.

The analysis of the intensive forest plantations and the urban park territories in the floodplains depends on their characteristics and requires an individual approach. In some of the poplar plantations the undergrowth is completely absent and they have a very low value as a forest habitat. In other cases, the forest cultures are of semi-natural character and have good biocorridor potential. Often the riparian forest habitats are greatly damaged by logging, clearing of river courses, etc. If necessary, a field check should be performed for identifying the current state. The general approach is to treat the most modified and low-value forest habitats as potential forest habitats (see parameter **P**).

2. *Riparian wetlands – Type 3 biocorridors*

The identification of the riparian wetlands is performed by means of recent satellite images and includes the entire river course. Due to the seasonal character of some wetland types, the satellite images should cover different seasons and years. The target wetlands comprise the natural and seminatural riparian wetlands in the floodplain. The first group includes mostly:

- River sidearms;
- Oxbow lakes;
- Seasonally flooded areas;
- Other permanent and temporary wetlands.

Target semi-natural riparian wetlands are:

- Old river beds that were disconnected from the river as a result of river embankments;
- The confluences of rivers that flow into the Danube;
- Shallow quarry lakes with riparian vegetation;
- Disused or extensive fishponds;
- Other shallow water bodies with a relatively constant water level, presence of riparian vegetation and a natural bottom.

The most characteristic natural habitat for the considered wetlands is:
3150 Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation.

Less frequantly in these wetlands are formed:

3130 Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea and
3140 Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.

As non-target for this evaluation are considered the following types of riparian wetlands:

- Impermanent wetlands. A characteristic of this wetland type (unlike the temporary wetlands that were considered above) is that they do not form lasting habitats associated with the wetlands. Most often the water body is formed for short periods in arable lands that are farmed most of the time;
- Deep quarry lakes;
- Dam lakes and dams;
- Artificial water bodies – canals, intensive fish ponds, etc.;
- Wetlands with considerable variations of the water level as a result of water use etc.

The inclusion of riparian wetlands in the biocorridor depends on their connectivity with the main river course. The wetlands in active floodplains hold more weight in the evaluation. This criterion refers to all target wetlands. For the purpose of the evaluation, the confluences of the rivers that flow directly into the Danube are considered as target wetlands in an active floodplain.

Specific additional criteria that is applied only for the target wetlands in the evaluated floodplain is the level of anthropogenic pressure.

Step2: Identifying the potential target habitats in the evaluated floodplain;

1. *Forest habitats - Type 1 and Type 2 biocorridors.*

To be considered in the evaluated floodplain is the combination of the actual state of the riparian forest habitats and the potential for creating new ones/extending the existing ones. In the neighbouring territories only the actual status of the forest territories is considered whereas the potential ones are not taken into account (see forest habitats – biocorridors Type 1 and Type 2).

The forest habitats are basic and on presumption their restoration is a characteristic component of the integrated project for floodplain restoration. The restoration potential for target forest habitats in the evaluated floodplain is determined by means of expert evaluation. Major factors/prerequisites for the restoration of forest habitats that have to be taken into account are:

- Areas in the riverbed and in the area between the dyke and the river bank;
- Damaged forest habitats;
- Intensive poplar plantations without undergrowth;
- Non-forested territories in the forest fund;
- Territories with natural and seminatural vegetation – pastures, meadows, abandoned land etc.;
- Riparian wetlands;
- Arable lands that are municipal and state property.

It is assumed that there is no potential for restoration when the above prerequisites are not present and instead there prevail:

- Urbanised territories and infrastructure objects;
- Intensive (particularly irrigation) agriculture;
- The territory has been split into small-sized plots that are private property.

When in the evaluated territory there are comparatively intact riparian forest habitats in terms of their biocorridor function and the value of perimeter **A** is "1", it is assumed that there is no restoration potential for riparian habitats and the value of **P** is "0".

2. *Riparian habitats - Type 3 biocorridors 3*

As potential wetlands are considered:

- Territories in which, when the floodplain is activated, new target riparian wetlands will form;
- Non-target riparian wetlands which after enlargement or pressure reduction will turn into target wetlands.

When in the evaluated territory there is one or more riparian wetlands that are not small-sized and are under moderate or less intensive anthropogenic pressure and the value of parameter **A** is "1", it is assumed that there is no restoration potential for riparian wetlands and the value of **P** is "0".

<u>Step3:</u> Indentification of Migration barriers

The presence of migration barriers lowers the biocorridor potential of a territory. The requirements of the different groups of organisms to the biocorridor characteristics are too broad, which makes it difficult to define common migration barriers. For example many „forest" plant species, birds, bats and ground mammals, insects etc. can disperse over large non-forest territories. For the current evaluation is used a generalised scale of three points.

1. *Migration barriers in Type 1 and Type 2 biocorridor*

Evaluated is the presence of migration barriers within the floodplain and directly along its borders. It there is a significant fragmenting structure in adjoining forest territories, the following approach is applied:

- Considered is only the part of the fragmented forest habitat that is connected to the evaluated floodplain.
- The part of the forest habitat that is isolated from the evaluated floodplain is excluded. If necessary, this is recorded as a correction of the value of parameter **M**.
- The fragmenting barrier is not considered and if there no other barriers, the value of parameter **B** is assumed to be "1".

2. *Migration barriers in Type 3 biocorridors*

Evaluated is the presence of migration barriers along the river course in the stretch between the two farthest riparian wetlands included in the analysis. In some cases this can mean considering the entire middle and/or lower course of a given river, including neighbouring river courses. Leading criteria for the evaluation are the number of barriers and their impact on fish. Fish were determined as an indicator group because in terms of swimming and migration abilities they are the most widely studied aquatic organisms. About them there are standardised approaches for the evaluation of migration barriers. As a reference approach for the current methodology was adopted the manual (SNIFFER, WFD111 (2a) Coarse resolution rapid-assessment methodology to assess obstacles to fish migration, 2011). Part of the requirements of this approach are field analysis of the shape and size of the barrier, species composition and size groups of the target species in varying hydrological conditions. This makes it very objective but also time-consuming. For the purposes of the current task, it is recommended to carry out an expert evaluation of the impact of the existing barriers on the basis of comparison to other barriers in Bulgaria with similar technical parameters, ichthyofauna and hydrological regime, for which an evaluation following the mentioned approach has already been made.

Step 4: Calculating the biocorridor potential

After analysing the present and potential habitats and migration barriers, the next step is to determine the values of the parameters **M**, **B**, **A** and **P** separately for each of the three biocorridor types. This is done by comparing the situation to sample ones, included in tables:

- Appendix 1, table 6: Presence and status of habiats outside the floodplain of interest, which are subject of reconnection by the biocorridor (параметър M);
- Appendix 1, table 7: Presence of migration barriers (Parameter B);
- Appendix 1, table 8: Scale for the assessment of migration barriers for fish by SNIFFER (2011) and Uzunova (2017);
- Appendix 1, table 9: Current status of target habitats in the considered river floodplain, through which the corresponding type of bio-corridor is realized (Parameter A);
- Appendix 1, table 10: Potential for restoration or extension of key habitats in the considered floodplain, through which the relevant bio-corridor type is realized (Parameter P).

The biocorridors of Type 1 and Type 2 have common elements. That is why the values of the parameters **A** and **P** for a biocorridor of Type 1 (**A1** and **P1**) and a biocorridor of Type 2 (**A2** and **P2**) are the same, respectively **A1**=**A2** и **P1**=**P2**.

The interim evaluation of the biocorridor potential of the considered floodplain (Bm) is calculated by means of formula (25). This parameter allows comparative analysis and ranking the floodplains within a river course according to their complex biocorridor potential.

SOCIO-ECONOMIC PARAMETERS

Parameter "Potentially affected buildings"

Description

The floodplains are being utilized for purposes other than agriculture and construction, including development of settlements, development of production activities and infrastructure. Thus, it is necessary to analyze the extent to which the selected floodplains are built up.

The indicator "potentially affected buildings" within the floodplains will give a quantitative expression of the extent of the built-up area. The greater the number of buildings, the greater the potential of floodplain flood damage and the financial means to compensate owners for foreclosure, which will make the performance assessment lower.

In order to compare the results of the indicator between floodplains with different area, its final value is expressed as the average density of buildings within the floodplain, namely the number of buildings per 1 sq. km.

It should be considered that this indicator applies to floodplains whose boundaries are defined in such a way that urbanized and industrial territories are removed in advance (see Adjustments to the extent of floodplains depending on land use). B However, within the floodplains there may be single buildings located outside the separate built-up areas.

Data source

The cadastral database of the Republic of Bulgaria, in which a polygon layer of buildings is available, should be used to calculate the indicator. This layer is not available throughout the country. For the area in which it is not available, other sources of information should be used, namely:

- A polygon layer of buildings from OpenStreetMap – https://osmbuildings.org/data/;
- A polygon layer of buildings from Copernicis, Land Monitoring Service, Building Height 2012 or later - https://land.copernicus.eu/local/urban-atlas/building-height-2012.

Whichever source is selected, it should be considered that they are not exhaustive. Therefore, aerial photography or satellite images with very high resolution with the highest relevance (taken no later than the last 5 years) should be used for validation. If new buildings are discovered, they should be added. If the buildings are destroyed or are not visible in the photo, they must be deleted.

Method of calculation

Step 1:

In GIS environment, the layers of buildings and floodplains that have to be evaluated are added. All buildings located entirely within the floodplain under consideration are selected. The selected buildings are saved in a new layer. The attribute table of the layer must indicate the data source and the unique identifier of the floodplain.

Step 2:

Visual examination of the floodplain in GIS environments using current aerial photos or satellite images as a basis. The examination is made to:

- Identify new buildings beyond the ones selected in the first step and add additional ones to them. Temporary structures, sheds, greenhouses should not be added as clearly as possible in the photograph / image.
- Delete buildings that can be uniquely identified as ruins in the picture.
- Delete buildings that do not exist in the photo. This can only be done if the cadastral information is older than the photo that is being used.

At the end of this step, the total number of buildings within the floodplain must be determined.

Step 3:

In this step, the density of the buildings within the floodplain is calculated, namely the number of buildings per 1 sq. км.

Example

The potential floodplain with BG_YN_PFP_006 along the Yantra River is taken as an example.

The floodplain extends into the lands of 4 settlements - Polski Trambesh, Karantsi, Polsko Kosovo and a very small part of the north is entering the borders of Byala. A cadastral database for the whole land is available only for Polski Trambesh and Byala. For the other two villages, the cadastral data is only available for the non-urbanized territory.

The building layer available from the cadastre intersects the estimated floodplain. It consists of 3 buildings. They are saved in a new layer.

The aerial photography gives a visual inspection of the territory. Firstly, it is verified that the identified 3 buildings exist. The entire floodplain territory is then traversed. As a result, 34 more buildings were identified and added to the layer. The total number of buildings in the floodplain is 37.

Next thing is to calculate of the density of the buildings. The floodplain area is 16,064 sq. km. The density of the buildings is 2.30.

Parameter "Land use"

Description

The parameter is used to analyze floodplains in terms of their adaptability to future flooding. In this regard, it is also important to determine the duration of the eventual flooding. It can vary widely - from days to weeks. For the purposes of this analysis, it is assumed to be the maximum flood duration typical for Bulgarian rivers (excluding the Danube River), which is about one month. Longer floodings are rare.

The parameter "Land Use" will be evaluated using the factor for flooding adaptibility. This factor can take three possible values:

- 1 – High level of adaptability to flooding;
- 3 – Average level of adaptability to flooding;
- 5 – Low level of adaptability to flooding.

Land use types with low levels (factor 5), in the case of future flooding, would suffer damage that would severely harm their condition. Examples for these are all built-up areas, arable land, etc. In the case of moderate adaptation (factor 3), flood damage would not cause significant damage to the territory. For example, studies on various fruit crops show that many of them are resistant to floods of such duration. High-adaptation land use types (factor 1) would not receive flood damage. Such are forests, wetlands and more.

It is advisable to be used land use data to calculate the parameter "Land Use". These data, in turn, should be characterized by high resolution and relevance (the data should be as consistent as possible with the current usage of the territory). The requirement for high resolution of the data also arises from the fact that floodplains throughout the country are relatively small in size. For example, the floodplains along the main course of the Yantra River have an average area of 11 sq. km and the smallest are less than 1 sq. km.

Data source

For the calculation of the "Land Use" parameter, it is advisable to use the land cover / land use layer of the LPIS. The LPIS is part of the Integrated Administration and Control System (IACS), which has been developed in all EU Member Countries in accordance with the main EU and EC regulations. Databases from this system, incl. land use is kept up-to-date because it is used to ensure that EU agricultural subsidy procedures are properly implemented. The data are provided upon request by the Ministry of Agriculture, Food and Forestry of the Republic of Bulgaria (MAFF).

The nomenclature of durable usages follows the main elements and definitions of CORINE, with some changes and additions to ensure the specificity and objectives of the LPIS.

The main advantages of a LPIS layer for the purposes of calculating the "land use" parameter are:

- Good spatial resolution. The minimum mapping unit in the layer is 0.1 ha. The layer is digitized on the basis of deciphering a digital orthophoto map (DOM), which accuracy is 1.5 meters.
- Data relevance. Every year, aerial capture of some territories is made and the layer is updated in a timely manner.

The main disadvantage of using a LPIS layer to determine the degree of adaptability to floods lies in the accepted nomenclature of land use types. It is designed to meet the requirements of IACS for supporting the provision of agricultural subsidies. Its purpose is not to differentiate between the types of land use with different adaptability to flooding. Therefore, under the umbrella of one type of one LPIS land use, it is possible to combine different types of uses with radically different ability to adapt to flood.

Method of calculation

Step 1:

Determing the land use types within the floodplain. This is done in a GIS environment where two layers are visualized - the ground cover and the floodplain analyzed. The standard intersect function creates a new layer of land use only within the floodplains boundaries. In the attribution table of this layer, there must be three fields - a unique floodplain identifier, land use type, and degree of adaptation to flooding. The first two fields are already completed.

Step 2:

Validation of the data. Before adapting the data to the level of flooding adaptation, it is advisable to check the data obtained in the first step for discrepancies and errors.

The first check is that the total land use area for a floodplain is equal to the area of the plain itself. A difference may be due to topological errors (overlaps and / or holes) in the land use layer. If any discrepancies are found, they should be corrected.

The second validation includes a visual inspection of the land use layer of up-to-date (newer than those used for digitalization of the layer) photographs / images for accurate representation of the floodplain. If any inaccuracies are found, they should be corrected.

The third validation is that all polygons in the layer are associated with land use type (permanent use mode). If there are deficiencies, they should be corrected.

Step 3:

Linking the level of adaptation to floods to each type of land use. For this purpose Appendix 1, table 11 is used. The levels of adaptation are recorded in the field in the attribute table of the land use layer.

Step 4:

Determing the area of the territories with different level of adaptability to flood. For this purpose, the attribution table of the land use layer summarizes the areas for each of the three levels of adaptability - low, medium and high.

Step 5:

Calculation of the Land Use parameter. For its calculation it is necessary to know the values of the floodplain area and the areas of the territories with the three levels of adaptability to flooding.

First, an assessment is made for each of the three adaptability factors using the following formula:

$$F_x = \frac{(x * A_x)}{A_0} \qquad (26)$$

where,

F_x - an interim evaluation for each of the three adaptability factors;

x – an adaptability factor that can accept three values – 1, 3 и 5;

A_x – area of the land with a land use corresponding to the respective adaptability factor;

A_0 – total area of the estimated floodplain.

The interim evaluation of the "Land use" parameter is obtained by summarizing the interim estimates for each of the three adaptability factors.

$$F_0 = F_1 + F_3 + F_5 \tag{27}$$

where,

F_0 – land use evaluation for the entire floodplain;

F_1, **F_3** и **F_5** – interim estimates for the territories with adaptability factors 1, 3 and 5.

Example

The example is the active floodplain BG_YN_AFP_001 on the Yantra River.

Intersection of a polygon layer on the floodplain with the LPIS layer. A new layer should be formed.

Data verification - topological validation for overlaps and holes and visual inspection of the aerial photo.

Binding the data for the Flood Adaptation Factor and each land use types. The data is stored in a separate field in the attribute table of the newly created layer.

Generation of area statistics for the territories with the three levels of adaptability and calculation of the parameter value for each individual degree.

Calculation of the overall score for the "Land use" parameter for the entire floodplain.

Flood Adaptation Factor	Area (sq.m)	Method of calculation	Interim evaluation of the "Land use" indicator
5	249,299	$= \frac{(5 * 249\,299)}{5\,689\,735} = 0.22$	1.23
3	141,432	$= \frac{(3 * 141\,432)}{5\,689\,735} = 0.08$	
1	5,299,004	$= \frac{(1 * 5\,299\,004)}{5\,689\,735} = 0.93$	
Total Area	5,689,735		

CLASSIFICATION AND EVALUATION OF FLOODPLAINS EFFECTIVENESS

The final evaluation of floodplains is to classify them according to the parameters studied in a 5-level scale. The methodology follows the Floodplain Evaluation Matrix (FEM) approach, according to which the estimated floodplains are given a certain rank depending on the list of selected indicators and the combination between them.

Evaluation of the floodplains is a 3-step process. Each step results in an assessment of the effectiveness of the relevant floodplain with respect to a particular indicator, group of indicators and overall complex assessment.

The process of evaluating floodplains includes 3 consecutive steps:

1. Generalized assessment of each indicator according to a 5-level scale (Table 6)
2. Overall assessment for each group of indicators - hydrological, hydraulic, ecological and socio-economic in a 3-level scale
3. Final evaluation of the effectiveness of the floodplain in a 3-level scale.

In order to be able to compare the estimates of the indicators in the different groups, they must be reduced to a common measurement scale. For this purpose, a 5-level scale is used, in which a value of 1 corresponds to a "very bad" rating and a value of 5 to a "very good" rating (Table 5).

Table 5: Five-level scale for evaluating floodplain parameters

1	Very bad
2	Bad
3	Satisfactory
4	Good
5	Very good

To classify the evaluation of each indicator according to to this 5-level scale, a threshold table was created -

Table *6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters*

. It specifies for each indicator the intervals at which its rating moves and the generalized scores from 1 to 5 it corresponds to.

In order to ensure a comparability of the assessment results in the frame of the project, an additional assessment of each parameter in a 3-level scale is performed, using the treshold values as presented in Table 7 below.

Table 6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters

GROUP	PARAMETER	GENERALIZED ASSESSMENT				
		1	2	3	4	5
HYDROLOGICAL PARAMETERS	Peak reduction / ΔQrel [%] /	p ≤ 1	1 < p ≤ 1.3	1.3 < p ≤ 1.7	1.7 < p ≤ 2	p > 2
	Flood wave translation / Δtrel [%] /	p ≤ 1	1 < p ≤ 2	2 < p ≤ 3	3 < p ≤ 5	p > 5
	Effects in case of extreme discharges /Δtcomp [%] /	p > 100	70 < p ≤ 100	50< p ≤ 70	20< p ≤ 50	p < 20
	Simple hydro-morphological evaluation	p > 2.0	1.5 < p ≤ 2.0	1.2 < p ≤ 1.5	1.1 < p ≤ 1.2	p ≤ 1.1
HYDRAULIC PARAMETERS	Water level / Δh [m] /	p ≤ 0.10	0.1 < p ≤ 0.2	0.2 < p ≤ 0.35	0.35 < p ≤ 0.50	p > 0.5
	Flow velocity / Δv [m/s] /	p ≤ 0.1	0.1 < p ≤ 0.3	0.3 < p ≤ 0.5	0.5 < p ≤ 0.75	p > 0.75
ECOLOGICAL PARAMETERS	Connectivity of floodplain water bodies	NA	p = 3.5	p = 4	p = 4,5	p = 5
	Existence of protected species	p ≤ 35	35 < p ≤ 70	70 < p ≤ 130	130 < p ≤ 200	p > 200
	Existence of protected habitats	p = 0	0 < p ≤ 50	50 < p ≤ 100	100 < p ≤ 200	p > 200
	Vegetation naturalness	0 ≤ p ≤ 20	20 < p ≤ 40	40 < p ≤ 60	60 < p ≤ 80	80 < p ≤ 100
	Potential for typical habitats	p ≤ 35	35 < p ≤ 70	70 < p ≤ 130	130 < p ≤ 200	p > 200
	Biocorridor, "stepping stone"	p ≤ 4	4 < p ≤ 6	6 < p ≤ 8	8 < p ≤ 10	p > 10
SOCIO-ECONOMIC PARAMETERS	Potentially affected buildings	p > 5	2 < p ≤ 5	1 < p ≤ 2	0 < p ≤ 1	p = 0
	Land use	p > 4.5	3.5 < p ≤ 4.5	2.5 < p ≤ 3.5	1.5 < p ≤ 2.5	p ≤ 1.5

Table 7: Threshold values for 3-level assessment of parameters

GROUP	PARAMETER	GENERALIZED ASSESSMENT		
		1	**3**	**5**
HYDROLOGICAL PARAMETERS	Peak reduction / ΔQrel [%] /	p ≤ 1.2	1.2 < p ≤ 2	p > 2
	Flood wave translation / Δtrel [%] /	p ≤ 1.5	1.5 < p ≤ 3	p > 3
	Effects in case of extreme discharges /Δtcomp [%] /	p > 90	20 ≤ p ≤ 90	p < 20
	Simple hydro-morphological evaluation	p > 1.8	1.1 < p ≤ 1.8	p ≤ 1.1
HYDRAULIC PARAMETERS	Water level / Δh [m] /	p ≤ 0.15	0.15 < p ≤ 0.35	p > 0.35
	Flow velocity / Δv [m/s] /	p ≤ 0.2	0.2 < p ≤ 0.5	p > 0.5
ECOLOGICAL PARAMETERS	Connectivity of floodplain water bodies	p ≤3.5	3.5 < p < 4.5	p ≥ 4.5
	Existence of protected species	p ≤ 55	55 < p ≤ 130	p > 130
	Existence of protected habitats	p ≤ 30	30 < p < 100	p ≥ 100
	Vegetation naturalness	0 ≤ p ≤ 30	30 < p ≤ 60	60 < p ≤ 100
	Potential for typical habitats	p ≤ 55	55 < p ≤ 130	p > 130
	Biocorridor, "stepping stone"	p ≤ 5	5 < p ≤ 8	p > 8
SOCIO-ECONOMIC PARAMETERS	Potentially affected buildings	p > 5	1 < p ≤ 5	0 < p ≤ 1
	Land use	p > 4	2.5 < p ≤ 4	p ≤ 2.5

For the national methodology, it is proposed to classify the floodplains, based on the overal assessment of each group of parameters - hydrological, hydraulic, ecological and socio-economic, using the following classification

	unfavorable - 1	satisfactory - 3	favorable - 5
Rating values for a group of parameters	≤ 2.5	>2.5 и ≤ 3.5	>3.5 и ≤ 5

This classification is done in two steps:

- An intermediate estimate is calculated for each parameter group, which is the arithmetic mean of the generalized estimates of all parameters, assessed in 5-level scale
- Based on the intermediate evaluation obtained, floodplains are classified according to the 3-level scale - favorable, satisfactory and unfavorable.

The overall assessment of the effectiveness of the floodplains is again presented in a 3-levels scale - high, medium and low efficiency. For this purpose, a matrix is created with the estimates that the floodplain has received for each of the four main groups of indicators. The following algorithm was proposed to determine the overall score:

- All floodplains that have a score of 3 on a maximum of 2 groups of parameters and do not have a score of 1 get high efficiency;
- Average efficiency is obtained by all floodplains having a maximum of one group of parameters with a score of 1;
- All other floodplains get low efficiency.

Table 8: Sample matrix representing the principle of generating an overall assessment of the effectiveness of floodplains

	GROUPS OF PARAMETERS				
	Hydrological	Hydraulic	Ecological	Socio-economic	Обща оценка на ефективност
floodplain 1	5	5	5	5	5
floodplain 2	5	5	3	5	5
floodplain 3	5	3	5	3	5
floodplain 4	1	5	5	5	3
floodplain 5	1	3	5	5	3
floodplain 6	1	3	3	3	3
floodplain 7	3	3	5	3	3
floodplain 8	1	3	1	5	1
floodplain 9	1	5	1	5	1

Prioritisation of the floodplains in the frame of the project

According to the planned project activities, the identified and assessed floodplains have to be classified by their restoration/preservation potential

The final ranking and prioritization of the floodplains will be performed after a ranking method is agreed at project level.

APPENDIX 1

The appendix includes tables of nomenclatures to be used in calculating floodplain performance indicators.

App.1 Table1: Connectivity scenarios
(related to parameter „Lateral connectivity of water bodies")

№	Scenario	Staring value
1	Connectivity at mean water level	5
2	Connectivity at high water level with probability of exceedance of 5%	4.5
3	Connectivity at extreme water level with probability of exceedance of 1%	4
	Connectivity at extreme water level with probability of exceedance less than of 1%	3,5

App.1 Table 2: Factors, limiting the connectivity (*related to parameter „Connectivity of floodplain water bodies")*

Factors , affecting the connectivity	Factor value
F1 – Distance between the wetland and the river	
The distance between the river and the wetland is more than 5 times width of the river at mean water level	1.00
The distance between the river and the wetland is less than 5 times river width at mean water level	0.80
For old river beds: The distance to the wetland at one of the ends of the river section is is less than 5 times river width at mean water level, and the distance at the other end is greater than this value.	0.90
F2 – Presence of infrastructure or urban areas in the area between the river and the wetland	
No infrastructural objects. The theritory is used for agricultural activities or forestry.	1.00
Availability of linear infrastructural objects – roads, water supply systems, dykes (other than the main protective dykes) and others through which, using bridges, underground canals etc., the connectivity can be ensured.	0.80
Availability of area objects. These are urban areas, industrial zones and other territories through which the hydraulic connection between the water bodies is severely restricted or impossible.	0.35
F3 – Internal fragmentation of the water body	
No internal fragmentation of the water body	1.00
Absence of destructive fragmentation structures and presence of up to two	0.90

insignificant fragmenting objects	
Presence of one or more destructive fragmentation structures or presence of more than two minor /insignisicant fragmenting objects	0.80
F4 – Vertical connectivity	
Minor impairment of vertical connectivity	1.00
Moderate impairment of vertical connectivity	0.90
Significant impairment of vertical connectivity	0.80

App.1 Table 3: Protected species
(to parameter „Existence of protected species")

№	Bulgarian names	Latin names
	1. ГРЪБНАЧНИ	**1. VERTEBRATES**
	КЛАС БОЗАЙНИЦИ	MAMMALIA
	РАЗРЕД ХИЩНИЦИ	*CARNIVORA*
	Сем. Порови	*Mustelidae*
1	Видра	Lutra lutra
	КЛАС ВЛЕЧУГИ	REPTILIA
	РАЗРЕД КОСТЕНУРКИ	*CHELONIA (TESTUDINES)*
	Сем. Блатни костенурки	*Emydidae*
2	Обикновена блатна костенурка	Emys orbicularis
3	Южна блатна костенурка	Mauremys rivulata (Mauremys caspica rivulata)
	КЛАС ЗЕМНОВОДНИ	AMPHIBIA
	РАЗРЕД ОПАШАТИ	*CAUDATA*
	Сем. Саламандрови	*Salamandridae*
4	Гребенест тритон	Triturus cristatus (T. cristatus cristatus)
5	Добруджански тритон	Triturus dobrogicus (T. cristatus dobrogicus)
6	Голям гребенест тритон	Triturus karelinii (T. cristatus karelinii)
	РАЗРЕД БЕЗОПАШАТИ	*ANURA*
	Сем. Бумки	*Discoglossidae*
7	Червенокоремна бумка	Bombina bombina
8	Жълтокоремна бумка	Bombina variegata
	2. БЕЗГРЪБНАЧНИ	**2. INVERTEBRATES**
	ТИП ЧЛЕНЕСТОНОГИ	ARTHRODOPA
	КЛАС РАКООБРАЗНИ	CRUSTACEA
	РАЗРЕД ДЕСЕТОНОГИ РАКООБРАЗНИ	*DECAPODA*
	Сем. Сладководни прави раци	*Astacidae*
	Ручеен рак	Austropotamobius torrentium
	КЛАС НАСЕКОМИ	INSECTA
	РАЗРЕД ВОДНИ КОНЧЕТА	*ODONATA*
	Сем. Ценагриониди	*Coenagrionidae*
9	Ценагрион	Coenagrion ornatum
	Сем. Гомфиди	*Gomphidae*

10	Офиогомфус	Ophiogomphus cecilia
	Сем. Кобилички, либелулиди	*Libellulidae*
11	Леукориния	Leucorrhinia pectoralis
	РАЗРЕД ПЕПЕРУДИ	*LEPIDOPTERA*
	Сем. Синевки	*Lycaenidae*
12	Лицена	Lycaena dispar
	Сем. Многоцветници	*Nymphalidae*
13	Еуфидриас	Euphydryas aurinia
14	Хидриас	Hypodryas maturna (Euphydryas maturna)

App.1 Table 4: Naturalness of the land cover
(to parameter „Vegetation naturalness")

Code	Types land cover/land use according to LPIS	Description	Naturalness factor
010	Arable land	Heavily modified	0
020	Permanent crop	Semi-natural	0.5
021	Vineyards	Heavily modified	0
022	Orchards	Semi-natural	0.5
023	Other Permanent crop	Semi-natural	0.5
030	Arable land in settlement	Heavily modified	0
031	Kitchen garden	Heavily modified	0
032	Urban territory near settlement	Semi-natural	0.5
040	Pasture and meadow	Natural	1
041	Natural pasture and meadow	Natural	1
043	Grazed woodland	Естествени	1
050	Mixed land use	Semi-natural	0.5
100	Non-arable land	Natural	1
101	Scrub and herbaceous vegetation associations	Natural	1
102	Gully and ravine	Natural	1
103	Dirt road	Heavily modified	0
200	Forest areas	Natural	1
300	Urban fabric	Heavily modified	0
301	Continuous urban fabric	Heavily modified	0
302	Discontinuous urban fabric	Heavily modified	0
303	Sport and leisure facility	Semi-natural	0.5
400	Water body and wetland	Natural	1
401	Rivers and river beds	Natural	1
402	Lakes, dams and swamps	Natural	1
403	Channels	Natural	1
404	Water body near state border	Natural	1
405	Wetlands	Natural	1
500	Disturbed land	Semi-natural	0.5

Code	Types land cover/land use according to LPIS	Description	Naturalness factor
501	Mineral extraction site	Semi-natural	0.5
502	Dump site and tailing pond	Heavily modified	0
600	Transport infrastructure	Heavily modified	0
601	Road with permanent pavement and associated land	Heavily modified	0
602	Rail network and associated land	Heavily modified	0
700	Bare and eroded land	Semi-natural	0.5
701	Sand, gravel and bare rocks	Natural	1
702	Open space with little vegetation	Semi-natural	0.5
800	Other land	Heavily modified	0
801	Small plot of non-arable land	Natural	1
802	Gorge	Natural	1
900	Land with other (non-arable) use	Semi-natural	0.5

App.1 Table 5: Natural habitats, typical for the river corridors
(to parameter „Potential for typical habitats")

Код	Description
1130	Estuaries
1310	Salicornia and other annuals colonising mud and sand
1340	Inland salt meadows
1410	Mediterranean salt meadows
1530	Pannonic salt steppes and salt marshes
2340	Pannonic inland dunes
3130	Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *IsoetoNanojuncetea*
3140	Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* - type vegetation
3260	Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
3270	Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation
6220	Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*
6240	Sub-pannonic steppic grasslands
6410	*Molinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinion caeruleae*)
6420	Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6440	Alluvial meadows of river valleys of the *Cnidion dubii*
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

Код	Description
91F0	Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)
92A0	*Salix alba* and *Populus alba* galleries
92C0	*Platanus orientalis* woods
92D0	Southern riparian galleries and thickets (*NerioTamaricetea* and *Securinegion tinctoriae*)

App.1 Table 6: Presence and status of habitats outside the floodplain boundaries, which are elements of the respective bio-corridor (parameter M)
(to the parameter „Biocorridor, "stepping stone"")

Biocorridor type	Presence and status of habitats outside the floodplain boundaries, which are elements of the respective bio-corridor	Value
Type 1 - Biocorridor connecting riparian forest habitats	Minor area riparian forest habitats located in the floodplain or completely absent.	1
	Small and fragmented riparian forest habitats in the floodplain river terrace.	3
	Relatively large and continuous riparian forest habitats in the floodplain river terrace.	5
Type 2 - Biocorridor connecting forest habitats outside the river floodplain	Negligible or completely absent forest habitats outside the floodplain river terrace.	1
	Small and fragmented forest habitats located outside the river terrace.	3
	Relatively large tracts of forest habitats located outside the river terrace.	5
Type 3 - Biocorridor of riparian wetlands	In the river basin there are no target riparian wetlands, located in active floodplains and there are at most 1 floodplain in a potential floodplain.	1
	In the river basin there are no target riparian wetlands located in active floodplains and there are 2-4 wetlands, located in potential floodplains.	3
	In the river basin there are no target riparian wetlands located in active floodplains and there are 5 or more wetlands, located in potential floodplains.	5
	In the river basin there is one target riparian wetland located in active floodplains and there is up to one wetland, located in potential floodplains.	3
	In the river basin there is one target riparian wetland located in active floodplains and there are more than one wetlands, located in potential floodplains.	5
	In the river basin there are more than one target riparian wetlands located in active floodplains .	5

App.1 Table 71: Presence of migration barriers (parameter B)
(to the parameter „Biocorridor, "stepping stone"")

Biocorridor type	Presence and nature of the migration barriers	Value
Type 1 and Type 2	No significant migration barriers	1
	Partial migration barriers. Roads and other linear infrastructure. Large urban areas with strips of forest vegetation along the river, etc.	0.75
	Presence of significant migration barriers such as dams and extensive urbanised territories without forest vegetation extending through the entire potential river corridor.	0.5
Type 3	No significant migration barriers	1
	Partial migration barriers. Presence of one or more migration barriers for fish of first and second passability level (see **App.1 Table**) that have no considerable impact on water runoff.	0.75
	Significant migration barriers. Presence of one or more migration barriers of first and second passability level that have a considerable impact on the water runoff.	0.5

App.1 Table 8: Scale for fish migration barriers assessment by SNIFFER (2011) and Uzunova (2017)
(to the parameter „Biocorridor, "stepping stone"")

Barrier's score	Impact on the fish population
First degree	Complete migration barrier for fish of all species with the exception of single individuals during certain hydrological periods.
Second degree	The barrier cannot be overcome during most of the year and by most individuals of a given species. A barrier with a major negative impact on the fish populations.
Third degree	Passage is possible during a part of the year and for a considerable number of the individuals of the separate populations. A barrier with a low degree of negative impact.
Forth degree	The barrier can be overcome by all species during most of the year. Increased energy loss for the fish or a delay of the migratory movement.

App.1 Table 9 Scoring of the current status of target habitats, through which the corresponding biocorridor type/ function is realized (parameter A)
(to the parameter „Biocorridor, "stepping stone"")

Biocorridor type	Current status description	Value
Type 1 and Type 2	There are no riparian forest habitats	0
	Small-sized and fragmented riparian forest habitats	0.5
	Comparatively continuous riparian forest habitats in terms of biocorridor function	1
Type 3	There are no riparian wetlands	0

	One or more riparian wetlands - relatively small –sized or under significant anthropogenic pressure.	0.50
	One or more riparian wetlands, at least mediumsized and under a moderate or smaller anthropogenic pressure.	1

App.1 Table 10: Scoring of the potential for restoration or extension of key habitats in the floodplain through which the relevant biocorridor type is realized (parameter P)
(to the parameter „Biocorridor, "stepping stone"")

Biocorridor type	Resrtoration potential - description	Value
Type 1 and Type 2	There is no potential for restoration of riparian forest habitats	0
	There is a potential for restoration of small-sized and fragmented riparian forest habitats,in case they are missing	0.3
	There is a potential for restoration of relatively continuous riparian forest habitats in case of presence of small –sized and fragmented riparian forest habitats.	0.3
	There is a potential for restoration of relatively continuous riparian forest habitats, in case of absence..	0.5
Type 3	There is no potential for restoration of riparian wetlands	0
	There is a potential for increasing the area or reducing the pressure on one or more existing riparian wetlands	0.3
	There is a potential for restoration of one or more riparian wetlands	0.5

App.1 Table 11: Factor on flooding adaptability of land use types
(to the parameter „Land use"")

Land use type code	Land use type	Flooding adaptibility factor value *
010	**ARABLE LAND** Cultivated areas regularly plowed; mainly by crop rotation (crop rotation). Include: Non-irrigated arable land, incl. • Land occupied by cereals, cereals, legumes and forage crops, industrial plantations, root crops and fallow land. • Nurseries (for flowers and saplings), vegetable gardens and plantings, whether outdoors (uncoated) or plastic or glass coated (incl. For commercial flowers). • plantations of aromatic, pharmaceutical and culinary plants. Irrigated arable land (arable land and rice fields) • Crops irrigated constantly and periodically, using	1

	permanent infrastructure (irrigation canals, drainage network). • Rice fields	
020	**PERMANENT CROPS (PERENNIAL CROPS)** Crops not subjected to crop rotation (unchanged) providing repeatable crops and occupying the land for a long time before it is plowed and replanted: mainly tree plantations.	1
021	**Vineyards** Areas planted with vines.	1
022	**Orchard** Areas planted with fruit trees and shrubs: monocultural or mixed fruit species, fruit trees associated with a permanent grass surface.	3
023	**Other permanent crop** Chestnut and walnut forest, as well as other nuts, olive groves, oil rose plantations and other industrial crops.	1
030	**ARABLE LAND IN SETTLEMENT**These areas are located within settlements. They are temporary crops (arable land or grassland) together with permanent crops sharing the same surface. They could form a closed area of small sections of different annual crops, pastures and permanent crops. They may also include discrete urban structures - buildings, highways and areas with artificial cover in conjunction with vegetation areas and "bare" soils	1
031	**Kitchen garden** See description of code 030.	1
032	**Urban territory near settlements** See description of code 030.	1
040	**PASTURE AND MEADOW**Areas with dense, dominant natural grass cover composed of grass species, including flowers and flowering grasses, not subject to crop rotation.	3
041	**Natural pastures and meadows** Natural pastures - arable land, naturally or artificially grassed, that will not be included in crop rotation (crop rotation) for 5 consecutive years from the date of their new use. Used primarily for animal grazing, but feed can also be collected mechanically. Meadows - located outside forests, mainly in flat territories.	3
042	**Pastures and meadows in arable land** This type of land use includes natural grassland representing secondary grassed land. Secondary grassed lands are arable land, artificially grassed or naturally grassed as a result of prolonged non-inclusion in crop rotation .	3
043	**Grazed woodland**This type of land use includes permanent pastures and meadows located in forests, mainly in hilly and mountainous terrains.	3
050	**MIXED LAND USE** This type of land use is associated with non-uniform	3

	agricultural land. Within one area (physical block), none of the agricultural uses occurring in it exceeds 75% of the total area of the physical block. In that areas, annual crops, perennials, complex cultivated plots or land mainly used for crops they may be found, abreast with significant areas of natural vegetation.	
100	**NON-ARABLE LAND** Areas occupied by shrubs and grasslands, gullies and culverts, field roads and clearings.	3
101	**Scrub and herbaceous vegetation associations** Grasslands, often with low shrubs, thorns, brooms, tassels, golden rain and more. The following types are available: • natural grassy areas; • grasslands with predominantly low and closed (up to surface) • mounds and / or shrubs, with shrubby trees; • abandoned arable land, naturally covered with tufts, weeds and herbs, unsuitable for grazing; • Shrubby or grassy vegetation with scattered trees. It can be either forest degradation or forest regeneration / colonization.	3
102	**Gully and ravine** Natural (water) troughs that serve as channels for storm water and snow melt water runoff.	5
103	**Dirt road** Field roads in arable land, livestock paths within permanent grassland and forest clearings wider than 4 m.	3
200	**FOREST** Areas occupied by coniferous, deciduous and mixed forests	5
300	**URBAN FABRIC**	1
301	**Continuous urban fabric**	1
302	**Discontinuous urban fabric**	1
303	**Sport and leisure facility** Green urban areas (parks) and sports and leisure facilities.	1
400	**WATER BODY AND WETLAND** Rivers and river beds, lakes, swamps and dams, canals and wetlands.	5
401	**River and river bed** Permanent and dry rivers and/or their beds.	5
402	**Lake, dam and swamp** Natural or artificial water areas - lakes, fishponds, dams and micro-dams.	5

403	**Channel** Irrigation and drainage channels. The minimum width for the outline, including the adjoining dikes, shrubs, trees, grassland, as a physical block is 4 m.	5
404	**Water body near state border** Danube river and Black sea	5
405	**Wetland** Swamps and other lands cover with water, different than those mentioned above.	5
500	**DISTURBED LAND** There are three types of sites included in this main category: 1. Quarries and open pit mines; 2. Landfills and tailings ponds; and 3. Construction sites.	1
501	**Mineral extraction site** Areas where open-cast mining and non-metallic minerals are mined, areas occupied by construction activities, soil or rock excavations, earth embankments, and adjacent areas and road and railway infrastructure.	1
502	**Dump site and tailing pond** Storage sites for public, industrial and mining waste, as well as their adjacent areas and road and railway infrastructure.	1
600	**TRANSPORT INFRASTRUCTURE**	1
601	**Road with permanent pavement and associated land** Highways with permanent pavement, incl. related facilities (warehouses, bridges, road clovers, office buildings, dikes and embankments).	1
602	**Rail network and associated land** Railways, incl. related facilities (stations, depots, warehouses, contact network, bridges, administrative buildings, dikes and embankments).	1
700	**BARE AND ERODED LAND**	5
701	**Sand, gravel and bare rock** Beaches, dunes, sandy and gravelly areas and bare rocks.	5
702	**Open space with little vegetation**	5
800	**OTHER LAND**	1
801	**Small plot of non-arable land** Lands with an area between 100 and 1000 square meters with	1

	non-agricultural permanent use.	
802	**Gorge** Territories of this type of permanent use are located in narrow river gorges when a river or railway passes along the river line or both. The territory includes all sites, namely rivers and river beds, roads and/or railway lines.	1
900	**LAND WITH OTHER (NON-ARABLE) USE** Other areas forbidden for agricultural use - reserves, national security sites, etc.	1
000	**UNKNOWN LAND USE** If there are physical blocks with this type of land use, they will be excluded from the performance evaluation on this indicator.	0

* The flooding adaptability factor is conformable to the duration of flooding of one month