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 2 – Results

April, 2020

TABLE OF CONTENTS

LIST OF FIGURES:

LIST OF TABLES:

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 contracted as external service and were performed by the team of Bulgarian company "Geopolymorphic Ltd".

This document presents the results of the identification and evaluation of the floodplains along the main river course of Yantra River. The methodology used is based on the methodology and FEM concept, agreed under the project, and further developed according to the river characteristics and the national conditions and data. The methodology is presented in a separate document (Part 1 of the Report).

The methodology for identification of floodplains is designed to delineate two main types of floodplains - active and potential. The active floodplains are those which have a hydraulic connection to the main river channel and the extent of the flooded area depends on the water quantity and the land forms. In the case of hydrotechnical facilities, for example dikes, the border of the active floodplain is limited by them. Potential floodplains include hydrotechnical structures that limit river overflow. In the past, before the construction of these facilities, they have functioned as active floodplains.

An evaluation of the effectiveness of floodplains (active and potential) is made with a view to taking future action to preserve and / or restore them. The methodology created for this purpose involves the survey of floodplains in various aspects, which can be divided into four main groups - hydrological, hydraulic, ecological and socio-economic. Each group includes a number of parameters that are selected so that they can be calculated with accessible, open and nation-wide data.

Both methodologies are applied for the identification and evaluation of all floodplains along the main course of the Yantra River. The floodplains along this course are distinguished by a great variety in terms of their land forms on the one hand and their urbanization on the other. The purpose of considering all floodplains is to investigate a larger set of conditions for the formation of floodplains in Bulgaria.

Identification of Floodplains along of the Yantra River

The methodology for identification of active and potential floodplains will be applied to the main course of the Yantra River.

The Yantra River is 223.5 km long and has a catchment area of 7 862 km2. The river originates from the Shipka part of the Balkan, east of Hadji Dimitar (Buzludzha) Peak 1439.8 m. It crosses the Predbalkan and the Danube Plains and flows into the Danube River near the village of Krivina (Russe), east of Vardim Island.

The catchment area of the Yantra River is fan-shaped - with an extended southern part and a narrowed northern one. The river receives three large tributaries, whose catchment area is equal to nearly 70% of the total catchment area of the Yantra River - Rositsa River (left tributary - 28.6%), Belitsa River (right tributary - 9.4%) and the Lefedzha River (30.9%).

Figure 1: Geographical map of the Yantra River catchment area

This study identifies floodplains along the main Yantra River course. Due to the relatively identical way of determining the active and potential floodplains, they were considered together.

Preliminary assessment of active and potential floodplains along the main course of Yantra River

1. Defining the study area

In this step, the territory with a direct outflow to the Yantra River is defined. According to the Methodology for Identification of Floodplains, this should be done through DEM-based catchment generation approach. In the case of convenience, a polygon layer with surface water bodies was used. Those with direct runoff to the Yantra River were selected, as well as those including the estuaries of rivers flowing into the Yantra River and forming large floodplains, such as the Rositsa River and the Lefedzha River.

The output territory has an area of 2 522 sq. km or about 30% of the total catchment area of the Yantra River. It has a narrow upper part - about 10 km wide, a relatively wider middle part - 20 km and a wide lower part - 40 km. In the next step, the data for the study will be collected for this territory.

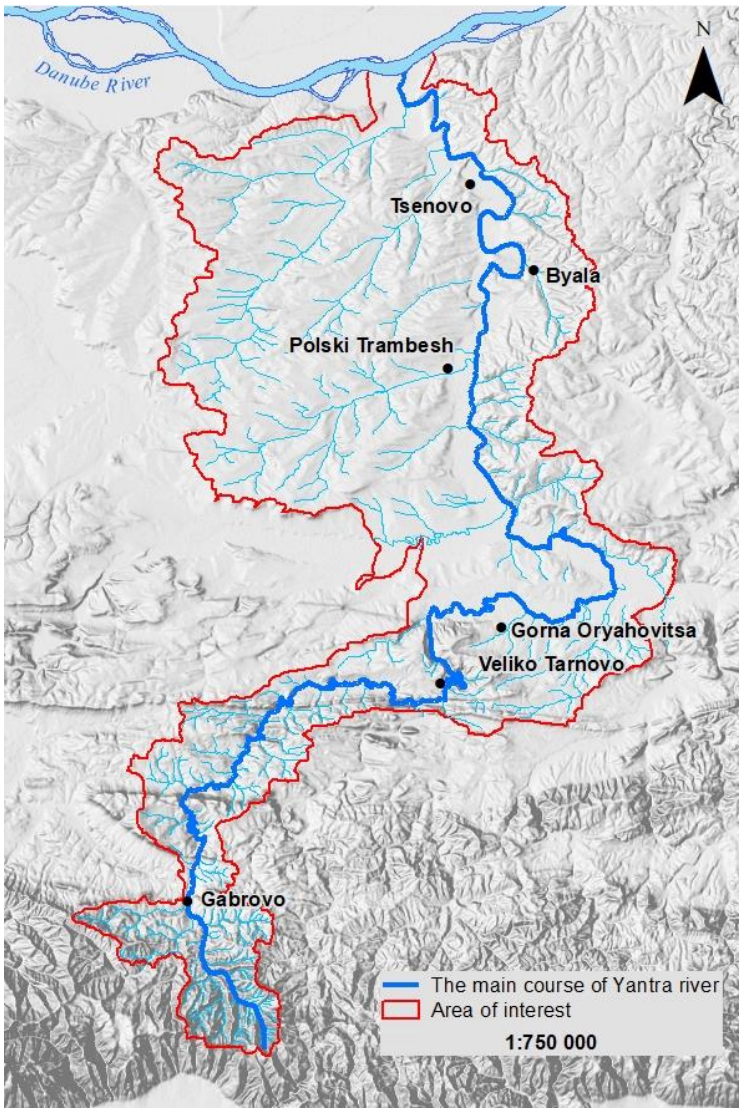

Figure 2: Main course of the Yantra River

2. Data collection

The following data were collected and / or generated for the entire study area:

Digital elevation model (DEM) with cell size 8 m;
Flooded areas corresponding to probability of 1% and 0.1% for river sections falling within the APSFR. They are located near the towns of Byala, Veliko Turnovo and Gabrovo. These river sections cover about 102.5 km or 46% of the total length of the main course of the Yantra River.
Dikes - For the mouth of the Yantra River (approximately 5 km upstream and on the banks of the Danube), the dykes are digitized with high horizontal accuracy. For the rest of the river, they were mapped from large-scale topographic maps (1:5,000). There is no accurate information on the elevation of the dyke crest.
Large scale topographic maps (1:5,000);
Hydrographic data on rivers and standing water bodies have been digitized. For the area around the mouth of the Yantra River there is a linear layer of channels with high horizontal accuracy.
Cadastral data;
Aero photo images from 2011, 2012 and 2014 for different parst of the study area;
Geological maps in scale of 1:100,000;
Archival satellite images before dike construction along Yantra River.

Collected data are organized in a common GIS database.

3. Identification of geomorphological floodplain

The identification of the geomorphologic floodplain was made for the entire course of the Yantra River by slope-based analysis. The boundaries of the delineated floodplains were refined using large-scale topographic maps and geological maps. Due to their small scale (1: 100,000), the geological maps were only applicable in the lower course of the Yantra River, where the river forms wide floodplains.

4. Hydraulic modeling

The floodplains definition is based on the results of a non-stationary two-dimensional hydraulic model. The hydraulic model SRH-2D was used. Models are defined using an unstructured network of triangular and quadrangular elements, varying in size to minimize defects in the digital terrain model (Figure 3 and Figure 4).

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

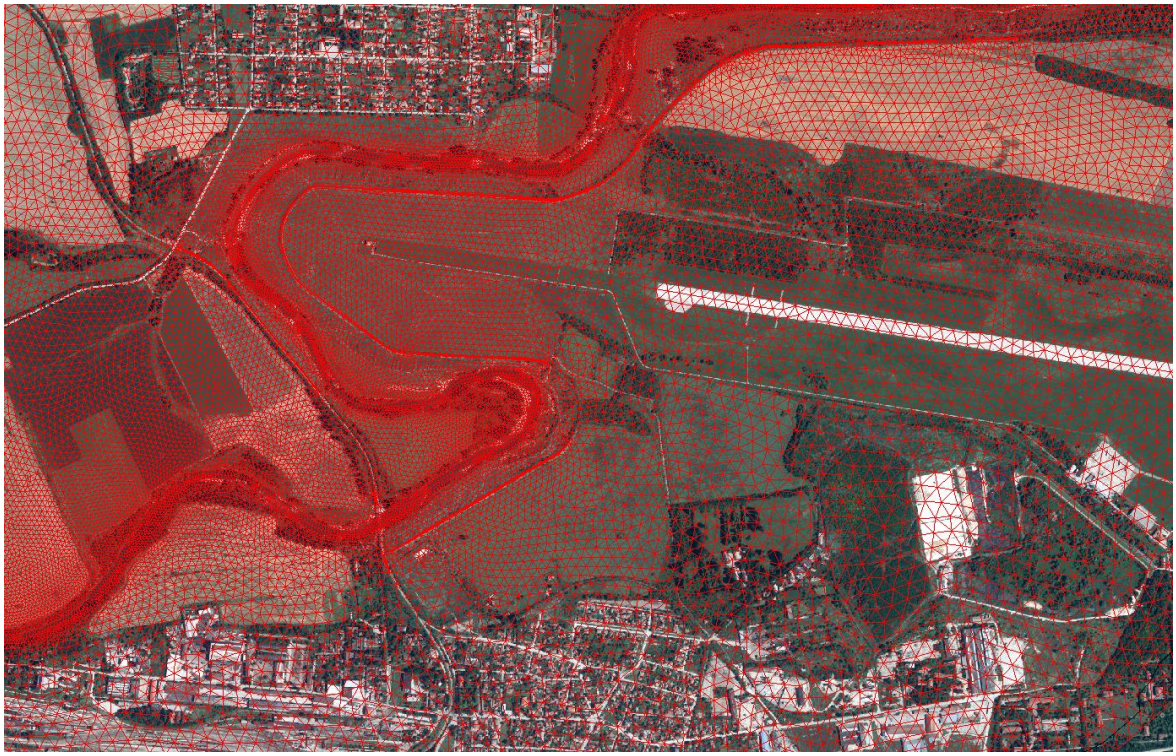

Figure 3: Computing network

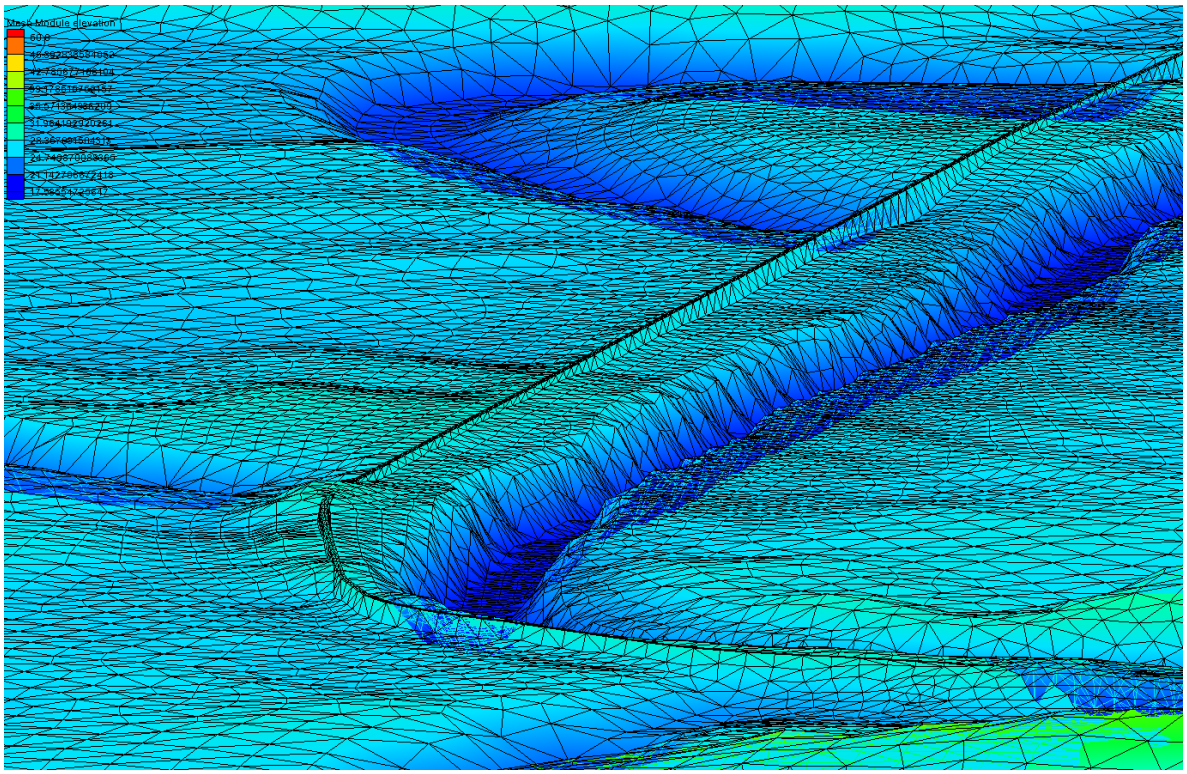

Figure 4: Computing network based on digital elevation model with dykes and riverbed

The poor quality of DEM is the reason for serious numerical instabilities in the computational model, which makes it impossible to determine the flow parameters. For this reason, some of the floodplains cannot be evaluated until a qualitative basis is obtained.

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

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

6. Defining the water mirror of the river

The water mirror of the Yantra River from the town of Gabrovo to the mouth of the river is digitized on the basis of actual aerial photos.

7. Defining the beginning and the end of the floodplains

Defining the floodplains beginning and end places was made on the basis of the accepted criterion for the ratio between the width of the floodplain and the width of the water mirror to be greater than 1. On this basis, 22 floodplains were determined along the main course of the Yantra River - 12 active and 10 potential.

Refining the boundaries of the active and potential floodplains along the main course of the Yantra River

This step of the Methodology involves conducting a detailed hydrological study using the approaches described in (Methodology for determining adjacent lands and floodplain areas in Bulgaria, 2012) and hydraulic testing with a 1D or, if necessary, a 2D model. A very high DEM precision is required. This step is beyond the scope of this study. Therefore, the designated floodplains will not change.

Classification of floodplains according to their size

The location of each floodplain along the Yantra River - upper, middle or lower part of the riever - has been made.

The river section from springs to the village of Vetrintsi was accepted as upper course of the Yantra River. Its length is 58.2 km. For the middle course, the section up to the confluence of the Lefedzha River was accepted. It is 75.9 km long. The rest of the river is part of lower course and is 90.4 km long.

After applying the thresholds for a minimum size of floodplains, two active floodplains in the lower course were excluded from the list.

The final result from identification of floodplains along the Yantra River is 10 active and 10 potentail floodplains. A list of floodplains is presented in Table 1, and Figure 5 shows their exact location.

Table 1: List of floodplains along the main course of the Yantra River

ACTIVE FLOODPLAINS

BG_YN_AFP_001	Area: 568 ha	Vardim (10118) Novgrad (51977) Krivina (39788) Batin (02854)
BG_YN_AFP_002	Area: 141 ha	Byala (07603) Starmen (70130)
BG_YN_AFP_003	Area: 238 ha	Byala (07603)

BG_YN_AFP_004	Area: 2129 ha	Dolna Oryahovitsa (22232) Lyaskovets (44793) Gorski dolen Trambesh (17124) Varbitsa (12735) Bryagovitsa (06731) Kessarevo (36782) Dzhulyunitsa (20835) Kozarevets (37664) Pissarevo (56472)
BG_YN_AFP_005	Area: 700 ha	Dolna Oryahovitsa (22232) Gorna Oryahovitsa (16359) Pravda (57981) Parvomaytsi (59094) Samovodene (65200)
BG_YN_AFP_006	Area: 64 ha	Veliko Tarnovo (10447) Shemshevo (83586)
BG_YN_AFP_007	Area: 458 ha	Shemshevo (83586) Lednik (43253) Pushevo (58791)
BG_YN_AFP_008	Area: 112 ha	Vetrintsi (10879) Gostilitsa (17350) Kalomen (35465)
BG_YN_AFP_009	Area: 24 ha	Kalomen (35465) Gostilitsa (17350) Chukovo (81726)
BG_YN_AFP_010*	Area: 421 ha	Gostilitsa (17350) Slaveykovo (66977) Skalsko (66768) Yantra (87463)
POTENTIAL FLOODPLAINS		
BG_YN_PFP_001	Area: 3276 ha	Vardim (10118) Karamanovo (36316) Novgrad (51977) Krivina (39788) Batin (02854)
BG_YN_PFP_002	Area: 1130 ha	Dzhulyunitsa (20849) Piperkovo (56366) Beltsov (03745) Tsenovo (78361)
BG_YN_PFP_003	Area: 794 ha	Tsenovo (78361) Dolna Studena (22277)
BG_YN_PFP_004	Area: 1040 ha	Dolna Studena (22277) Starmen (70130) Botrov (05877) Byala (07603)

BG_YN_PFP_005	Area: 595 ha	Byala (07603) Polsko Kossovo (57368)
BG_YN_PFP_006	Area: 1606 ha	Byala (07603) Polski Trambesh (57354) Polsko Kossovo (57368) Karantsi (36405)
BG_YN_PFP_007	Area: 1375 ha	Polski Trambesh (57354) Karantsi (36405) Radanovo (61279) Polski Senovets (57340) Petko Karavelovo (65471)
BG_YN_PFP_008	Area: 2403 ha	Petko Karavelovo (65471) Kutsina (40782) Krusheto (40172) Yntra (87453)
BG_YN_PFP_009*	Area: 1494 ha	Krusheto (40172) Yantra (87453) Draganovo (23100)
BG_YN_PFP_010*	Area: 1425 ha	Dolna Oryahovitsa (22232) Gorski dolen Trambesh (17124) Varbitsa (12735) Draganovo (23100)

* For the indicated floodplains, overall evaluation was not performed due to poor DEM quality, which causes serious numerical instability in the computational model.

As a result of the floodpain identification, a GIS dataset of the identified flodplains is created. A passport , describing the basic characteristics is elaborated for all FPs.

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.

The template of the floodplains is presented in the Part 1 of the Report (methodology).

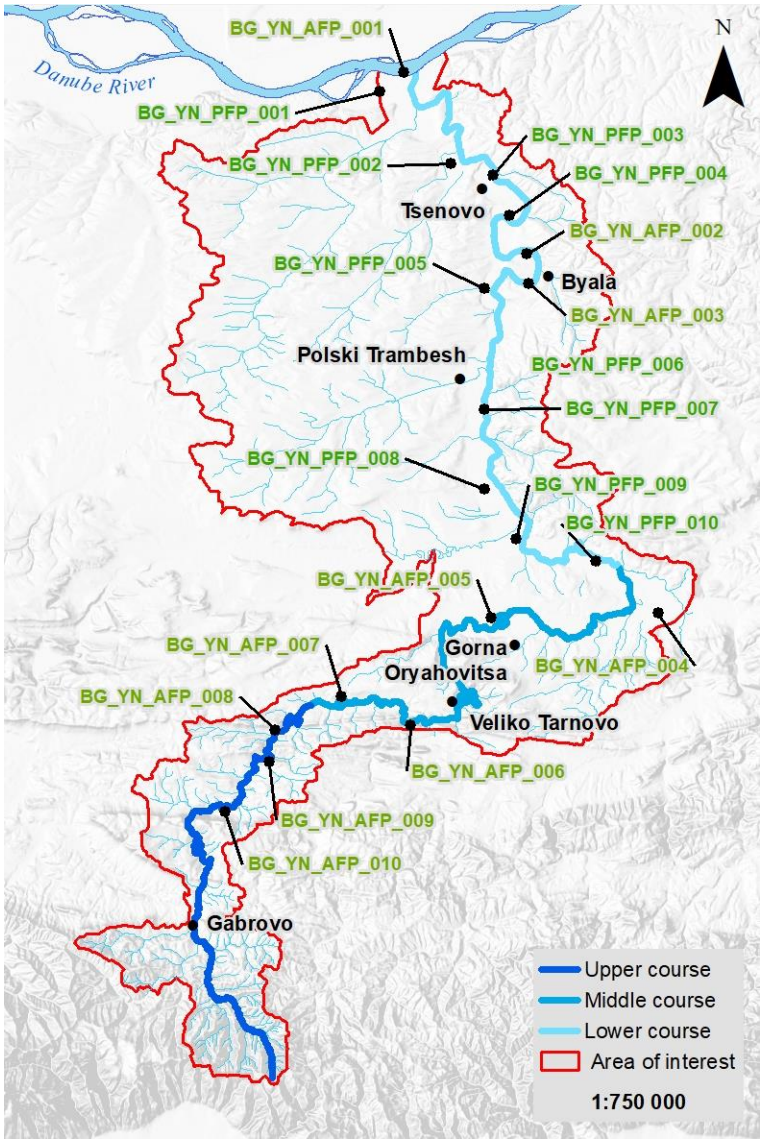

Figure 5: Map showing the position of the floodplains along the Yantra River main course - upper, middle and lower.

Evaluation of the Efficiency of Floodplains along the Yantra River

The methodology for assessing efficiency was applied to all floodplains – active and potential, identified in Table 1, positioned along the main course of Yntra River.

The assessment was performed for the parameters and according to the approaches, incl. tresholds, presented in the Part1 of the Report. Besides the table with the asessment rezults, detail maps presenting the evaluation by parameters were created for each floodplain,

HYDROLOGICAL AND HYDRAULIC PARAMETERS

The hydrological parameters used to evaluate the effectiveness of floodplains are:

- Flood peak reduction;
- Flood wave translation;
- Effect in case of extreme discharge;
- Simple hydro-morphological evaluation*.

*) the parameter is proposed and used at national level; it is not included in the ptroject's FEM

The hydraulic parameters used to evaluate the effectiveness of floodplains are:

Water level;
Flow velocity.

The calculation of hydrological and hydraulic parameters is based on the results of a non-stationary two-dimensional hydraulic model. The hydraulic model SRH-2D was used. The models are defined using an unstructured network of triangular and quadrangular elements, varying in size to minimize defects in the digital terrain model. The model is built on the basis of a digital elevation model with cell size of 8 m, described in **Hydraulic modeling**.

The coefficients of roughing are determined on the basis of the land cover data of the LPIS land use layer (Figure 6). The reason is that there is no information available on the water levels and water quantities in the Yantra River needed to calibrate the model. Hydrographs of the high wave entering the study section are used as upper boundary conditions for hydraulic models, and key curves are used as lower boundary conditions.

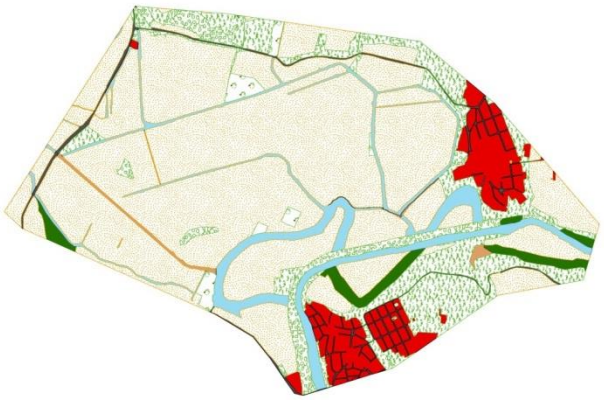

Figure 6: Map of land cover / land use types

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% or 0.1%, which is this particular case is obtained by implementation of regional relations.

The hydrograph $\boldsymbol{Q = f(t)}$ is built using table 9.11 in the (Gerassimov, 1980), which actually is calculated from the equation:

$$y = 10^{-a\frac{(1-x)^2}{x}} \quad (1)$$

where,

$\boldsymbol{y = \frac{Q}{Q_p}}$ and $\boldsymbol{x = \frac{t}{t_p}}$ are relative coordinates;

$\boldsymbol{a = f(\lambda)}$ is a parameter, which depend on the hydrograph's shape coefficient $\boldsymbol{\lambda = \frac{Q_p.t_п}{W_p}}$

For each λ there is a certain value of the coefficient of asymmetry of the hydrograph.

$$K_s = \frac{W_п}{W_p} = f(\lambda) \quad (2)$$

where,

$\boldsymbol{W_п}$ is the volume of the flood wave from its start up to the peak of the hydrograph.

The coefficient $\boldsymbol{K_s}$ is determined using an analogue catchment with similar parameters and then $\boldsymbol{\lambda = \lambda_a}$, which is given in the table. The rise time of the hydrograph can be calculated using the equation $\boldsymbol{t_п = \frac{\lambda_a W_p}{Q_p}}$. When these parameters are calculated, using the relative coordinates, given in the table, mentioned above, the absolute coordinates $\boldsymbol{t = x.t_п}$ and $\boldsymbol{Q = y.Q_p}$ can be obtained easily.

Figure 7: High wave hydrograph used in the computational model

The results from the models are the water level, the maximum extent of flooding, depths, flow

velocities. (Figure 8). In each of the computational models, the input and output hydrographs necessary to determine the hydrological performance are recorded.

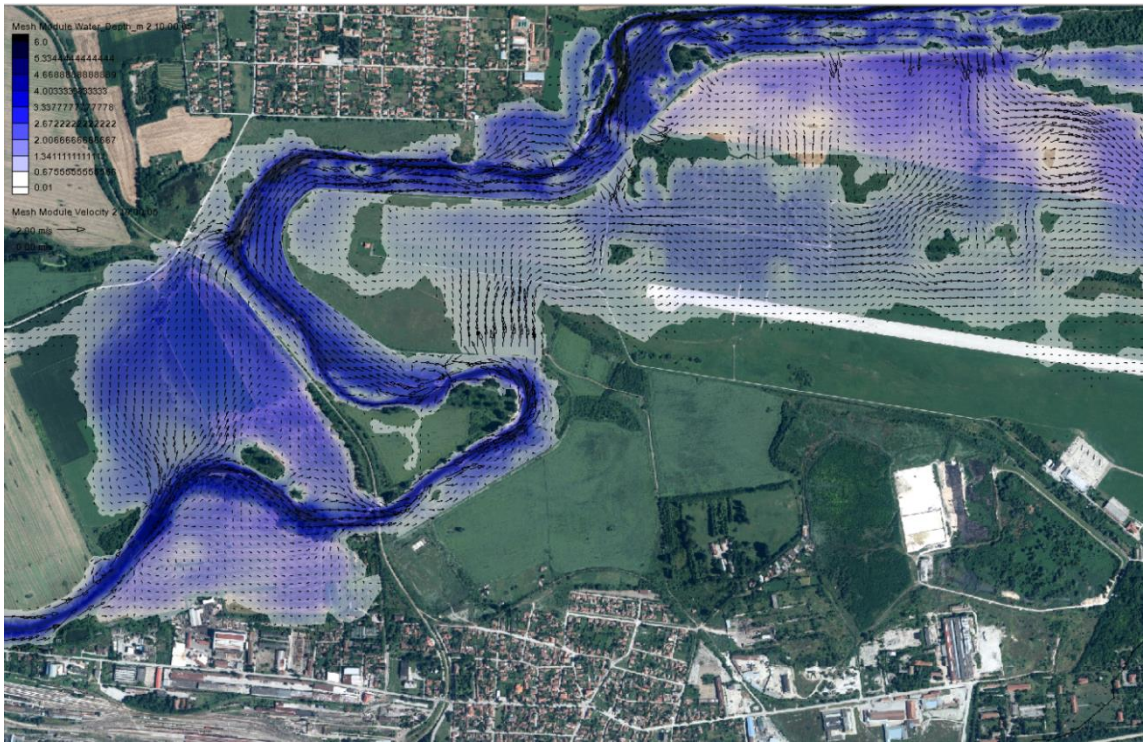

Figure 8: Flood extent, flood depths, flow velocities

Due to the very low quality of the available digital terrain model and the presence of local elevations and reductions in the riverbed, the bottom tangential stresses calculated from the model are incorrect and should not be used as an evaluation criterion until a quality model is obtained.
The poor quality of DEM is the reason for serious numerical instabilities in the computational model, which makes it impossible to determine the flow parameters. For this reason, some of the floodplains cannot be evaluated until a qualitative basis is obtained.

Hydrographs on floodplains

The following hydrographs have been calculated for the floodplains along the main course of the Yantra River.

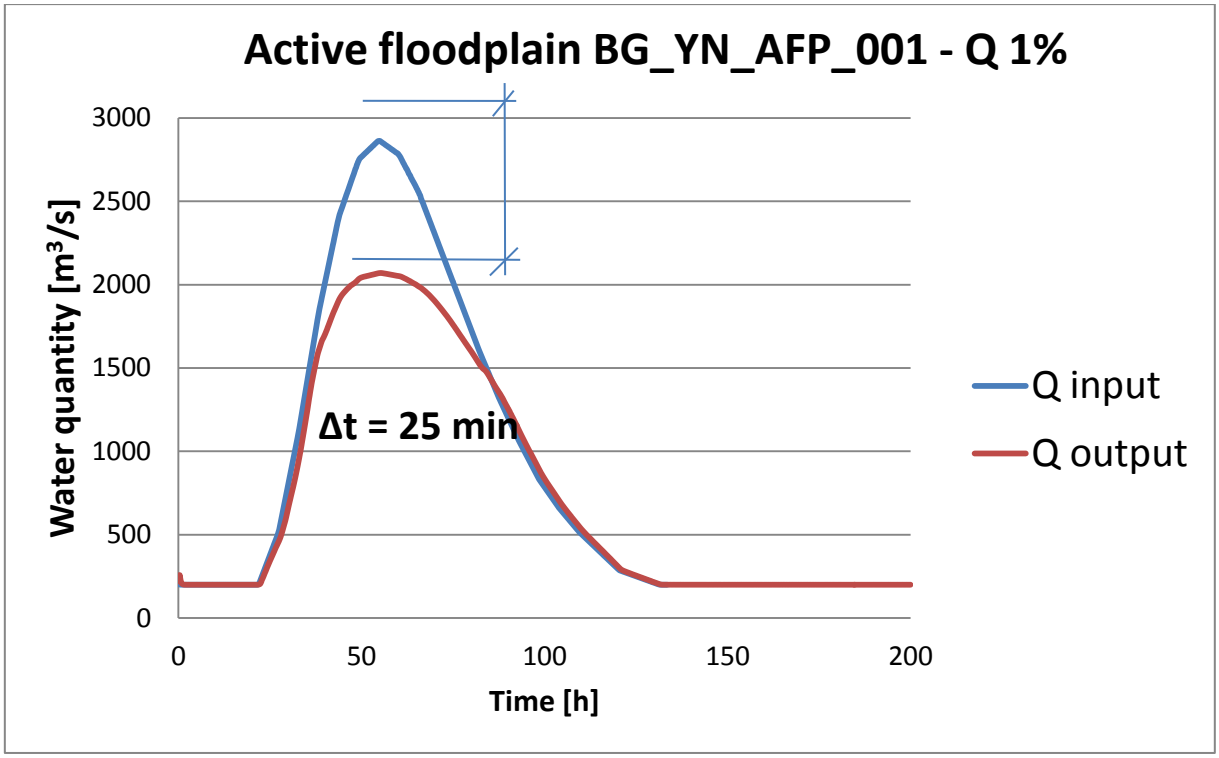

Figure 9: Hydrograph of active floodplain BG_YN_AFP_001

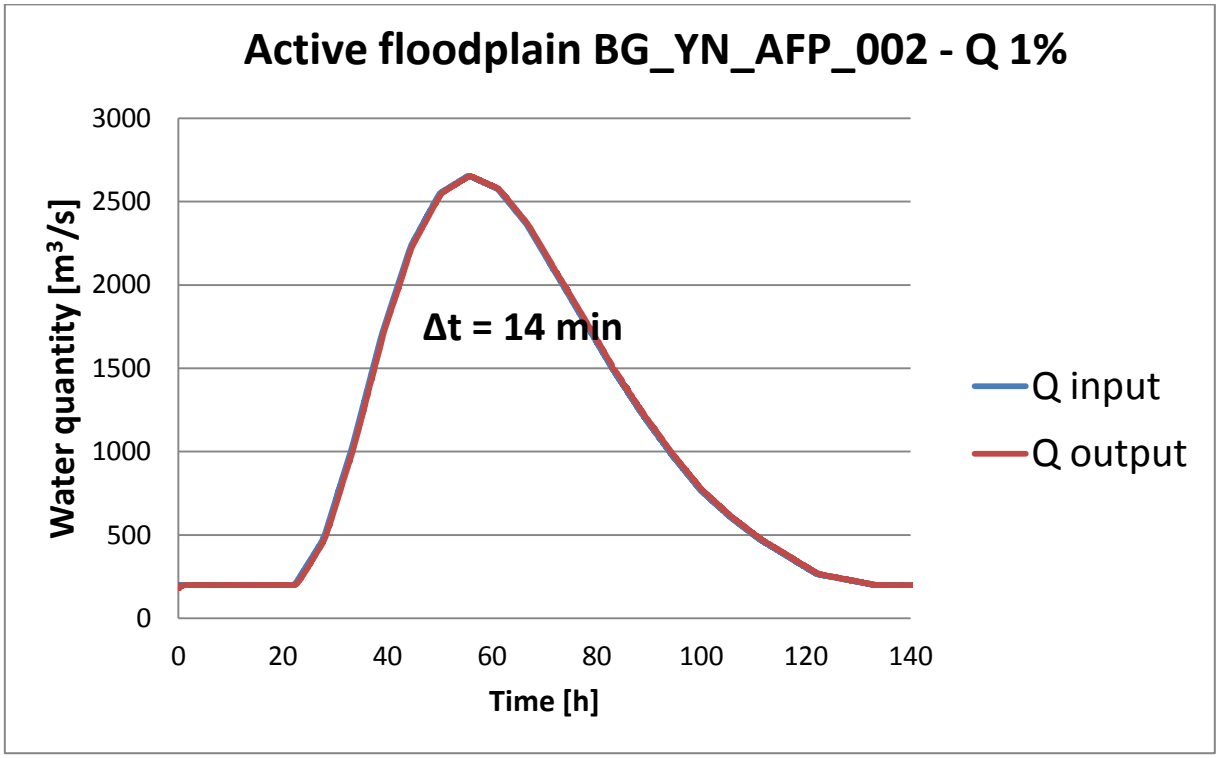

Figure 10: Hydrograph of active floodplain BG_YN_AFP_002

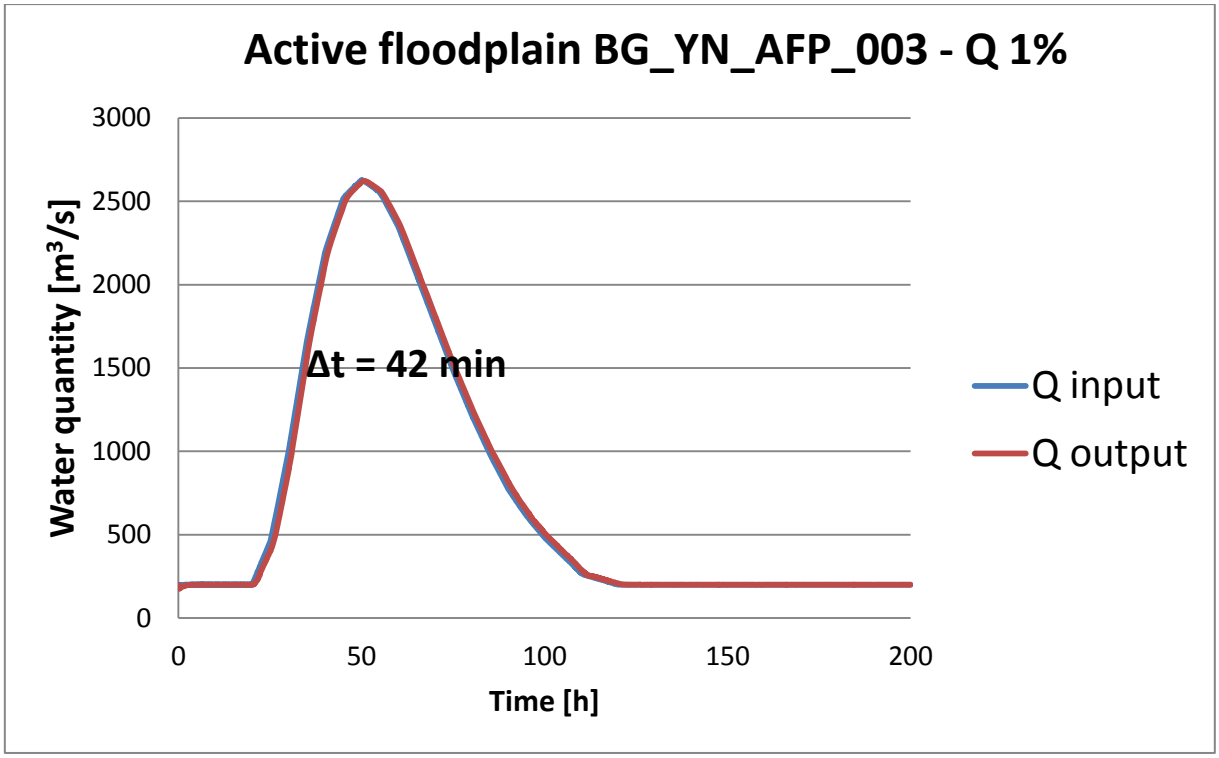

Figure 11: Hydrograph of active floodplain BG_YN_AFP_003

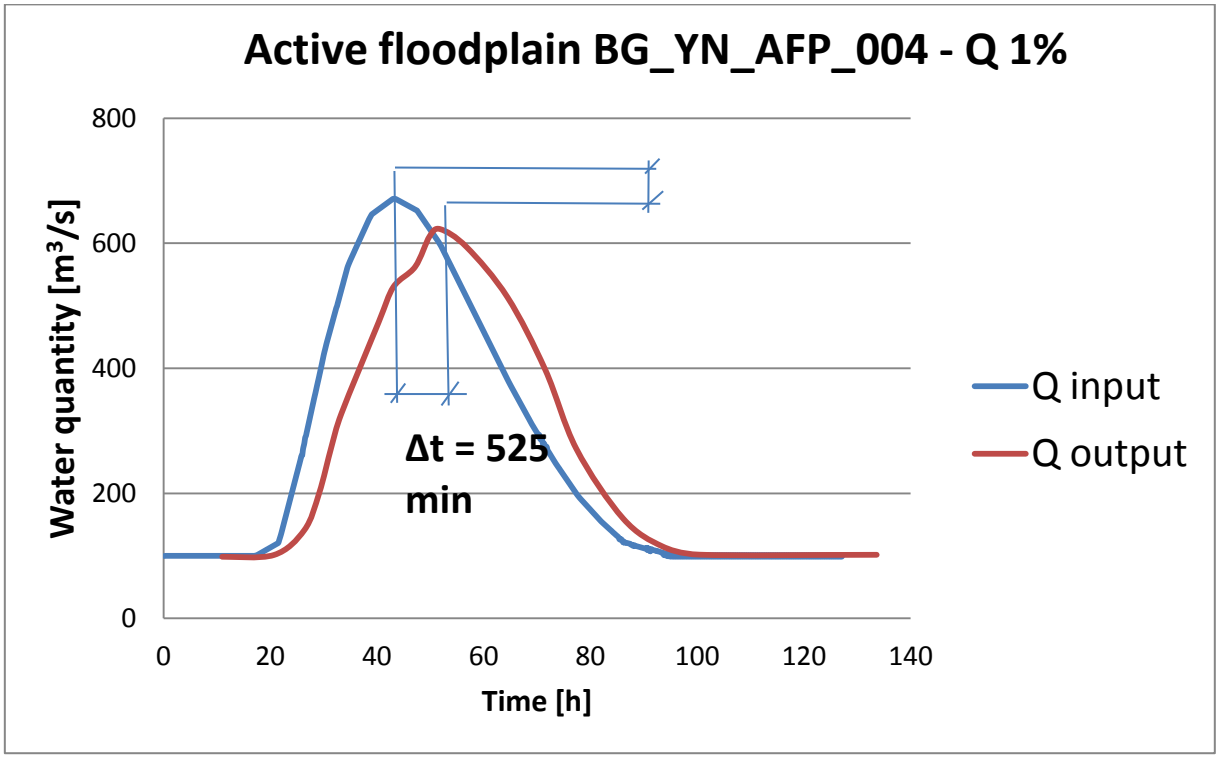

Figure 12: Hydrograph of active floodplain BG_YN_AFP_004

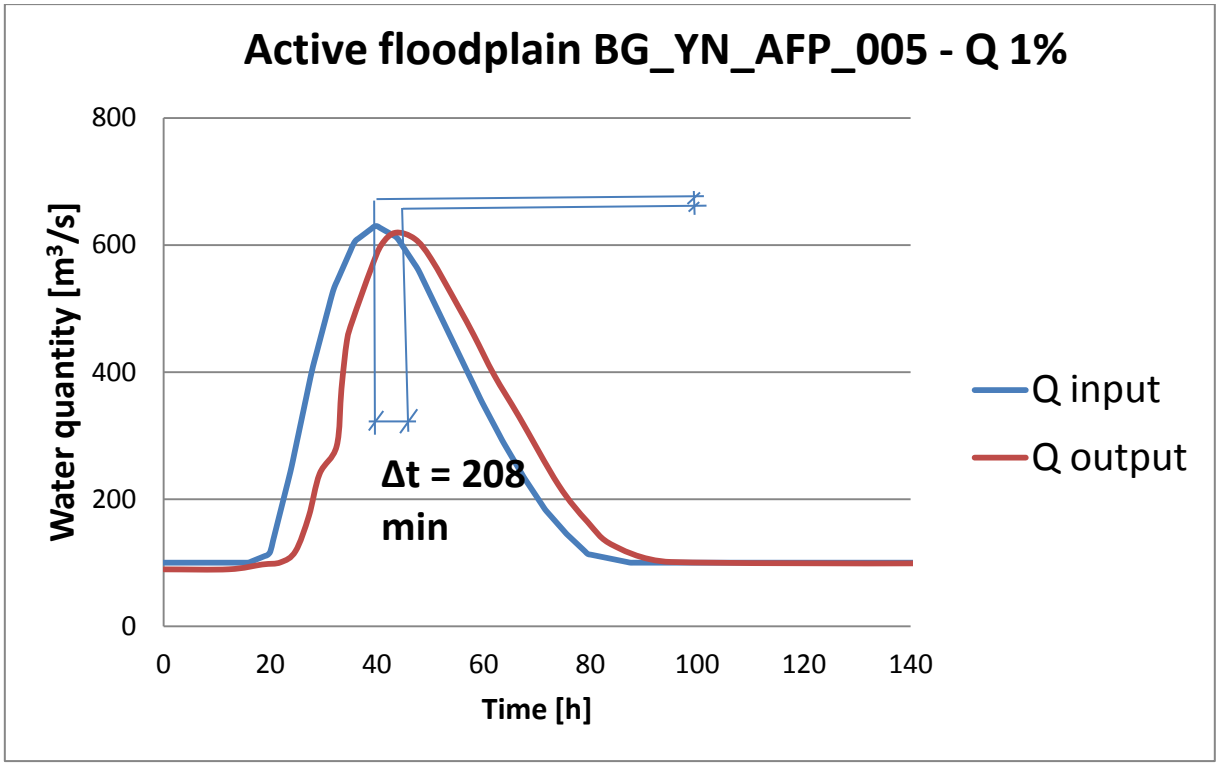

Figure 13: Hydrograph of active floodplain BG_YN_AFP_005

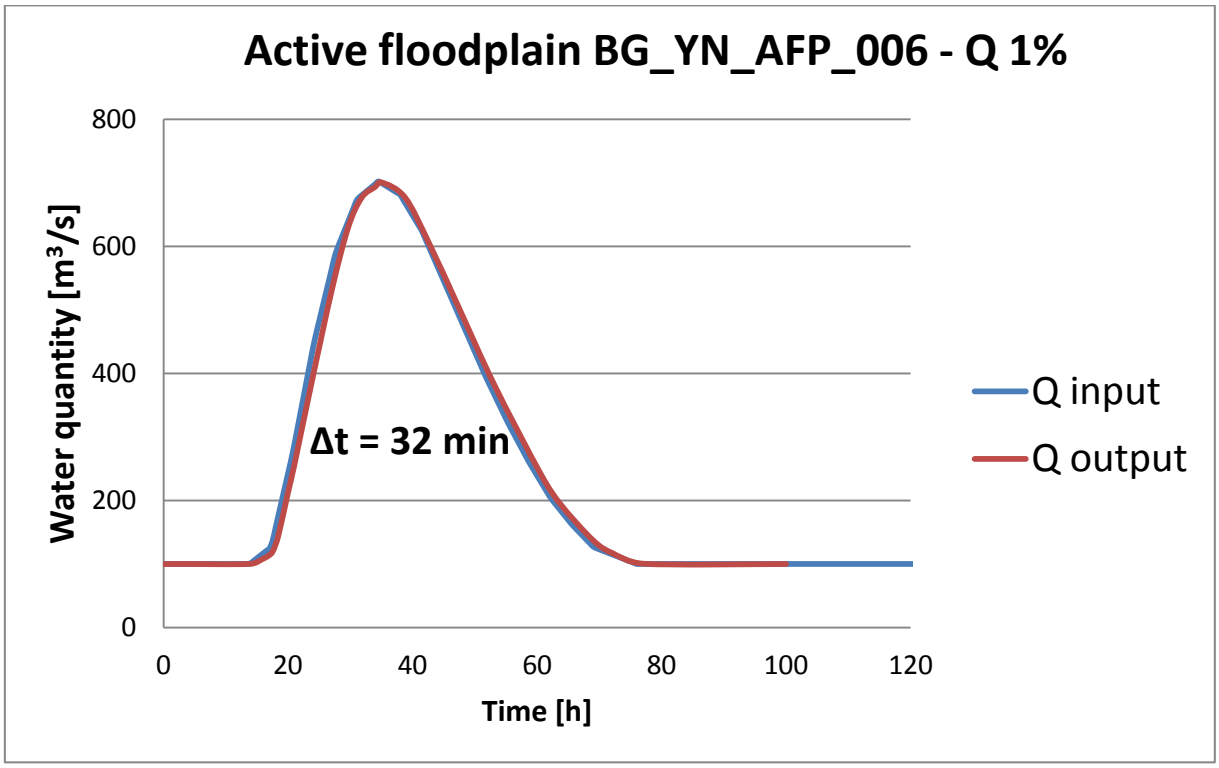

Figure 14: Hydrograph of active floodplain BG_YN_AFP_006

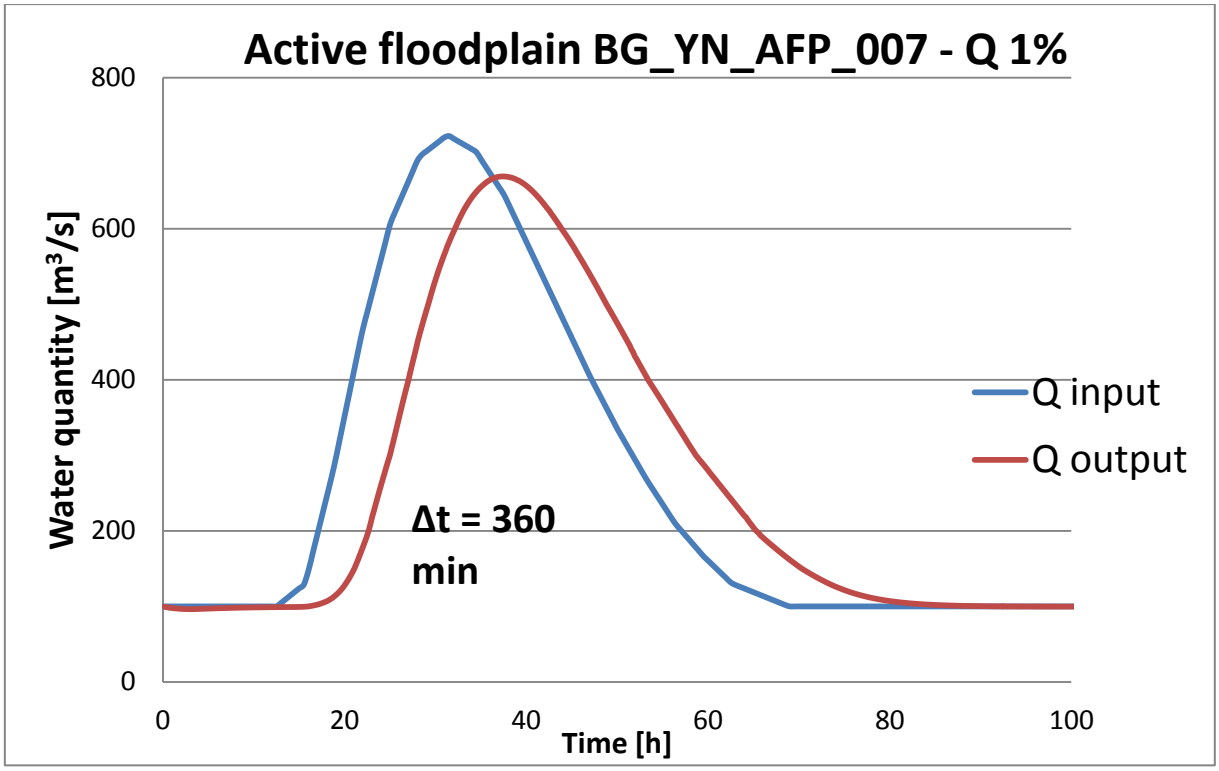

Figure 15: Hydrograph of active floodplain BG_YN_AFP_007

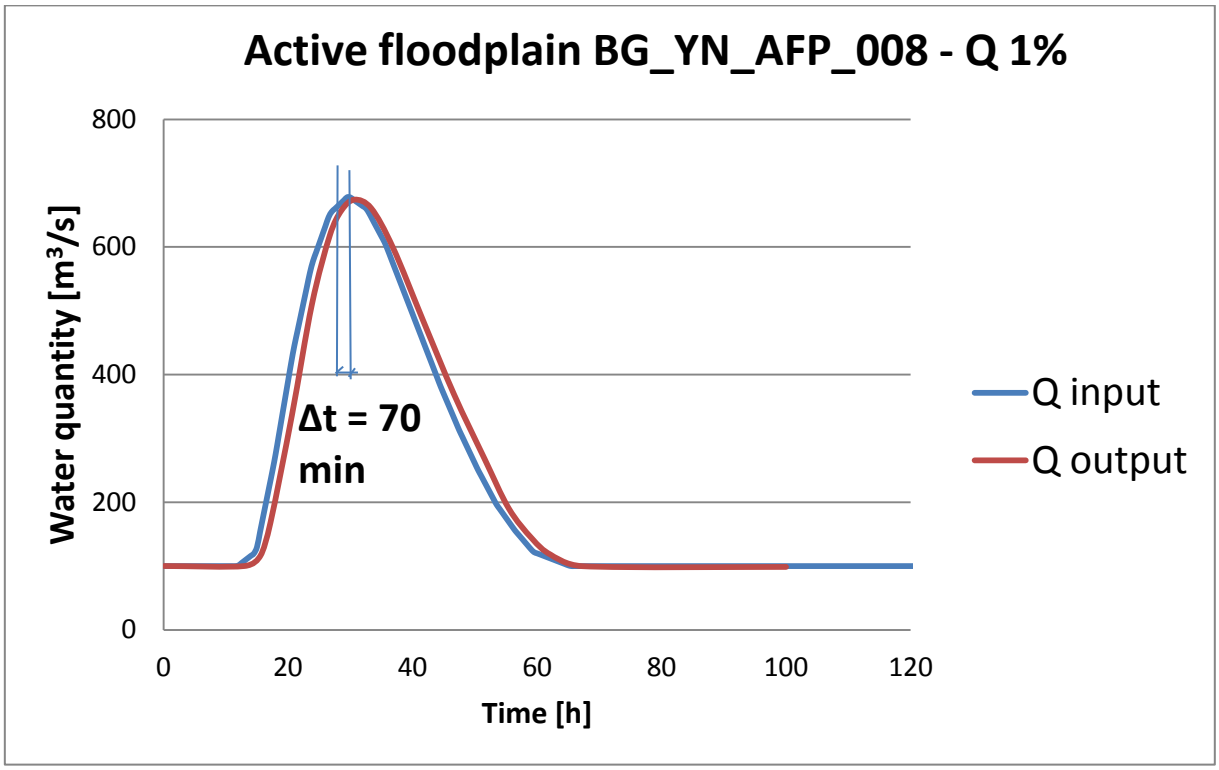

Figure 16: Hydrograph of active floodplain BG_YN_AFP_008

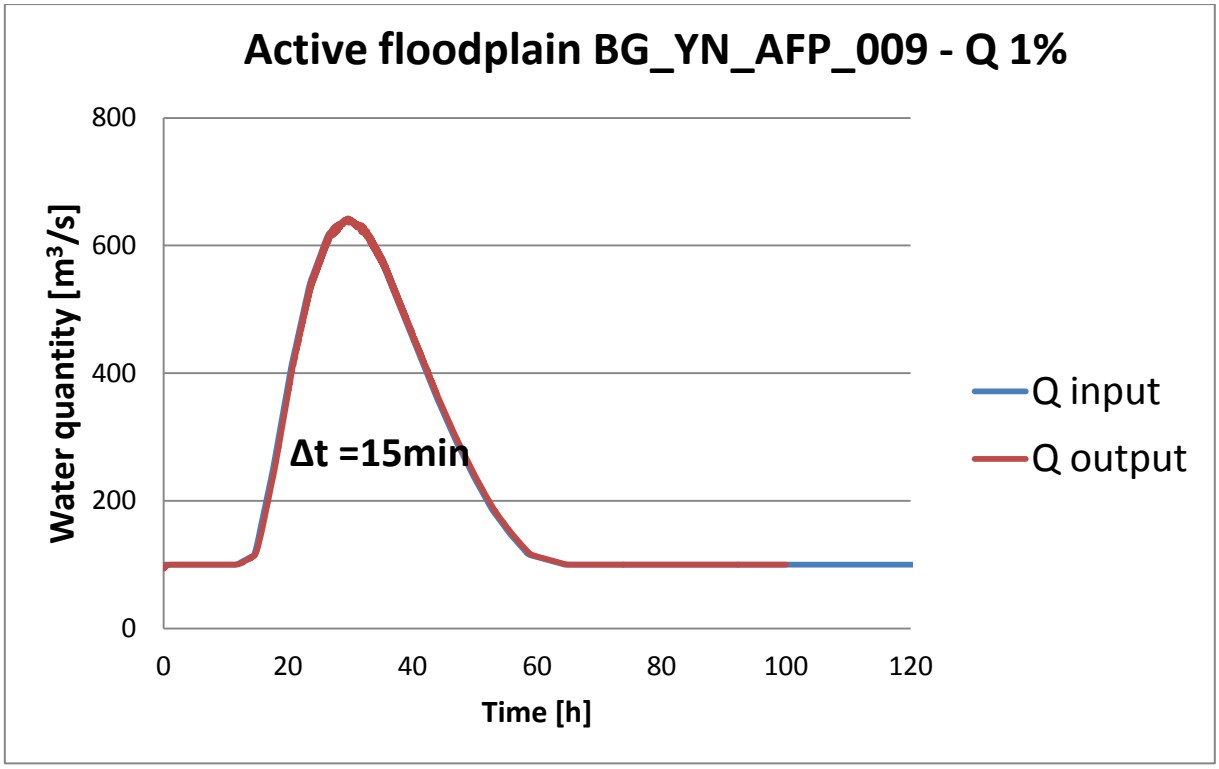

Figure 17: Hydrograph of active floodplain BG_YN_AFP_009

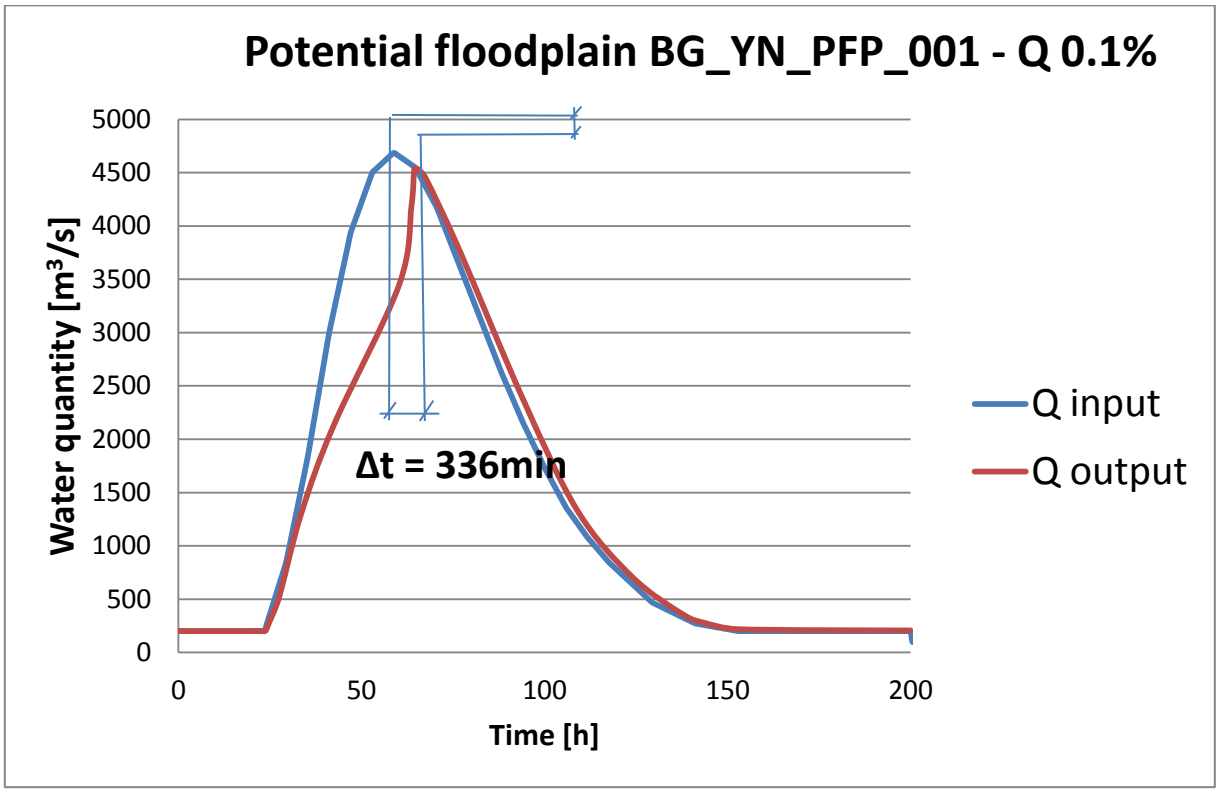

Figure 18: Hydrograph of potential floodplain BG_YN_PFP_001

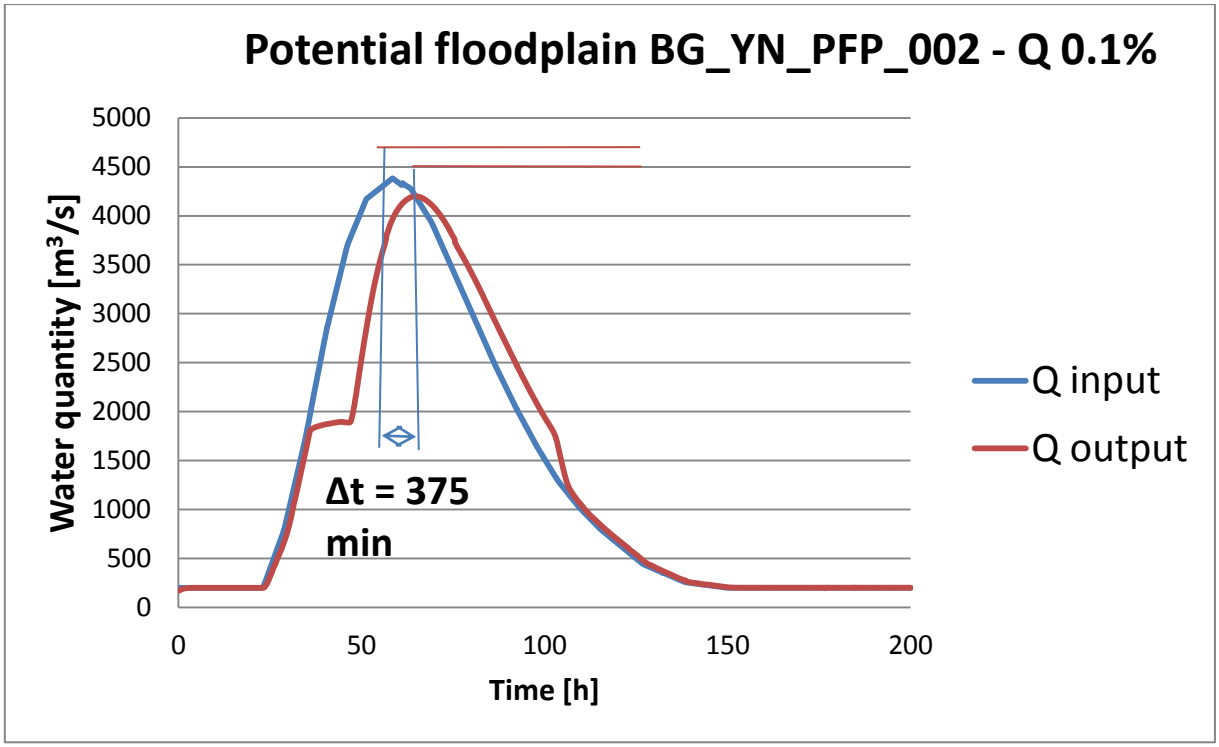

Figure 19: Hydrograph of potential floodplain BG_YN_PFP_002

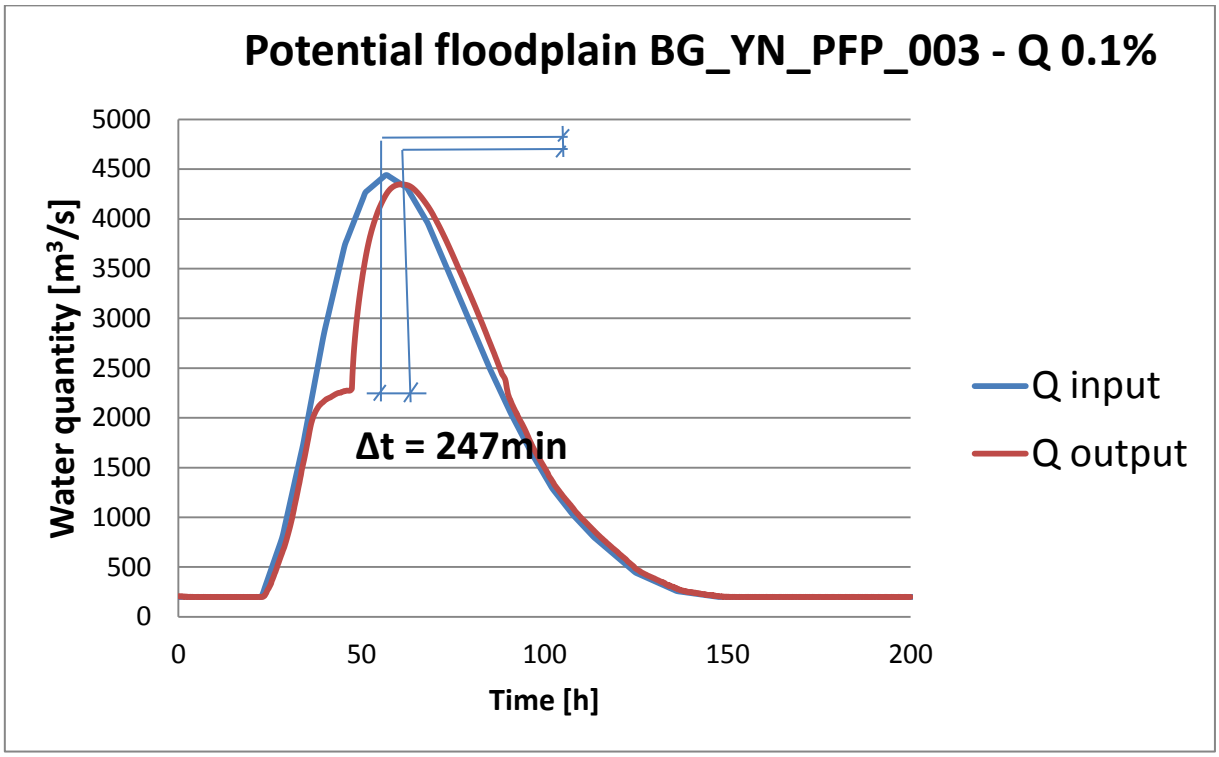

Figure 20: Hydrograph of potential floodplain BG_YN_PFP_003

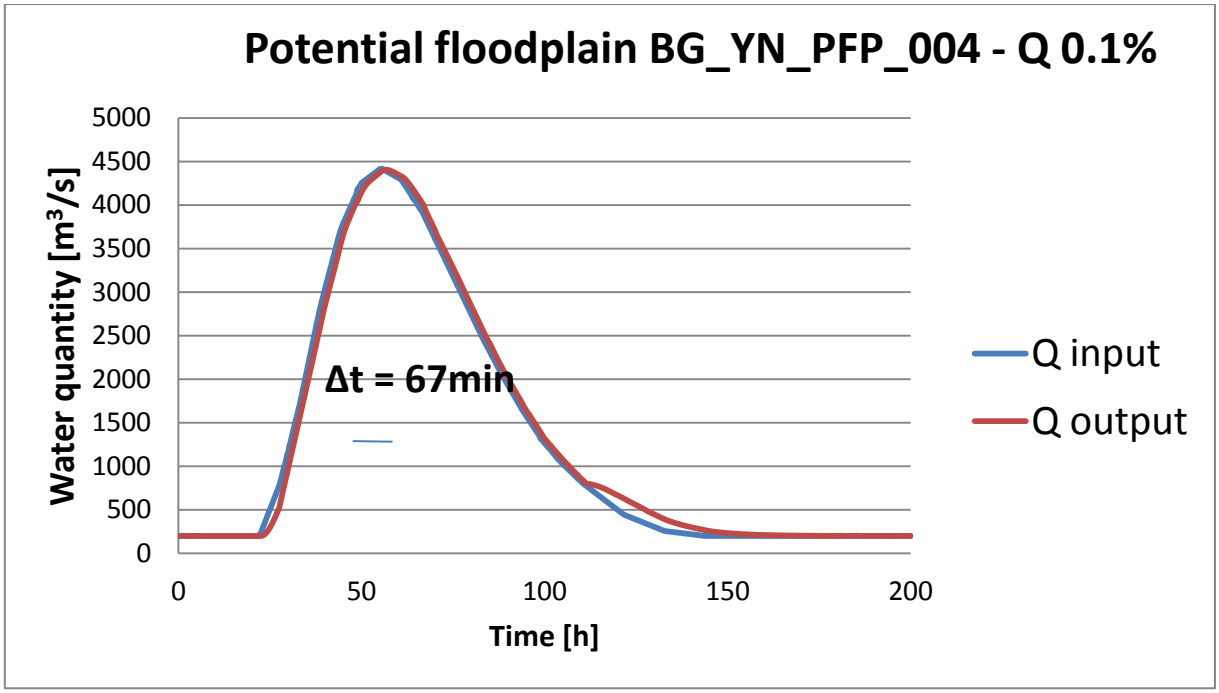

Figure 21: Hydrograph of potential floodplain BG_YN_PFP_004

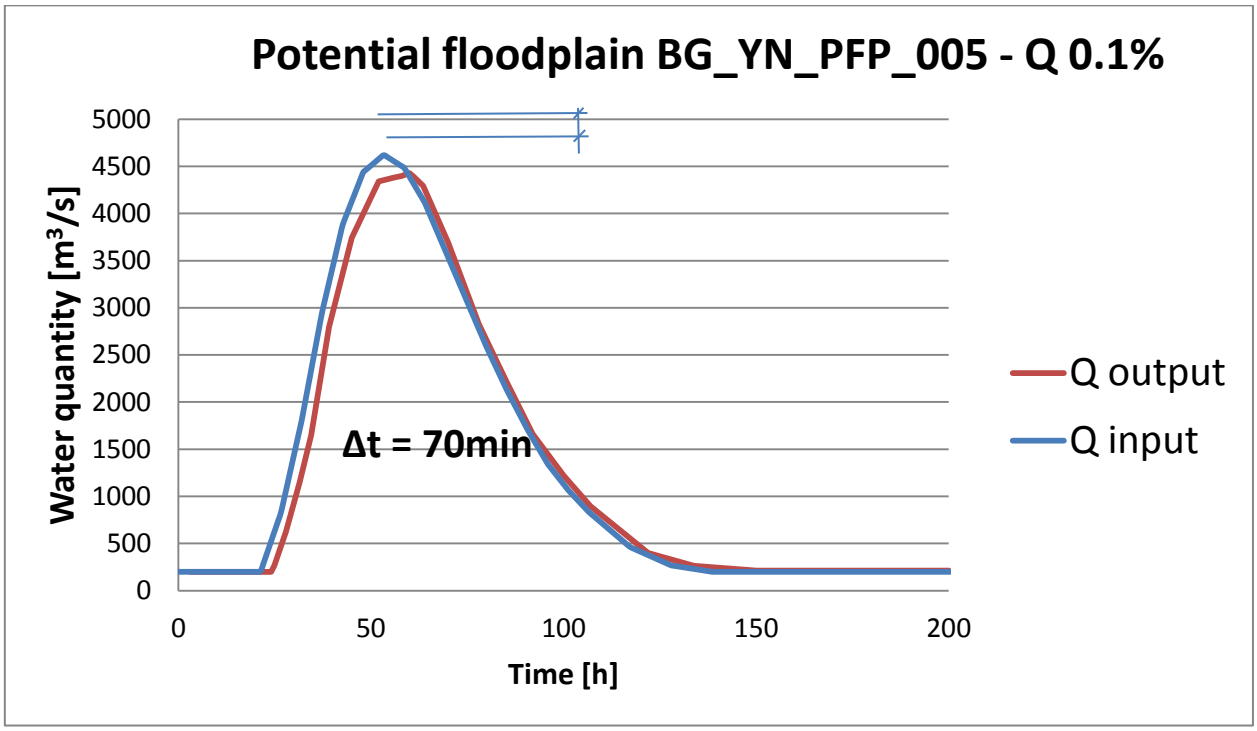

Figure 22: Hydrograph of potential floodplain BG_YN_PFP_005

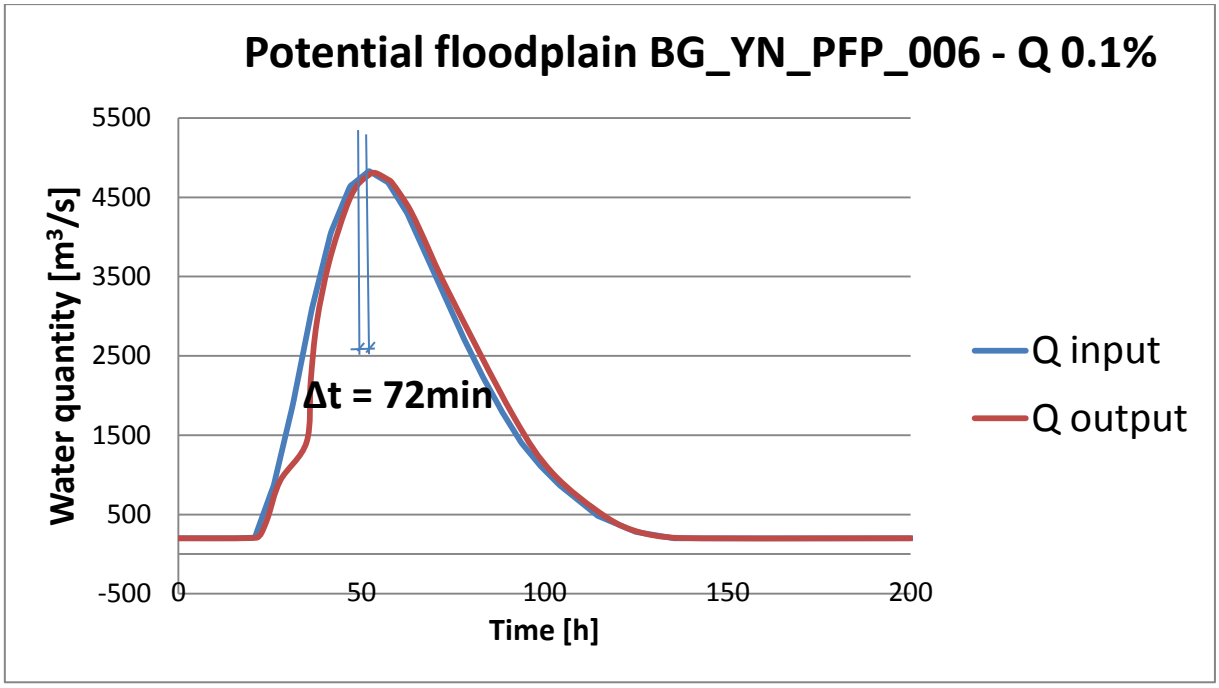

Figure 23: Hydrograph of potential floodplain BG_YN_PFP_006

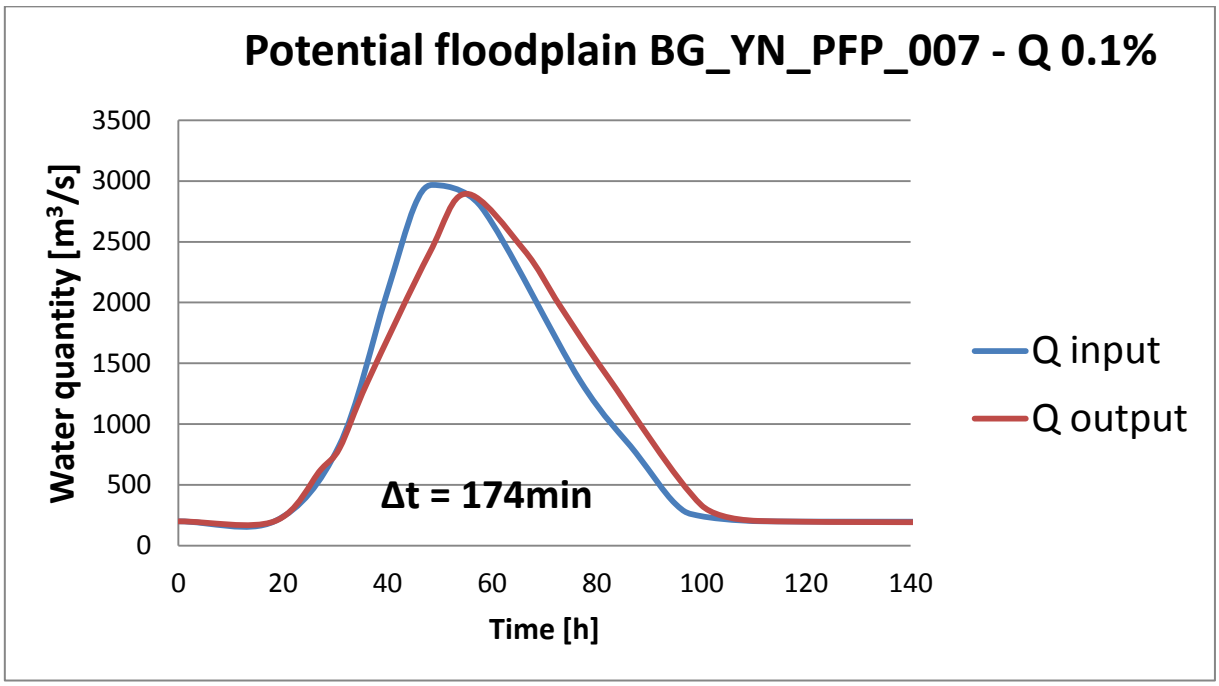

Figure 24: Hydrograph of potential floodplain BG_YN_PFP_007

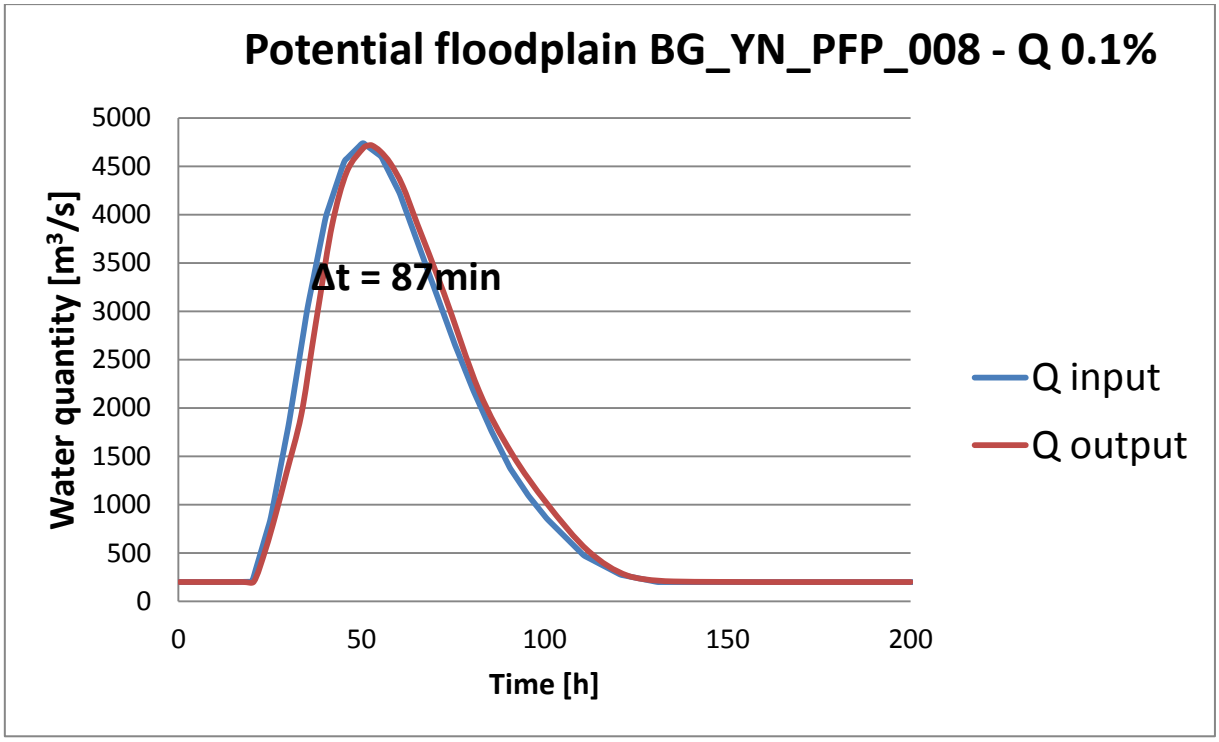

Figure 25: Hydrograph of potential floodplain BG_YN_PFP_008

"Simple hydro-morphological evaluation" parameter shows the effect of floodplain restoration on the stability of the river section. 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.

The Yantra River has been adjusted using dikes in part of its middle course and almost entirely in its lower course. The exploration of the old river bed was done through archival satellite images. These satellite images are valuable information for studying the morphology of the rivers during a long period of time. Such source of information for the previous century together with the aerial photos represents the series of satellites images which are made available at the USGS repositories. For the period 1960-1984 several thousands of images for the whole world were declassified from former U.S. photo intelligence satellites Hexagon, Corona, Argon and Lanyard. After 1992 the data were evaluated for environmental studies, and since their data were no longer critical to the U.S. security, the data were declassified and used for global research. The satellites acquired photographs of the Earth's surface with a telescopic camera system and transported the exposed film through the use of recovery capsules. The spatial resolution of the data varies from very high resolution 2-4 feet, to low resolution 460 feet. Corona archival satellite images from 1968 have been used for the purposes of this study and georeferenced with good accuracy. In some of the satellite images, the Yantra River has not yet been corrected, while in others it has been done relatively recently and the old river bed is very clear (see Figure 26). Aerial photos taken for different parts of the stream in 2011, 2012 and 2014 were used to determine the current river bed.

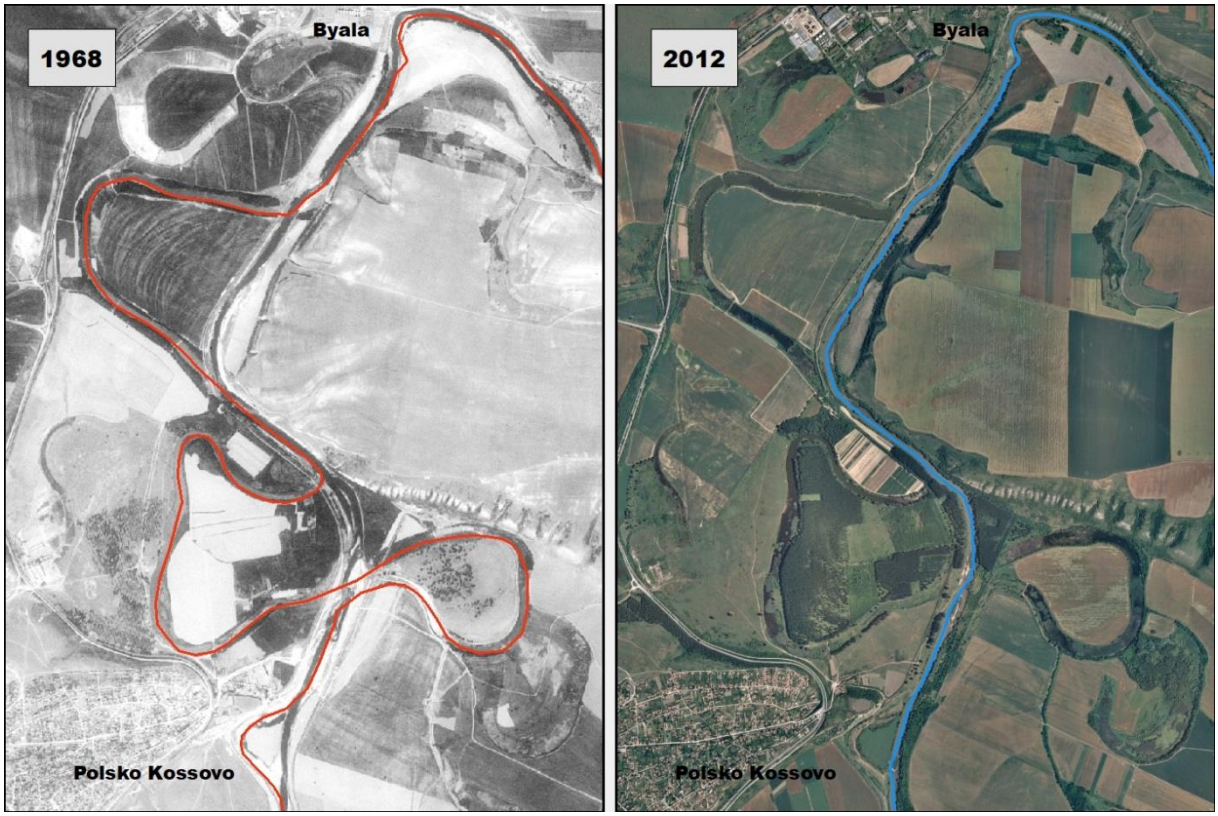

Figure 26: Old and current river bed of the Yantra River in the section between Polsko Kossovo village and Byala station

Results of the evaluation of the effectiveness of floodplains by hydrological parameters

The value of each parameter is calculated according to the corresponding algorithm described in the Methodology for evaluating the effectiveness of floodplains. This value is then equated to a 5-level scale to obtain a generalized estimate. The tresholds for scoring of the parameters according to the 5-level scale are preseted in Part 1 of the Report, Table 6*: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters,*

To obtain an overall assessment of the whole group of hydrological parameters, the individual estimates are summed up, the arithmetic mean is calculated, which is equated to a 3-level scale - favorable, satisfactory and unfavorable. The approach and the tresholds for recalculating of the rating values of the group of parameters to the 3-level scale,are presented in Part 1 of the Report ("Methodology")

Table 2: Evaluation of floodplains in the main course of the Yantra River by hydrological parameters

	Flood peak reduction			Flood wave translation			Effect in case of extreme discharge		Simple hydro-morphological evaluation		Overall assessment of hydrological parameters
	ΔQ [m^3/s]	ΔQ_{rel} [%]	Score	Δt [min]	Δt_{rel} [%]	Score	Δt_{comp} [%]	Score	Value	Score	
BG_YN_AFP_001	792	27.67	5	25	0.35	1	16	5	1.99	2	satisfactory
BG_YN_AFP_002	3	0.12	1	14	0.39	1	118	1	1	5	unfavorable
BG_YN_AFP_003	6	0.23	1	42	0.78	1	173	1	1	5	unfavorable
BG_YN_AFP_004	48	7.21	5	525	10.94	5	98.5	2	1.33	3	favorable
BG_YN_AFP_005	10	1.64	3	208	4.33	4	93	2	1.11	5	satisfactory
BG_YN_AFP_006	1.5	0.21	1	32	0.89	1	96.7	2	1	5	unfavorable
BG_YN_AFP_007	54	7.5	5	360	10	5	102	1	1	5	favorable
BG_YN_AFP_008	4	0.57	1	70	1.94	2	163	1	1	5	unfavorable
BG_YN_AFP_009	2	0.24	1	15	0.42	1	84	2	1	5	unfavorable

	Flood peak reduction			Flood wave translation			Effect in case of extreme discharge		Simple hydro-morphological evaluation		Overall assessment of hydrological parameters
	ΔQ [m^3/s]	ΔQ_{rel} [%]	Score	Δt [min]	Δt_{rel} [%]	Score	Δt_{comp} [%]	Score	Value	Score	
BG_YN_PFP_001	145	3.1	5	336	2.2	3	892	1	1.99	2	satisfactory
BG_YN_PFP_002	183	4.18	5	375	4.8	4	411	1	1.87	2	satisfactory
BG_YN_PFP_003	91	2.01	5	247	3.74	4	803	1	1.55	2	satisfactory
BG_YN_PFP_004	11	0.25	1	67	0.93	1	176	1	1.24	4	unfavorable
BG_YN_PFP_005	190	4.01	5	70	1.17	2	1.75	5	2.48	1	satisfactory
BG_YN_PFP_006	20	0.41	1	72	1.2	2	156	1	1.43	3	unfavorable
BG_YN_PFP_007	73	2.44	5	174	3.64	4	52.8	3	2.04	2	satisfactory
BG_YN_PFP_008	23	0.49	1	87	1.44	2	5728	1	1.8	2	unfavorable

Results of the evaluation of the effectiveness of floodplains by hydraulic parameters

The value of each parameter is calculated according to the corresponding algorithm described in the Methodology for evaluating the effectiveness of floodplains. This value is then equated to a 5-level scale to obtain a generalized estimate. The tresholds for scoring of the parameters according to the 5-level scale are preseted in *Part 1 of the Report*, *Table* 6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters

To obtain an overall assessment of the whole group of hydrological parameters, the individual estimates are summed up, the arithmetic mean is calculated, which is equated to a 3-level scale - favorable, satisfactory and unfavorable. The approach and the tresholds for recalculating of the rating values of the group of parameters to the 3-level scale,are presented in Part 1 of the Report.

Table 3: Evaluation of floodplains in the main course of the Yantra River by hydraulic parameters

	Water level		**Flow velocity**		**Overall assessment of hydraulic parameters**
	$\Delta h\ [m]$	Score	$\Delta v\ [\mathrm{m/s}]$	Score	
BG_YN_AFP_001	0.05	1	0.05	1	unfavorable
BG_YN_AFP_002	0.57	5	0.4	3	favorable
BG_YN_AFP_003	0.64	5	1.47	5	favorable
BG_YN_AFP_004	0.11	2	0.49	3	unfavorable
BG_YN_AFP_005	0.64	5	0.32	3	favorable
BG_YN_AFP_006	1.38	5	1.92	5	favorable
BG_YN_AFP_007	2.15	5	0.46	3	favorable
BG_YN_AFP_008	1.51	5	1.19	5	favorable
BG_YN_AFP_009	4.83	5	1.06	5	favorable
BG_YN_PFP_001	0.05	1	0.05	1	unfavorable
BG_YN_PFP_002	0.64	5	0.83	5	favorable
BG_YN_PFP_003	0.01	1	0	1	unfavorable
BG_YN_PFP_004	0.58	5	0.15	2	satisfactory
BG_YN_PFP_005	2.11	5	0.63	4	favorable
BG_YN_PFP_006	0.31	3	0.14	2	unfavorable
BG_YN_PFP_007	0.95	5	0.22	2	satisfactory
BG_YN_PFP_008	1.16	5	0.31	3	favorable

ECOLOGICAL PARAMETERS

The ecological parameters used to evaluate the effectiveness of floodplains are:

Connectivity of floodplain water bodies;
Existence of protected species;
Existence of protected habitats;
Vegetation naturalness;
Potential for typical habitats;
Biocorridor, "stepping stone".*

*) the parameter is proposed and used at national level; it is not included in the ptroject's FEM

Various data were used to calculate these indicators, including:

Recent satellite imagery and / or aerial photography (from the last 10 years) in different seasons and at least two different years. These include images from Sentinel-2 and Landsat as well as aerial photos;
National Register of Protected Areas, maintained by the Executive Environment Agency of the Republic of Bulgaria and available here: http://eea.government.bg/zpo/bg/;
National Register of Protected Sites of NATURA 2000, maintained by the Ministry of Environment and Water of the Republic of Bulgaria and available here: http://natura2000.moew.government.bg/Home/Natura2000ProtectedSites;
Land cover / land use layer of the Land Parcel Identification System (LPIS);
Field surveys from the last 10 years, available mainly for the territories falling within Natura 2000 sites.

Results of the evaluation of the effectiveness of floodplains by ecological parameters

The value of each parameter is calculated according to the corresponding algorithm described in the Methodology for evaluating the effectiveness of floodplains. This value is then equated to a 5-level scale to obtain a generalized estimate. The tresholds for scoring of the parameters according to the 5-level scale are preseted in *Part 1 of the Report,Table 6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters*

To obtain an overall assessment of the whole group of hydrological parameters, the individual estimates are summed up, the arithmetic mean is calculated, which is equated to a 3-level scale - favorable, satisfactory and unfavorable.

The approach and the tresholds for recalculating of the rating values of the group of parameters to the 3-level scale,are presented in Part 1 of the Report.

Table 4: Evaluation of floodplains in the main course of the Yantra River by ecological parameters

	Connectivity of floodplain water bodies		Existence of protected species		Existence of protected habitats		Vegetation naturalness		Potential for typical habitats		Biocorridor, "stepping stone"		Overall assessment of ecological parameters
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	
BG_YN_AFP_001	5	5	96.79	3	104	4	97.2	5	209.17	5	8.8	4	favorable
BG_YN_AFP_002	5	5	29.97	1	100	3	30.02	2	49.82	2	4.8	2	unfavorable
BG_YN_AFP_003	5	5	30.78	1	100	3	50.57	3	26.94	1	3.2	1	unfavorable
BG_YN_AFP_004	5	5	263.14	5	26	2	23.62	2	88.38	3	6.84	3	favorable
BG_YN_AFP_005	5	5	91.26	3	32	2	46.61	3	134.5	4	7	3	favorable
BG_YN_AFP_006	5	5	11.97	1	83	3	93.22	5	160.95	4	6	2	satisfactory
BG_YN_AFP_007	5	5	43.98	2	29	2	45.08	3	96.66	3	8	3	satisfactory
BG_YN_AFP_008	5	5	12.58	1	32	2	68.11	4	100.05	3	8	3	satisfactory
BG_YN_AFP_009	5	5	3.7	1	93	3	99.61	5	68.06	2	8	3	satisfactory
BG_YN_PFP_001	4.5	4	225.2	5	35	3	19.05	1	69.45	2	8	3	satisfactory
BG_YN_PFP_002	4.5	4	85.76	3	27	2	19.91	1	64.24	2	7.2	3	unfavorable
BG_YN_PFP_003	4.5	4	80.1	3	63	3	37.97	2	121.4	3	7.2	3	satisfactory
BG_YN_PFP_004	4.5	4	91.32	3	35	2	27.39	2	59.48	2	6.4	3	satisfactory

	Connectivity of floodplain water bodies		Existence of protected species		Existence of protected habitats		Vegetation naturalness		Potential for typical habitats		Biocorridor, "stepping stone"		Overall assessment of ecological parameters
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	
BG_YN_PFP_005	4.5	4	68.81	2	78	3	54.17	3	94.81	3	7.2	3	satisfactory
BG_YN_PFP_006	4.5	4	145.77	4	66	4	33.78	2	105.69	3	5.6	2	favorable
BG_YN_PFP_007	4.5	4	140.33	4	36	2	23.84	2	96.18	3	8.8	4	favorable
BG_YN_PFP_008	4.5	4	249.34	5	61	3	31.21	2	110.05	3	8.8	4	favorable

SOCIO-ECONOMIC PARAMETERS

The socio-economic parameters used to evaluate the effectiveness of floodplains are:

Potentially affected buildings;
Land use.

Cadastral data and actual aerial photos were used to calculate the "potentially affected buildings" parameter. The cadastral data, and in particular the layer of buildings, were not available for most of the study area. Therefore, aerial photos were used to digitize the missing buildings.

For the calculation of the "land use" parameter, the corresponding layer of the Land Parcel Identification System (LPIS) was used. The LPIS is part of the Integrated Administration and Control System (IACS), which has been developed in all EU Member States 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 nomenclature of land cover follows the main elements, nomenclature and definitions of CORINE, with some changes and additions to ensure the specificity and objectives of the LPIS. The data has very high spatial resolution. The minimum mapping unit is 0.1 ha. They are digitized based on aerial photos, whose accuracy is 1.5 meters, the same used for mapping buildings.

Results of the evaluation of the effectiveness of floodplains by socio-economic parameters

The value of each parameter is calculated according to the corresponding algorithm described in the Methodology for evaluating the effectiveness of floodplains. This value is then equated to a 5-level scale to obtain a generalized estimate. The tresholds for scoring of the parameters according to the 5-level scale are preseted in *Part 1 of the Report,Table 6: Threshold values for calculating the generalized assessment of floodplain effectiveness parameters*

To obtain an overall assessment of the whole group of hydrological parameters, the individual estimates are summed up, the arithmetic mean is calculated, which is equated to a 3-level scale - favorable, satisfactory and unfavorable. The approach and the tresholds for recalculating of the rating values of the group of parameters to the 3-level scale,are presented in Part 1 of the Report .

Table 5: Evaluation of floodplains in the main course of the Yantra River by socio-economic parameters

	Potentially affected buildings		Land use		Overall assessment of socio-economic parameters
	Value	Score	Value	Score	
BG_YN_AFP_001	0.2	4	1.23	5	favorable
BG_YN_AFP_002	2.3	2	3.85	2	unfavorable
BG_YN_AFP_003	1.7	3	3.03	3	satisfactory
BG_YN_AFP_004	1.3	3	4.25	2	unfavorable
BG_YN_AFP_005	2.6	2	3.62	2	unfavorable
BG_YN_AFP_006	9.4	1	2.28	4	unfavorable
BG_YN_AFP_007	1.3	3	3.44	2	unfavorable

	Potentially affected buildings		Land use		Overall assessment of socio-economic parameters
	Value	Score	Value	Score	
BG_YN_AFP_008	0	5	2.73	3	favorable
BG_YN_AFP_009	4.1	2	1.48	5	satisfactory
BG_YN_PFP_001	0.7	4	4.41	2	satisfactory
BG_YN_PFP_002	0	5	4.35	2	satisfactory
BG_YN_PFP_003	0	5	3.79	2	satisfactory
BG_YN_PFP_004	0.3	4	3.99	2	satisfactory
BG_YN_PFP_005	0.5	4	3.11	3	satisfactory
BG_YN_PFP_006	2.3	2	4.03	2	unfavorable
BG_YN_PFP_007	0.7	4	4.16	2	satisfactory
BG_YN_PFP_008	0.3	4	4.03	2	satisfactory

ADDITIONAL EVALUATION RESULTS

Besides the above-presented 5-level evaluation, used at national level, an additional assessment of each parameter in a 3-level scale has been performed in order to ensure comparability of the results from evaluation of the floodplains on the Danube tributaries, subject of the project.

The 3-level evaluation is done using the same calculated values of the parameters used for the 5-level assessment and the tresholds presented in Table 7 in Part 1 "Methodology".of the Report

The results of the 3-level evaluation are presented in **Table 6** below:

The final ranking and prioritization of the floodplains according to their restoration/preservation potential will be performed after a ranking method is agreed at project level.

Table 6: Evaluation of the floodplains on Yantra River by parameters in 3-level scale

Floodplain code	HYDROLOGICAL PARAMETERS				HYDRAULIC PARAMETERS		ECOLOGICAL PARAMETERS						SOCIO-ECONOMIC PARAMETERS	
	Flood peak reduction	Flood wave translation	Effect in case of extreme discharge	Simple hydro-morphological evaluation	Water level	Flow velocity	Connectivity of floodplain water bodies	Existence of protected species	Existence of protected habitats	Vegetation naturalness	Potential for typical habitats	Biocorridor, "stepping stone"	Potentially affected buildings	Land use
BG_YN_AFP_001	5	1	5	1	1	1	5	3	3	5	5	5	5	5
BG_YN_AFP_002	1	1	1	5	5	3	5	1	3	3	1	1	3	3
BG_YN_AFP_003	1	1	1	5	5	5	5	1	3	3	1	1	3	3
BG_YN_AFP_004	5	5	1	3	1	3	5	5	1	1	3	3	3	1
BG_YN_AFP_005	3	5	1	5	5	3	5	3	3	3	5	3	3	3
BG_YN_AFP_006	1	1	1	5	5	5	5	1	3	5	5	3	1	5
BG_YN_AFP_007	5	5	1	5	5	3	5	3	3	3	3	3	3	3
BG_YN_AFP_008	1	3	1	5	5	5	5	1	3	5	3	3	5	3
BG_YN_AFP_009	1	1	3	5	5	5	5	1	3	5	3	3	3	5
BG_YN_PFP_001	5	3	1	1	1	1	5	5	3	1	3	3	5	1
BG_YN_PFP_002	5	5	1	1	5	5	5	3	3	1	3	3	5	1
BG_YN_PFP_003	5	5	1	3	1	1	5	3	3	3	3	3	5	3
BG_YN_PFP_004	1	1	1	5	5	1	5	3	3	1	3	3	5	3
BG_YN_PFP_005	5	1	5	1	5	5	5	3	3	3	3	3	5	3

Floodplain code	HYDROLOGICAL PARAMETERS				HYDRAULIC PARAMETERS		ECOLOGICAL PARAMETERS						SOCIO-ECONOMIC PARAMETERS	
	Flood peak reduction	Flood wave translation	Effect in case of extreme discharge	Simple hydro-morphological evaluation	Water level	Flow velocity	Connectivity of floodplain water bodies	Existence of protected species	Existence of protected habitats	Vegetation naturalness	Potential for typical habitats	Biocorridor, "stepping stone"	Potentially affected buildings	Land use
BG_YN_PFP_006	1	1	1	3	3	1	5	5	5	3	3	3	3	1
BG_YN_PFP_007	5	5	3	1	5	3	5	5	3	1	3	5	5	1
BG_YN_PFP_008	1	3	1	3	5	3	5	5	3	3	3	5	5	1

The results of the identification and evaluation of Yantra floodplains described above, are included in the following aditional files, provided together with this Report, wich shall be considered as a part of the report:

1. Boundaries of the identified floodplains on Yantra River (*.shp – file)*
2. Assessment results (*Excel table*)
3. Examples of Maps for separate floodplains, presening the assessment by parameters (*two maps - .pdf files*)