# EXTRACT OF CONCEPT PLAN OF POSSIBLE TECHNICAL INTERVENTIONS AIMING THE IMPROVEMENT OF THE ECOLOGICAL STATUS OF BARCSI OLD-DRAVA

**CLIENT:**

DUNA-DRAVA NATIONAL PARK DIRECTORATE (DDNPD)

**SUBCONTRACTOR:**

INNO-WATER RESEARCH AND ENVIRONMENTAL SERVICES LTD. (IW)

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# 1 Introduction

## *1.1 Introduction of the „LIFE Old-Drava (LIFE13 NAT/HU/000388)" project*

As river regulations were conducted along the River Drava in the 20th century numerous river bends (meanders) were cut off from the main riverbed. Nowadays some of these meanders function as side-arms and has freshwater supply from the River Drava only in case of high flood waters. Other cut-offs became oxbows with no direct hydraulic connection to the river. The longest oxbow is the Old-Drava located on the left bank on the north of Barcs.

With the „LIFE Old-Drava" project **the principal aim of the competent Croatian and Hungarian authorities together with non-governmental organizations is to prevent and mitigate the further degradation of the natural values along the Barcsi-Old-Drava.**

In order to the effective nature prevention the main objective of the project, led by the Danube-Drava National Park Directorate (DDNPD), is to preserve the aquatic and riverine habitats with improvements of the water household, and increasing the biodiversity of the riverside forest belts.

To improve the water balance of the Old-Drava **the development of the water supply,** and reduction of the ecological risks of the prolonged low-water periods can be solved by the installation of a **proper water retention structure**.

As the average water level of the oxbow follows the trend of the water level changes of River Drava, due to the progressive sinking of the Drava riverbed both the groundwater level and the Barcsi-Old-Drava water level decreased in the last decade. According to the preliminary concept, **one or two weirs** (or other suitable structures) should be installed **to increase water levels of the oxbow in the low water period**.

Currently, the primary source of water supply of the Barcsi-Old-Drava is the River Babócsai-Rinya, however in dry periods the water discharge into the oxbow is limited. Due to the continuous riverbed sinking, the River Drava can only flush the oxbow on the occasion of floods and very high water levels, however it is a rather rare event. Therefore the River Drava is currently not able to assure significant water-supply for the oxbow.

Since neither the Babócsai-Rinya nor the Drava can provide continuous and adequate volumes of water supply, the occurrence of low precipitation periods can result significant ecological problems risking the aquatic habitat and related species. In order to meet the satisfactory ecological water requirements, beyond the water retention **the project also examines the possibility of a new water-canal connecting the River Drava and the upper section of the Barcsi-Old-Drava**.

Through the regulated water retention and the improved water supply, **the oxbow's average water level can rise by 0.5-1.0 meters**, which can mitigate the risks of the extreme low water periods. The permanently elevated water level is expected to have a positive impact on both the river-side high-priority habitats and the aquatic habitats.

The ensured adequate groundwater regime will enhance the regeneration of the native gallery forests species (with special regards to the following species: *Populus nigra*, *Populus alba*, *Salix alba*) and the suppression of invasive species. The higher water level also provides favorable living conditions for numerous Natura2000 fish species (*Rhodeus serriceus amarus*, *Cobitis taenia*, *Misgurnus fossilis*).

## *1.2 Tasks to accomplish*

Regarding the planned water retention structure of the “LIFE-Old Drava” project the Inno-Water Ltd was entrusted by the DDNPD with the completion of the following tasks:

- **“Field surveys and consultation with the Croatian designers about dimensions, location and implementation method of the planned structures before and during the planning period. Concept plan preparation on a feasibility plan level.”**
- **“Translation and possible modification of the water right license plan made by the Croatian partner, in order to meet the prescriptions of the Hungarian regulations on the water licensing procedure.”**
- **"Preparation of construction cost estimates of the planned structures."**

The objective of the Inno-Water Ltd. was to prepare the **conceptual plan of the required interventions** in order to improve the ecological state of the project area. It was one of the main goals to provide basic information for the Croatian partner carrying out the planning, which can be taken into consideration during the decision making and planning.

Therefore the present study contains the technical information of the concept plan translated to English as an extract of the comlete Hungarian cocept plan.

The studies carried out during the preparation of concept design can be prioritized around the following key questions:

- What water level should be set (and maintained) on the Barcsi-Old-Drava in order to reach the desired positive ecological impacts?
- What kind of water supply can be used for the water level raise?
- Which possible alternatives can be considered for the permanent increase of the oxbow water level?
- On which location of the oxbow should the structure be installed?
- What is the required minimal height of the structure capable to hold the planned water level?
- What impacts can the proposed interventions have on the water quality of the oxbow?
- What impacts can the proposed interventions have on the conditions of the riverbed?
- What impacts can the proposed interventions have on the water balance of the surrounding area?

All these questions are answered in details in the referring chapters of the study.

## 1.3 Methodology

The following section contains a brief summary on the methodologies used for the essential phases of the study, addressing the key focus points of the individual working phases.

**In the first phase of the work all the data and information was collected** from the Croatian and Hungarian partners, as well as from publicly available sources. Thus the **basic information about the project area** was at our disposal for the concept plan development. Besides, the **digital terrain model** of the area and the **HEC–RAS model** built from the Drava, Babócsai-Rinya, Barcsi-Old-Drava river sections by the Croatian Hidroing Ltd. for the IPA project „Revitalization and infrastructural development of the Kriznice area” in 2008, were also provided for further work *[Hidroing, 2008]*.

In addition the Danube-Drava National Park Directorate (DDNPD) and the South Transdanubian Water Directorate (STWD) provided the **Hydrographic Atlas of the River Drava** complied in 2005 and the **hydrographic data of the rivers involved**.

About the **water quality of the rivers** the documents of the **National Water Management Plan (OVGT)** and the attached studies *[www.vizeink.hu]*, and the surface water database of the **National Environment Protection Information System** (OKIR) *[http://web.okir.hu/hu/fevisz]* provided information.

Following the joint on-site visit at the project area, consultations were held with the experts of the National Park and they presented recommendations about the required water levels to achieve the targeted ecological conditions. According to the recommendation of the DDNPI experts, **the ideal water level for the Barcsi-Old-Drava is 50 cm (102.72 maB)** therefore we set a target water level of 102.75 maB.

**Within the second phase of the preparation of the study, the careful assessment and verification of the technical data was carried out, with special regard to the riverbed geometry of the oxbow built up in the HEC-RAS model.** For this, in May 2015 the experts of the Inno-Water Ltd. performed **control measurements for water depth** along the Barcsi-Old-Drava section on the south end from the discharge point, where River Babócsai-Rinya flows into the oxbow.

**For the cross-verification of the digital terrain model** the data of the Hydrographic Atlas of the Drava was used. According to the check inspections the congruence of the data used in the models could be accepted.

**In the third phase of the preparation the following examinations were carried out** on the basis of the previously verified and accepted data.

*Evaluation of the relevant river courses in terms of the water supply of the Barcsi-Old-Drava*

According to the preliminary investigations three watercourses were investigated as potential water supply of the Barcsi-Old-Drava: the River Drava, the River Babócsai-Rinya and the Babócsai-Malom-Árok.

In the initial phase of the examinations Malom-Árok was excluded from the potential alternatives owing to its fluctuating water discharges and its intermittent/temporary nature.

The possibility of using the River Drava as a water supply arose in the study prepared by Hidroing Ltd in 2008 as well *[Hidroing, 2008]*. According to the Drava water level data measured at the Barcs-gauge, and the slope of the riverbed collected from the Hydrographic Atlas of the Drava **the characteristic Drava water level to the water-inlet point recommended in the 2008 study was calculated**. These defined values were compared with the planned 102.75 maB water level of the Barcsi-Old-Drava, and **the possible hydraulic connection between the two waterways was examined**.

Since the River Babócsai-Rinya is the current water-supply of the oxbow, in the assessment of the alternatives a special emphasis was given to the examination of this watercourse. On the basis of the terrain model **the area and volume of the open water surface for different water levels of the oxbow were defined.** Applying this calculation and the water load data of the Babócsai-Rinya (recorded at Babócsa) **the connection between the stored water volume and the level of recharge** (considering the evaporation as well) was defined in order to assess the suitability of the Babócsai-Rinya as a water supply for increased water levels.

*The effects of the water level elevation on the water quality*

Since in case of persistently elevated water levels the residence time can be significantly increased as well, **the possible changes in the water quality were also examined**. For this purpose, the general water chemistry parameters measured at Nagyatád és Babócsa sections of the Babócsa Rinya were evaluated, and the potential pollutant loads were assessed. On the basis of the water discharge of the Babócsai-Rinya and the stored water volumes of the Old-Drava for different water levels and Rinya water discharges **the characteristic residence time of the oxbow was determined**. From the water quality data and the calculated residence time **conclusions were drawn on the potential changes in the oxbow's eutrophication tendency.**

*The effects of the water level elevation on the environment of the Old-Drava:*

There is a basic relationship (balance) between the volume of water in the oxbow and the level of the surrounding groundwater. Therefore, in case of the long-term increase of the Barcsi-Old-Drava water levels, the groundwater level in the surrounding areas will rise as well. The effects of the elevated groundwater level also should be taken into further consideration, and it has to be examined whether it will cause inundation in any protected or agricultural areas. To predict this possibility we used the data of the digital terrain model. As the section of the terrain model and the plane of the different water levels of the oxbow the **areas which might get flooded (as the water level permanently rises to the given level) were determined.**

*Alternatives for the location and size of the water level elevation structures:*

To achieve the defined goal, to permanently ensure the 102.75 maB Old-Drava water level, techical intervention is required. According to the discussions with the DDNPD experts, the water retention should be preferably realized with passive objects (maintenance-free regular operation).

Therefore with the help of the HEC-RAS model of the oxbow, **the effects of weirs with different size and location on the water balance of the Barcsi-Old-Drava were assessed**. According to the observations made during the site visit and the recommendation of the DDNPD experts three possible locations were selected and with the HEC-RAS model **the minimal weir height capable to permanently ensure 102.75 maB water level at the gauge was defined**. In the model tests **the changes of the flow conditions were also evaluated**, with particular regard to the determination the changing water flow rates. These measures have a great significance regarding the riverbed stabilization of the downstream section (whether riverbed deepening, sinking should be expected in the downstream section because of the increased flow rates), regarding the water quality of the oxbow (how the water slows down on the dammed up section, and whether it becomes backwater-like) as well as regarding the planned stability of the structure (what flow can develop by the of the weir).

*Keeping in mind the cross-border nature of the work carried out within the framework of the project, attention has to be drawn to the difference between the Croatian and Hungarian height data (due to the different sea-level baselines) In the present study the altitude data is consistently given in Baltic Sea altitude (maB) (representing 67.47 cm lower values than the height above the Adriatic Sea level which is used in Croatian standards).*

# 2 Characterization the hydraulic and water quality conditions of the Barcsi-Old-Drava and the surrounding water courses

## *2.1 Statistical analysis of the water regime of the concerned watercourses*

### *2.1.1 Statistical analysis of the water regime of the River Babócsai-Rinya observed at the public road bridge of Babócsa*

In this chapter, we analyze the hydrological conditions of the River Babócsai-Rinya based on the water level and runoff data measured on the gauge of Babócsa.

The River Babócsai-Rinya is under the care of the South-Transdanubian Water Directorate (STWD). There are two gauges along the stream, one at Nagyatád (26.58 river km) and the other at Babócsa (5.312 river km). The gauge of Babócsa is located closer to the affected Drava section, therefore we have considered the water level data measured here (*Table 2.1.*).

| **River-gauge data** | | |
|---|---|---|
| **Name of watercourse** | | **River Babócsai Rinya** |
| **Cross section** | ***[rkm]*** | 5.312 |
| **Name of gauge** | | Babócsai Rinya, Babócsa |
| **Zero point of the gauge** | ***[maB]*** | 107.5 |
| **LWL (Lowest water level)** | ***[cm]*** | -30 |
| **HWL (Highest water level)** | ***[cm]*** | 300 |
| **I. alert level** | ***[cm]*** | - |
| **II. alert level** | ***[cm]*** | - |
| **III. alert level** | ***[cm]*** | - |
| **Regional Directorate** | | STWD (Pécs) |

*Table 2.1. - The water level data measured on the gauge of Babócsa*

Below, we present the water level and discharge data registered between 1995 and 2015 at the measuring station located under the road bridge of Babócsa.

*Figure 2.1.* shows the **water levels** measured between 1969 and 2015 **as a function of** the contemporaneously measured or calculated **water discharge** data. A correlation can be observed between data pairs (higher water levels occur at higher discharges), which can be approached with linear sections of different slope. In the case of very high flows, smaller growth in water level belongs to a given growth in discharge, the approximate straight lines has smaller slope. Using this relationship, the STWD generate discharge data belonging to the frequently measured water levels by calculation, and for verification, from time to time, they perform flow measurements.

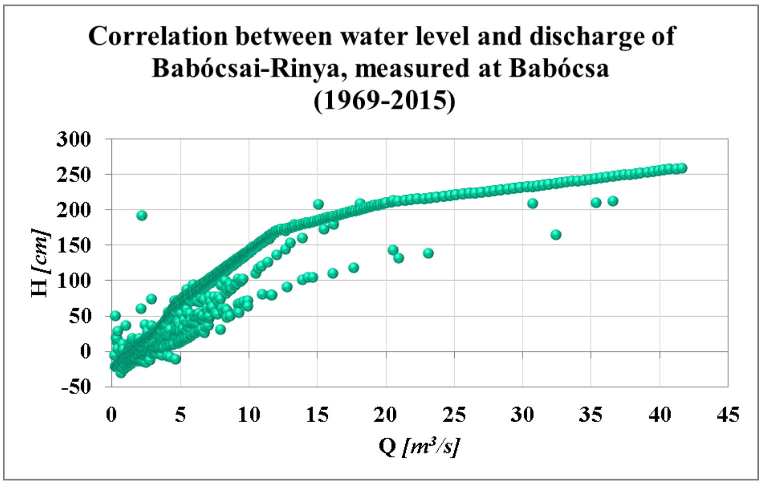


*Figure 2.1.– Correlation between water level and dicharge of the River Babócsai-Rinya measured under the road bridge of Babócsa (1969-2015)*

**Water levels** of Babócsai-Rinya, measured between 1969 and 2015 are shown in *Figure 2.2*. The water level typically varies from -30 to 50 cm (the average is about 45 cm). Water levels excessing the 100 cm are rare, but during the largest floods, the water level exceeded even the 200 cm. The highest water level occurring during the entire study period was 259 cm in April 2013.

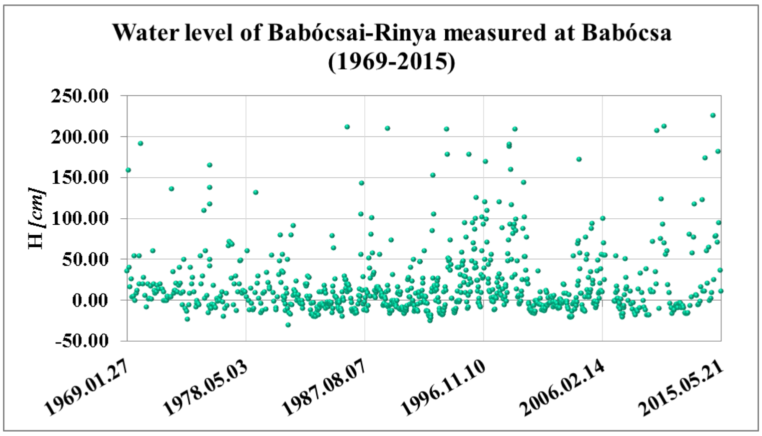


*Figure 2.2. - Water level of the River Babócsai-Rinya measured under the road bridge of Babócsa (1969-2015)*

The *Figure 2.3*. indicates the **water's absolute height above the level of the Baltic Sea** knowing the zero point of the gauge. The typical water level was between 107.3 and 108.3 maB during the measurement period. The lowest water level varied 107.2 maB, the highest was 110.1 maB and the average water level was 107.9 maB.

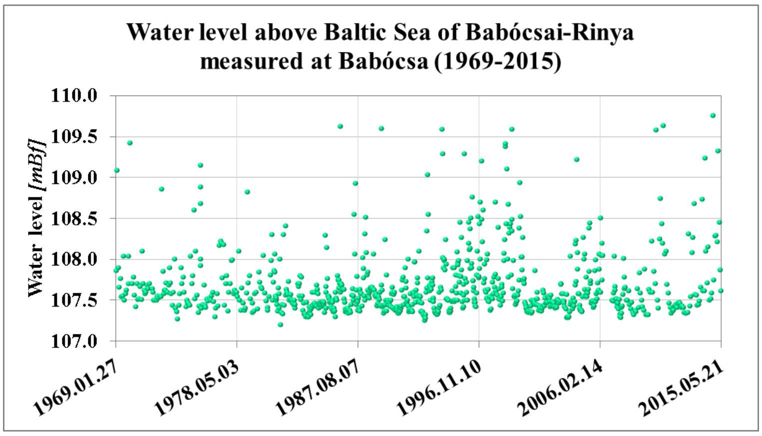


*Figure 2.3. - Water level above Baltic Sea of Babócsai-Rinya measured under the road bridge of Babócsa (1969-2015)*

We plotted the available **discharge** data for the period 1969-2015 as well (*Figure 2.4.*). During the entire period, the typical flow varied between 1-7 $m^3/s$. The average flow was 4.56 $m^3/s$, the highest discharge (41.6 $m^3/s$) was registered in April 2013, and the lowest (0.21 $m^3/s$) in November 1975.

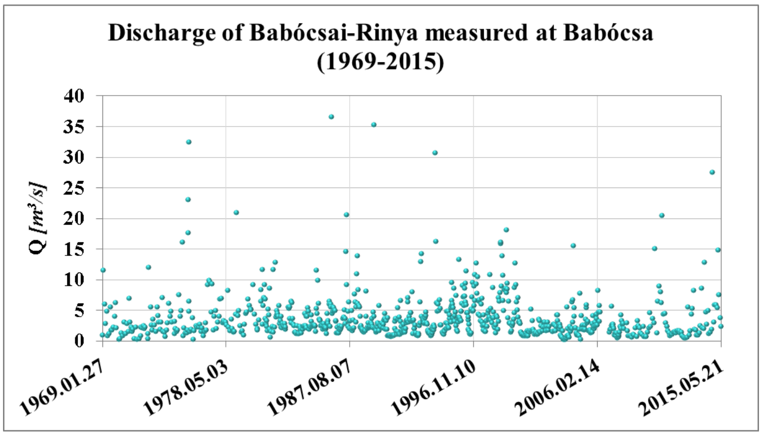


*Figure 2.4. - Discharge of the River Babócsai-Rinya measured under the road bridge of Babócsa (1969-2015)*

*Figures 2.1-2.4.* show the calculated discharge permanency values (probabilities of occurrence) of Babócsai-Rinya, based on the data measured at Babócsa (5.312 rkm) from 1969 to 2015.

To prepare the discharge permanency curve for the period of 1969-2015 (*Figure 2.5.*), we have used 15027 data. On the basis of the diagram it can be stated that over the 46 year period **90% of the** measured (or calculated) **water discharge values exceeded of 1.21 $m^3/s$. 50% of the values were greater than 3.13 $m^3/s$, and in 10% of the measurements the discharge exceeded 9.70 $m^3/s$.**

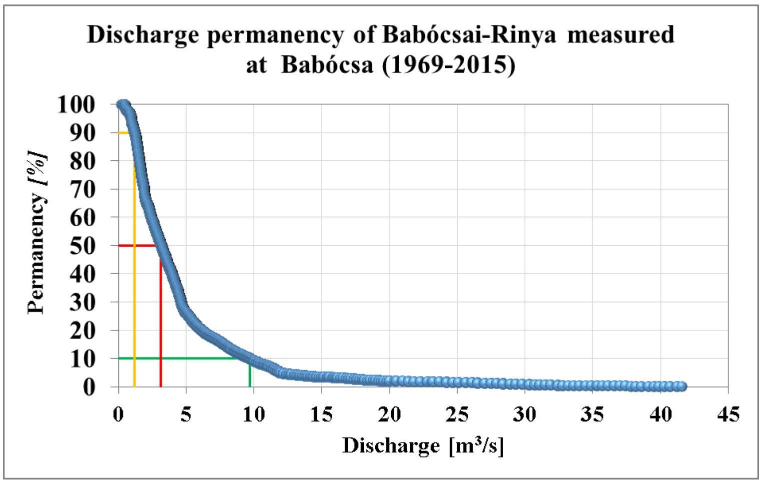


*Figure 2.5. - Permanency values of discharge measured under the road bridge of Babócsa (1969-2015)*

*Figure 2.6.* shows the permanencies of water levels relative to the zero point of the gauge of Babócsa. During the period, more than 90% of the water level data were greater than -8 cm, 50% exceeded the 25 cm, and water level above 135 cm were recorded only in 10% of the measurements. In the period of 1969-2015, the lowest water level (-30 cm) was measured in August 1981, the highest one (259 cm) in April 2013.

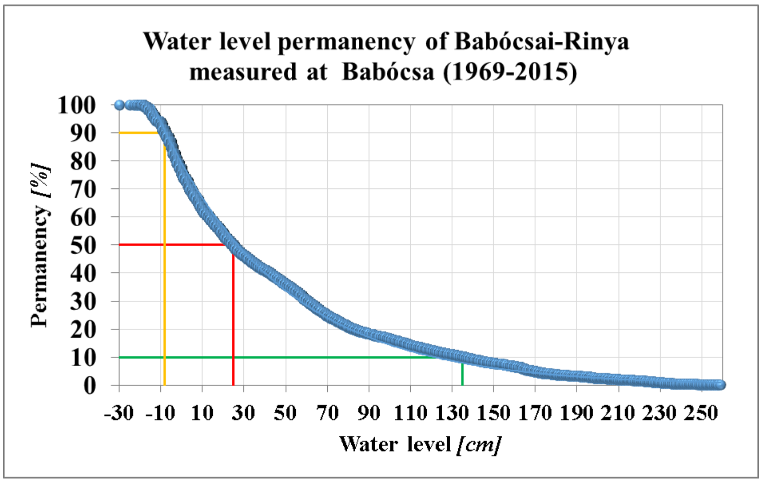


*Figure 2.6. - Permanency values of water levels measured under the road bridge of the River Babócsa (1969-2015)*

On *Figure 2.7.* water level altitude permanencies are plotted. The zero point of Babócsa gauge is situated at 107.5 maB, so to the permanency of 90%, 50% and 10% 107.42 maB, 107.75 maB and 108.85 maB values belong respectively.

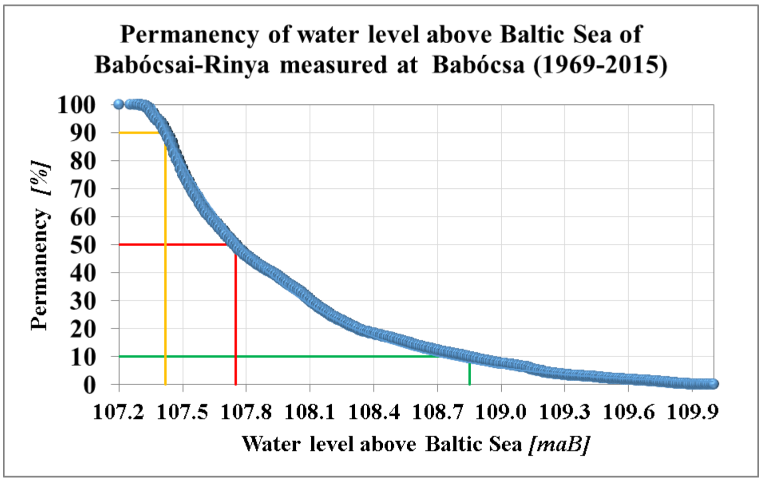


*Figure 2.7. – Permanency values of water levels above Baltic Sea of Babócsai-Rinya, measured under the road bridge of Babócsa (1969-2015)*

From the above presented hydrological data of the River Babócsai-Rinya, we used the discharge data of given probabilities (10-50-90%) for analysis of the water supply possibilities and evaporation conditions of the Barcsi-Old-Drava oxbow.

### *2.1.2 Statistical analysis of the water regime of River Drava, observed at Barcs*

Below the hydrological conditions of Drava are analysed based on the water levels and the water flow data.

*Table 2.2.* shows the data of the gauge located at River Drava's 154,1 rkm, near Barcs in the territory of Directorate of Water Management

| **River-gauge data** | | |
|---|---|---|
| **Name of watercourse** | | **River Drava** |
| **Cross section** | ***[fkm]*** | 154.1 |
| **Name of gauge** | | Drava Barcs |
| **Zero point of the gauge** | ***[mBf]*** | 98.14 |
| **LWL (Lowest water level)** | ***[cm]*** | -164 |
| **HWL (Highest water level)** | ***[cm]*** | 618 |
| **I. alert level** | ***[cm]*** | - |
| **II. alert level** | ***[cm]*** | - |
| **III. alert level** | ***[cm]*** | - |
| **Regional Directorate** | | DDVIZIG (Pécs) |

*Table 2.2. - Data of gauge on the River Drava near Barcs*

Figure *2.8.-2.9.* illustrate the water levels in maB, measured on the River Drava. It can be stated that the measured water levels of Drava showed a downward trend, indicating the sinking of the riverbed. The average water level was 36.7 cm (98.5 maB), the highest measured value was 618 cm (104.3 maB), the lowest measured value was -164 cm (96.6 maB).

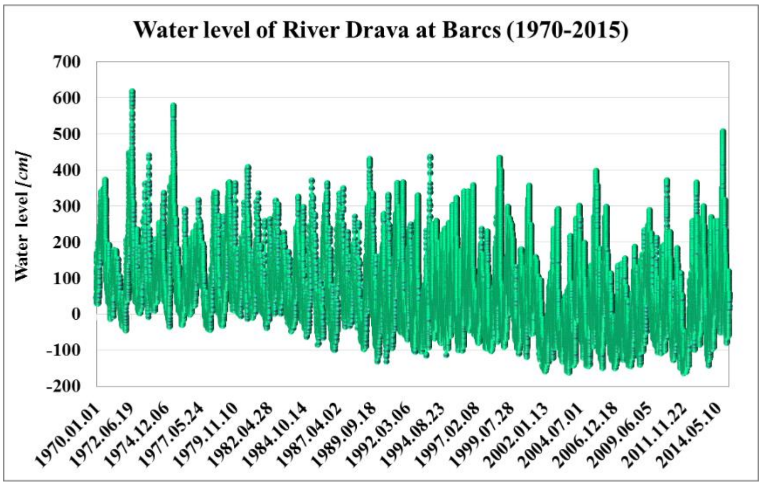


*Figure 2.8. - Water level of the River Drava measured at Barcs (1968-2015)*

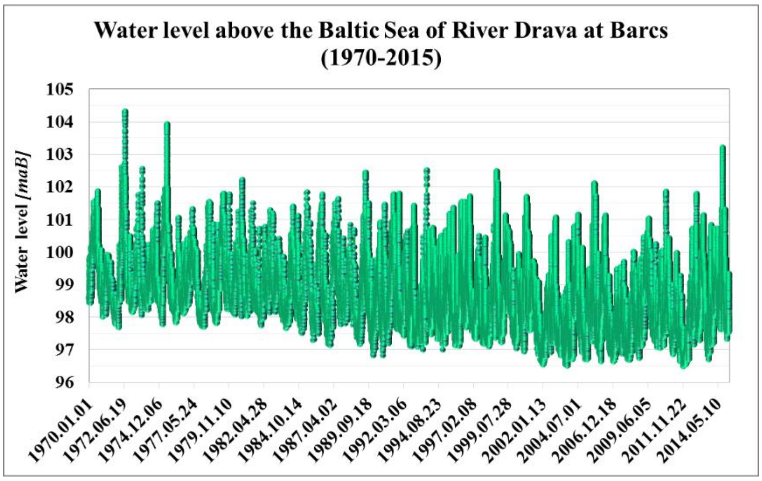


*Figure 2.9. - Water level above Baltic Sea of the River Drava measured at Barcs (1968-2015)*

We have measured discharge data for the period of 1968-2012 *(Figure 2.10.*). From 2013 to 2015 there are no measured flow data available, therefore *Figure 2.11.* indicates the calculated discharge values. The water discharge values were usually below 1,500 $m^3/s$. On the diagrams of the examined period, higher water levels and discharges can be observed during the spring and early summer floods.

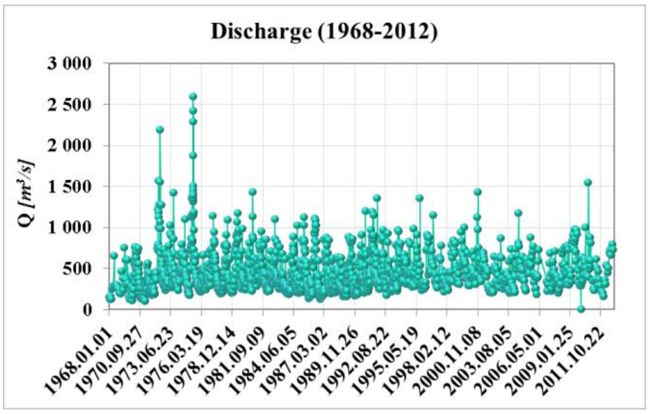


*Figure 2.10. - Discharge of the River Drava, measured at Barcs (1968-2012)*

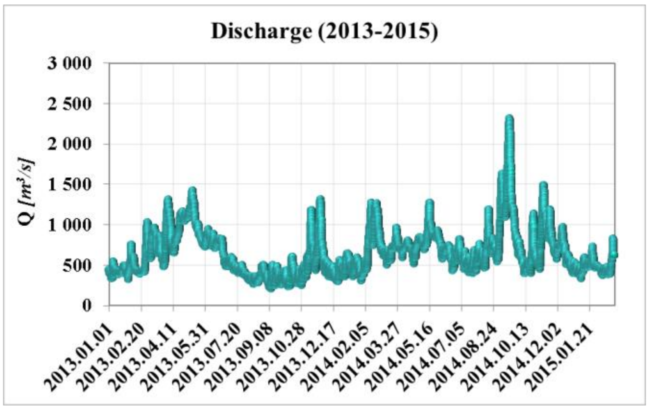


*Figure 2.11. - Discharge of the River Drava, measured at Barcs (2013-2015)*

Relationship between water level at Barcs and discharge values of River Drava (the Q-H curve) for the period of 1968-2012 is shown in *Figure 2.12.*

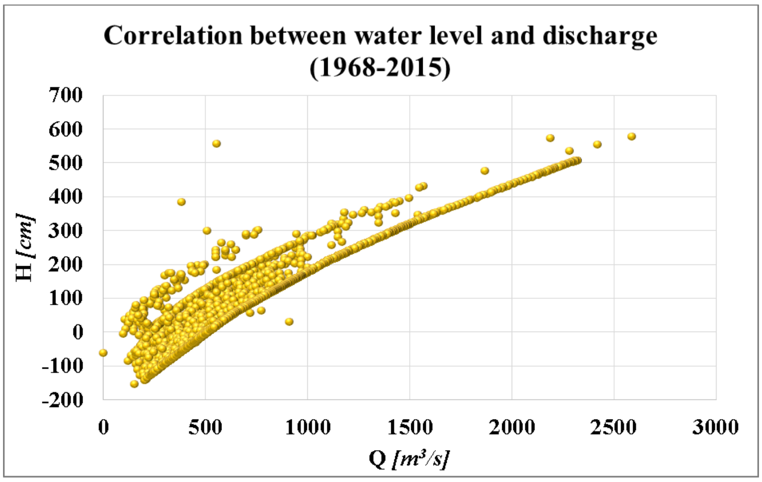


*Figure 2.12. – Correlation between water level and discharge of the River Drava, measured at Barcs (1969-2015)*

*Figures 2.13.-2.15.* show the permanency values of the water regime data of the River Drava (water discharge and water level values of given probabilities) measured at Barcs during the period of 1968-2015.

On *Figure 2.13*. the permanency values of Drava's discharge can be seen. 90% of measured discharge data were higher than 333 $m^3$/s, 50% were greater than 553 $m^3$/s and 10% exceeded 1020 $m^3$/s in the considered period. During the reference period, the minimum water flow (100 $m^3$/s) was measured in 1971, and the maximum (2.589 $m^3$/s) in 1975.

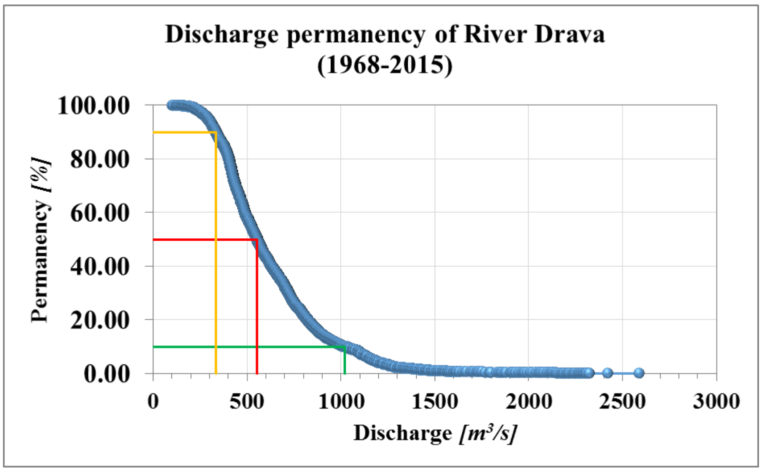


*Figure 2.13. - Permanency values of discharge of the River Drava, measured at Barcs (1969-2015)*

On *Figure 2.14.* the permanency values of water levels measured from the zero point of the gauge of Barcs are shown. 90% of the measured water levels exceeded the -71 cm, while 50% of the values were above 25 cm. 10% of the water levels were higher than 164 cm. The lowest water level during the period (-164 cm) was measured in November 2011, the highest value (618 cm) in July 1972.

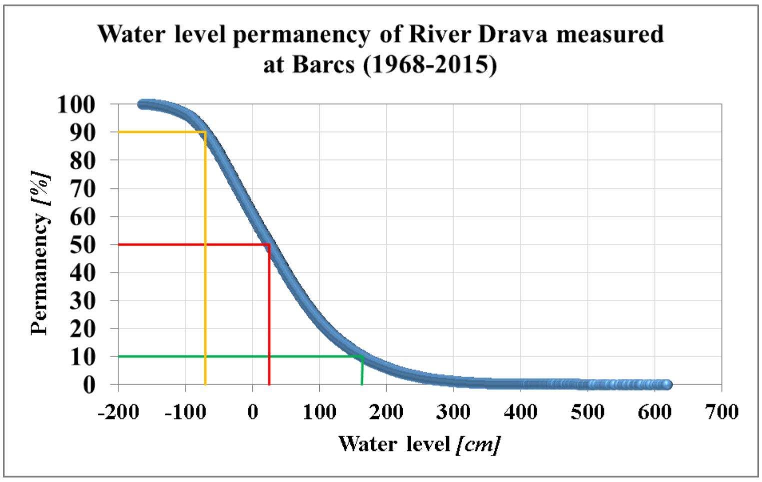


*Figure 2.14. - Permanency values of the River Drava water levels measured at Barcs (1969-2015)*

On *Figure 2.15.* the permanency values of water levels converted into absolute altitude are shown. The zero point of the gauge of Barcs was designated at a height of 98.14 maB, therefore the water levels related to permanecies of 90%, 50% and 10% are 97.43 maB, 98,39 maB and 99.78 maB respectively.

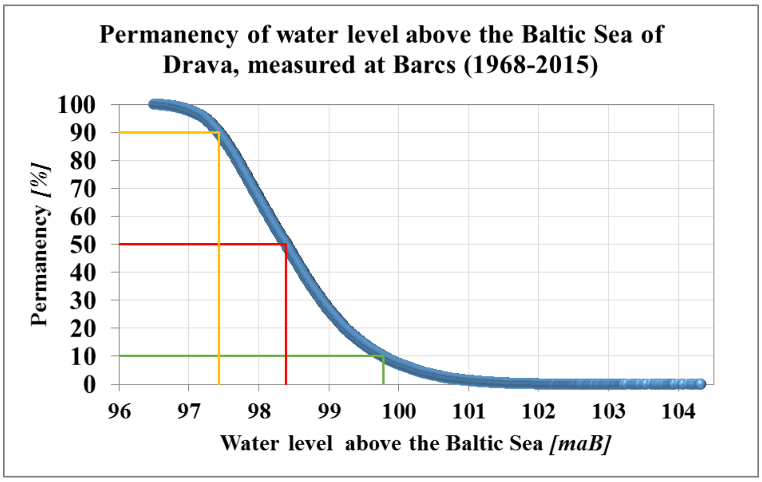


*Figure 2.15. - Permanency values of water levels above Baltic Sea of the River Drava, measured at Barcs (1969-2015)*

From the above presented Drava water regime data of the River Drava, the water level values were used primarily for further calculations in the analysis of the potential alternatives of water supply from the River Drava (see *Chapter 2.2.*).

## 2.2 Analysis of water levels of the River Drava near the connection point

**We have determined the Drava water levels of the River Drava at the connection point** based on the data measured at the gauge of Barcs. Using the measured data and the water levels in the Drava Atlas, the slope of the water surface for the 168 rkm section of the River Drava was calculated, resulted approximately 15 cm/km.

Based on the obtained values, it has been found that the water levels on the Drava section near the planned water inlet area (168-169 river km) are about 210 centimeters higher than that measured at the gauge of Barcs (154.1 river km). Therefore, the characteristic water levels for the planned connection point was obtained by extrapolation from data series measured at Barcs during the period of 1970-2015. Given the fact that the riverbed of Drava has deepened significantly since the 1970s (*Figure 2.16.*), **the water levels of the River Drava were analyzed in details starting from 2009.**

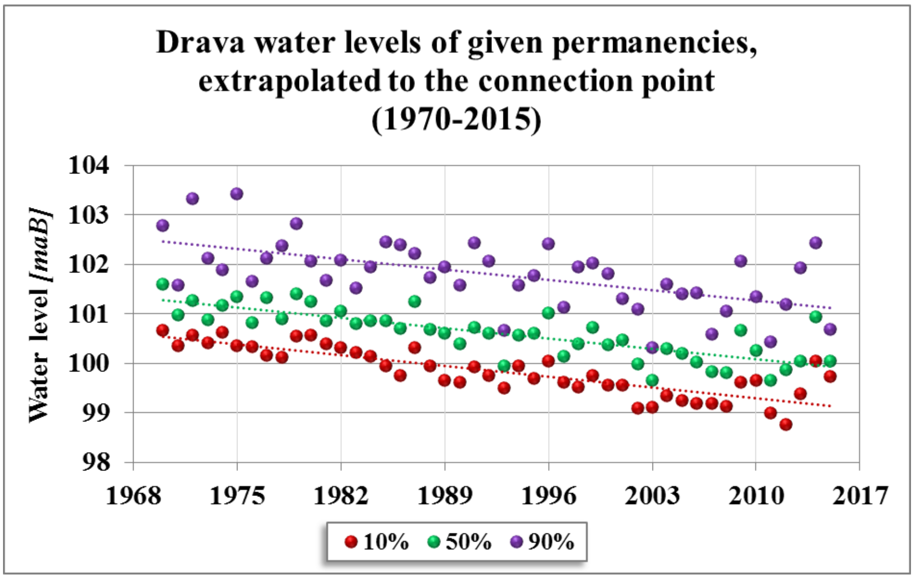


*Figure 2.16. - Yearly Drava water level data of 10; 50 and 90% permanency, extrapolated to the connection point (1970-2015)*

*Figure 2.17.*shows the water level values extrapolated to the planned water transfer point of the River Drava for the period of 2009-2015.

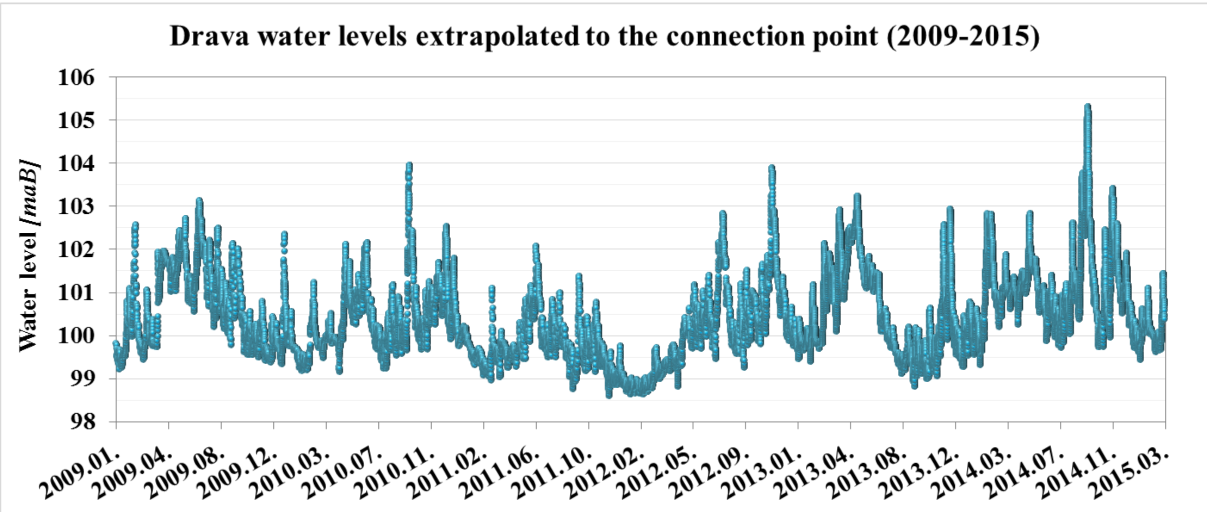


*Figure 2.17. Drava water levels extrapolated to the planned connection point (2009-2015)*

**For each year in the period of 2009-2015, we determined the number of days when it was physically possible to recharge the Barcsi-Old-Drava from the River Drava using the calculated water level values. The results are presented in *Chapter 4*. It is important to note that the riverbed on the examined section of the River Drava section is still deepening by approximately 3.5 cm/year, therefore the frequency of the desired water levels is expected to decrease in the future (*Figure 2.16.*).**

Using the water level values extrapolated from the water levels of the River Drava recorded between 2009 and 2015, the characteristic water level permanecies at the connection point were determined (*Figure 2.18.*). As for he previously described measuring points, we calculated the water level values to the given permanency (cumulative frequency) values (10%, 50% and 90%) for the planned connection point as well. It is shown on the figure that 90% of the water level values extrapolated to the introduction point exceed the elevation of 99.31 maB. The value of the 50% water level permanency is 100.22 maB, while **only 10% of the water level data were higher than 101.76 maB**.

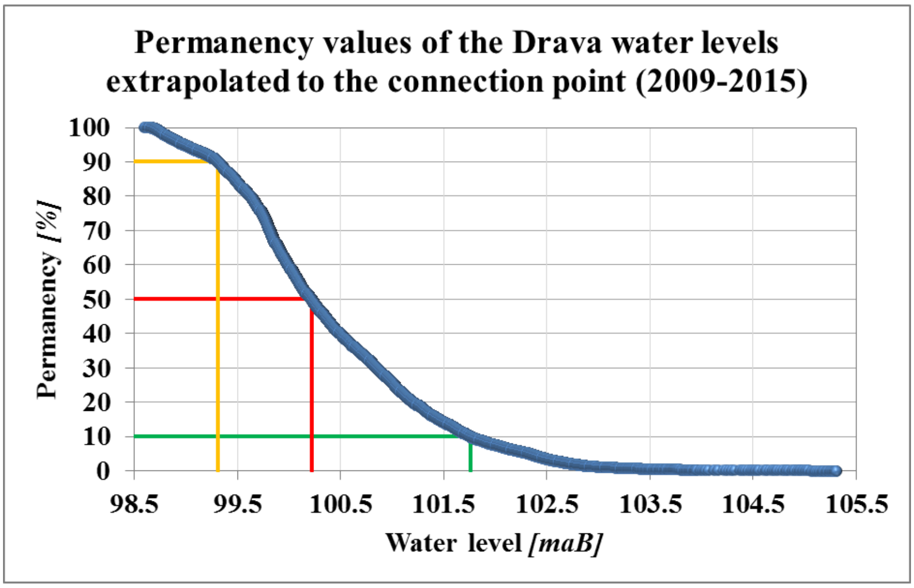


*Figure 2.18. – Permanency values of the River Drava water levels extrapolated to the connection point (2009-2015)*

# 3 Water level analysis of the Barcsi-Old-Drava oxbow

In the following chapter the potential effects of the water level change on the hydraulic conditions of the oxbow are discussed.

As a part of the assessment, for different water levels the expansion of the water covered areas, the evaporation rate, the potential inundation of low-lying areas and the water residence time are examined.

The provided terrain model *[Hydroing, 2008]* was cross-checked with the elevation data of the Hydrographic Atlas of the River Drava. Besides the riverbed geometry data of the Old-Drava *[Hydroing, 2008]*, and the water flow data of the River Babócsai-Rinya were also employed for the calculations.

For the determination of the **location and the extension of the water covered areas the terrain model and the water levels were compared**. The aim of the calculation was to determine the areas under the potential risk of inundation that might occur a result of the damming.

The calculations were set using the following water levels: **101.75 maB, 102.22 maB (zero point of the gauge), 102.75 maB (planned water level = 53 cm) and 103.50 maB.** The areas lying below the set water levels were marked.

As the results show, **applying these water levels, there will not be extential water covered areas beside the riverbed of the Barcsi-Old-Drava, there are no low-lying fields around the oxbow.** The graphic display of the calculations can be seen on the figures below (*Figure 3.1-3.4.).*

<u>**Therefore as a result of applying the 102.75 maB water level recommended by the experts of the DDNPD, inundation in the surrounding areas is not expected to occur.**</u>

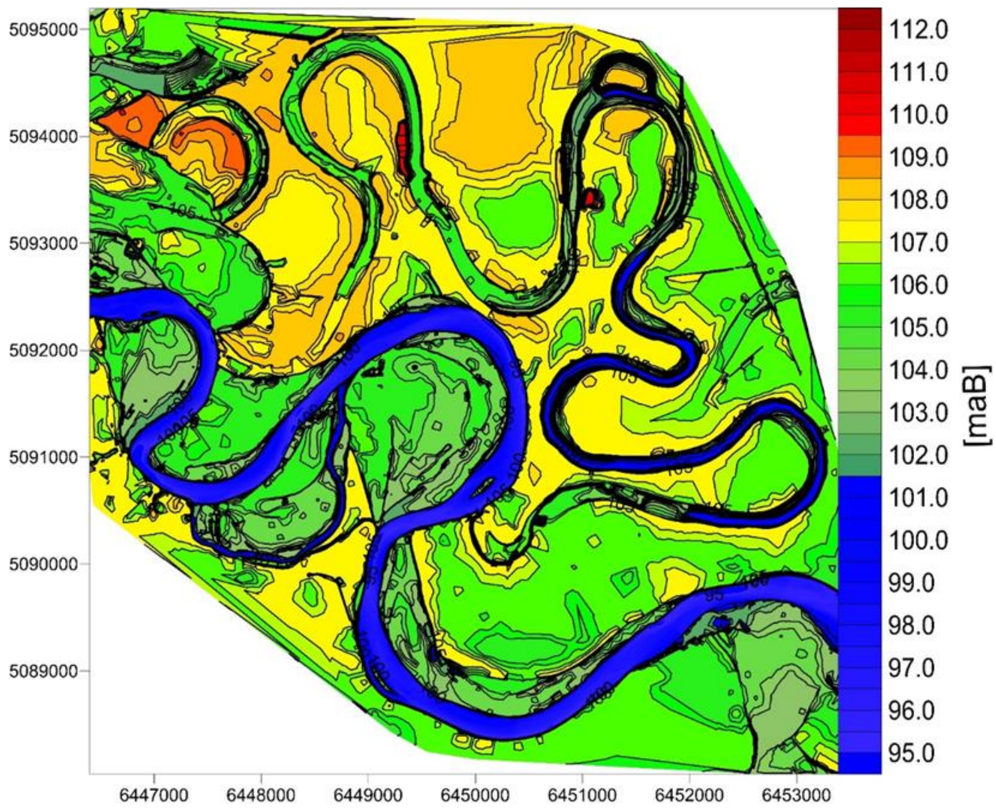


*Figure 3.1. - Potentially water covered areas at 101.75 maB water level*

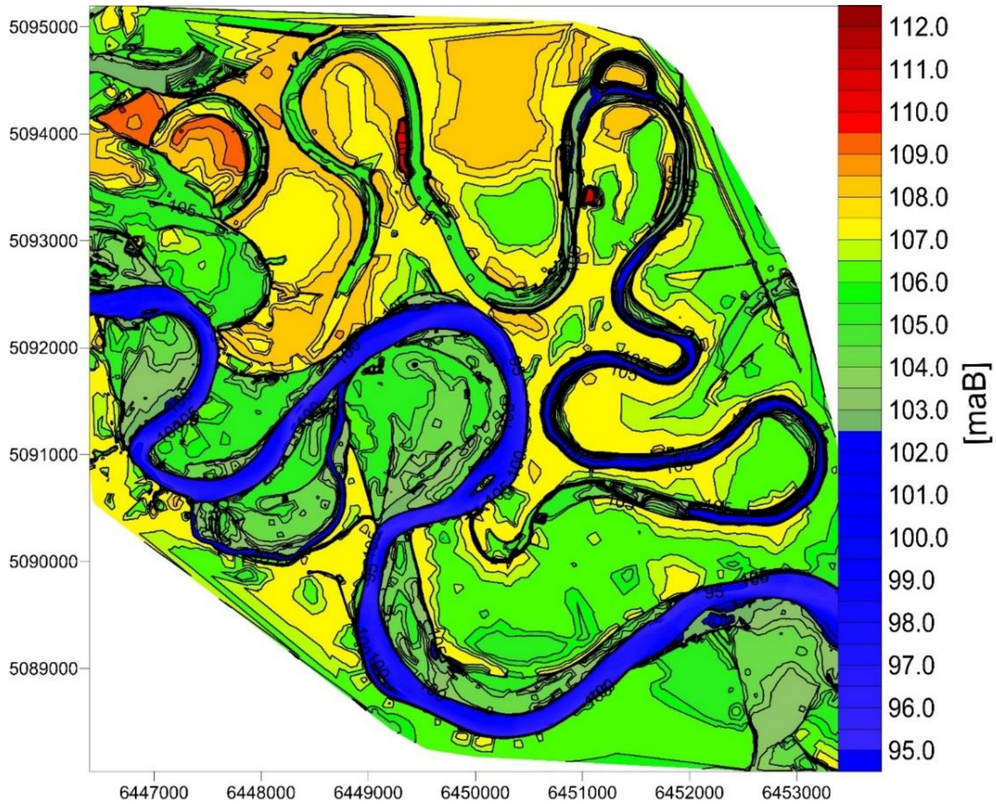


*Figure 3.2. - Potentially water covered areas at 102.22 maB water level (102.22 maB= zero point of the river-gauge)*

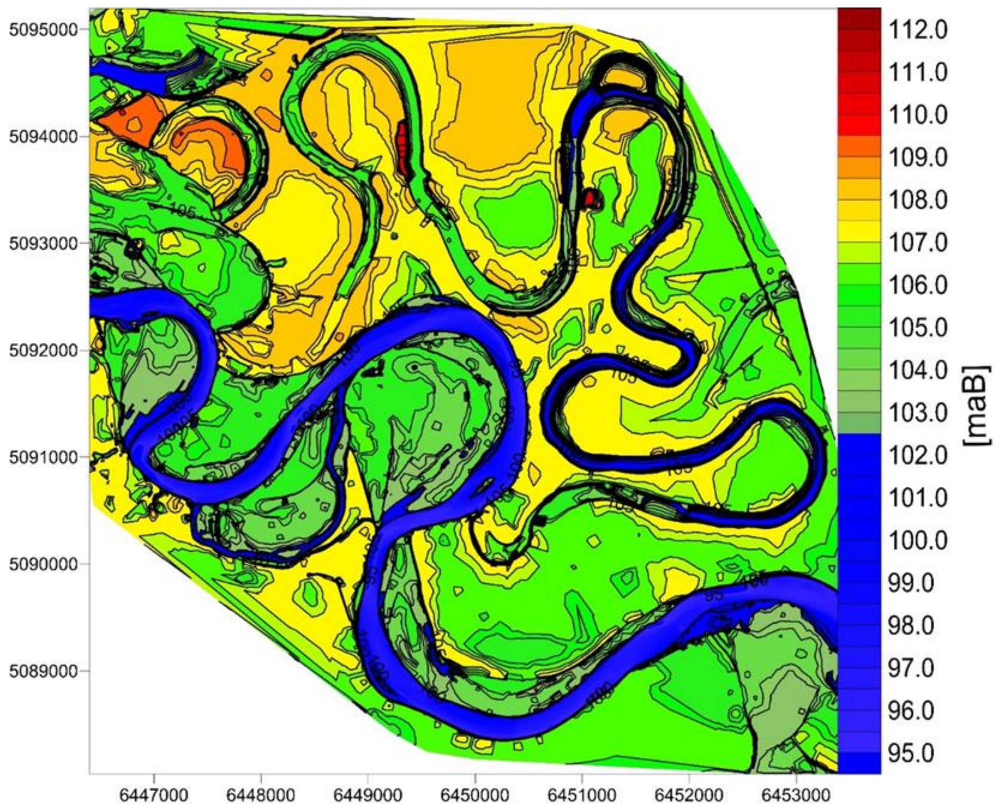


*Figure 3.3. - Potentially water covered areas at the proposed 102.75 maB water level*

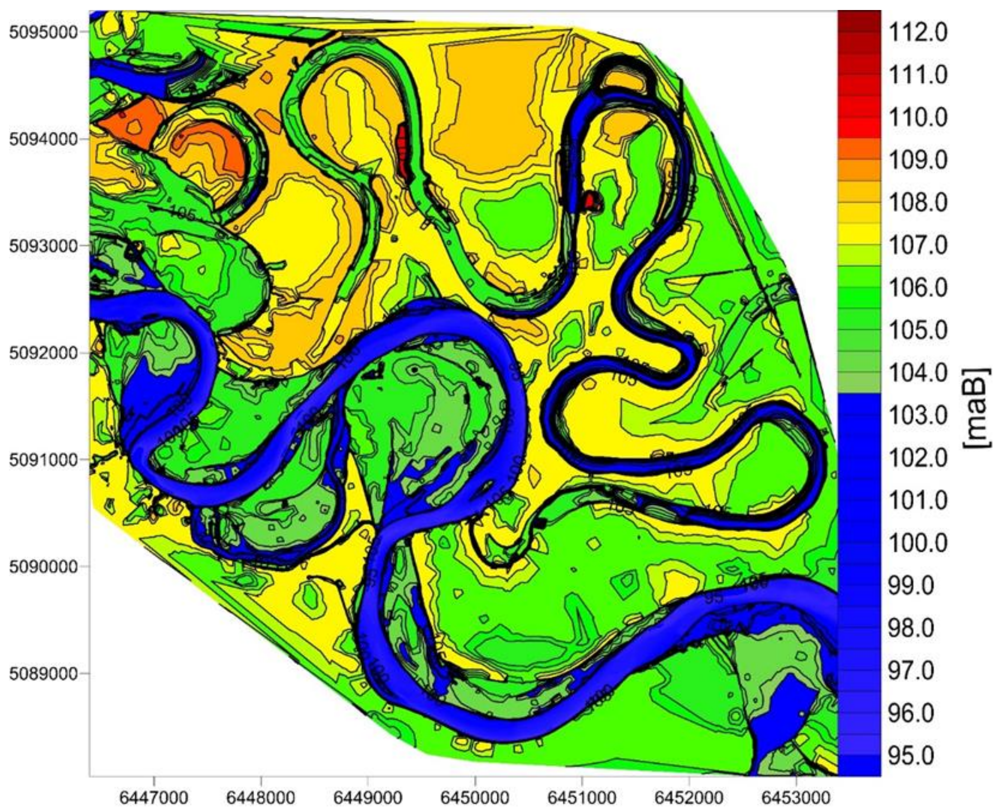


*Figure 3.4. - Potentially water covered areas at the 103.50 maB water level*

The Barcsi-Old-Drava can be characterized with water levels fluctuating over a wide range. Due to the increase in water supply, in a rainy period the water level can significantly rise. As the rate of the water supply decreases (or completely stops) the water level starts to dwindle. In the spring-summer period the change in the water level can reach 1 meter height.

At the time of the field visit the water level of the Barcsi-Old-Drava was 25 cm, which is 102.47 maB. It should be noted that **prior to this survey the water level of the oxbow was not recorded**. **However, as part of the project the data of the newly installed gauge has to be collected and analyzed.**

Based on the estimation of the experts of the DDNPD, familiar with the oxbow's condition, the following water levels can be expected in the spring-summer period (compared to the conditions seen during the site visit in May):

- **May: 40 cm decrease (102.07 maB);**
- **June: 60-80 cm decrease (101.77 maB);**
- **August: 100 cm decrease (101.47 maB);**

Considering the data above, **the water volumes and water surface areas were determined for each set water level**. **Thus the water residence time (consequently the tendency to eutrophication) can be defined.**

The estimations were based on the terrain model provided by Hydroing Ltd. according to the methodology presented below.

The riverbed data of the digital terrain model were cross-checked with the control data recorded during the field visit in May 2015 by the Inno-Water Ltd.

**Since the preparation of the terrain model the geometry of the riverbed did not change significantly, which could alter the flow conditions of the channel. The conducted comprehension check also verified that <u>the provided digital terrain model can be accepted for the further calculations.</u>**

Considering that only the Barcsi-Old-Drava is relevant in terms of the calculation of the stored water volume, and the water surface area, the first step was the convertion of the terrain model into a grid (an area divided into small regular squares, each one representing a defined height) and the oxbow with the surrounding area was cut out of the terrain model.

For the second step of the calculation as the riverbed of the oxbow was cut from the grid file, the height data of the riverbed remained undisturbed but the grid cells of the surrounding areas were left "empty" ("empty" means that the cell does not contain information, and it is left out from the calculation). The isolated terrain model of the riverbed was intersected with flats defined by the characteristic water levels of the spring-summer period. In such way only the areas below the flat were left for the further calculations.

Considering that the boundaries of the grid cells containing valid height data were set to the actual riverbed, the section remaining after the cut the water covered riverbed was delineated.

For the determination of the volume and the area we applied the following estimatios. A single grid cell was set as a basic surface unit. The terrain model was built by using 2 m x 2 m grid cell network. Therefore each height data was assigned to a 4 $m^2$ surface unit and “empty” cells were assigned to 0 $m^2$.

By using this method for summarizing the grid cell surfaces a good approximation can be given on the area of the actual water surface for the determined water levels.

Approximating the whole water surface with the summarized grid cells surfaces carries some overestimations at the boundary of the area, since the grid cells intersected by the boundary of the riverbed are counted with their whole surface.

It is important to note that since the project area containing the oxbow is 2650 hectares, the set 2 m x 2 m grid cell spacing is sufficient for detailed and punctual measurements, considering the limits of the data processability. Considering the whole surface of the oxbow the size of the cells affected by the riverbed boundary are negligible, therefore the overestimation of the boundary cell sizes are acceptable.

*Figure 3.5* illustrates the results of the calculations made. It can be noted that the water surface area and the proposed water levels have an approximately linear relation (in the range of the lowest characteristic summer water level and the water levels proposed for the intervention).

The higher water level represents larger water surface which can have a beneficial effect on the wildlife of the Barcsi-Old-Drava. However the larger surface also indicates higher evaporation rate, which also has to be taken into consideration during the implementation of the project.

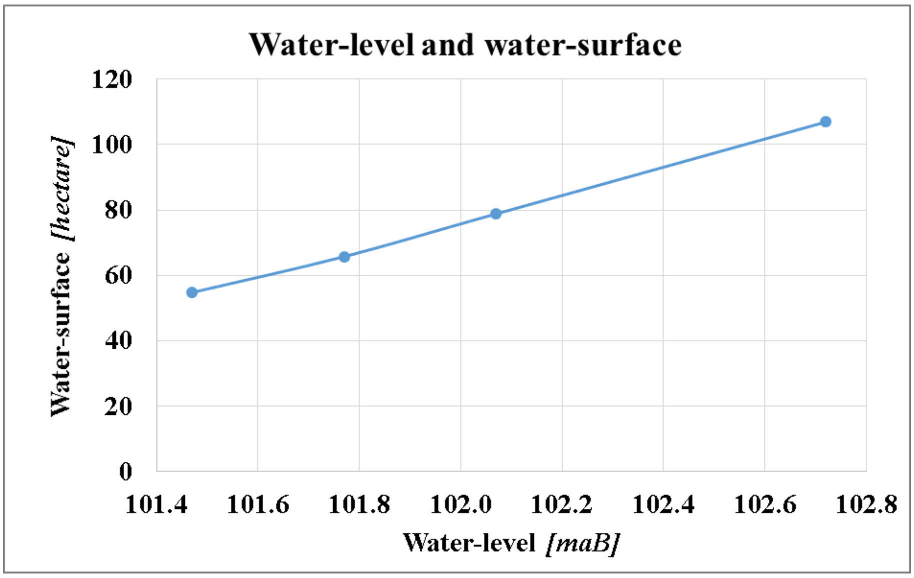


*Figure 3.5. – The relation between the Barcsi-Old-Drava water levels and the area of the water-surface*

In case of the examined characteristic water levels the stored water volume was determined in a similar way to the surface area measurement, with the only difference that in this case instead of the basic cell surface unit the basic volume units, the multiplication of the cell surface and the cell water depth (the difference of the height of the terrain model and the height of the water level) were summed up. The results are illustrated on *Figure 3.6.*

It is noted that in the examined range **the relation between the water level and water volume is not linear (just approximately)**. In the higher water level range the stored water volume has a greater increase which can be explained by the cross sectional characteristics of the riverbed, it gets wider near the surface and it is more tapering at the bottom.

Considering the preparation of the intervention this conclusion has a great importance. The higher water volume has a positive ecological effect, but it is important to take into consideration that **the exchange rate of the increased retained water volume can considerably vary compared to characteristic values before the intervention**, which may affect the eutrophication tendency of the oxbow.

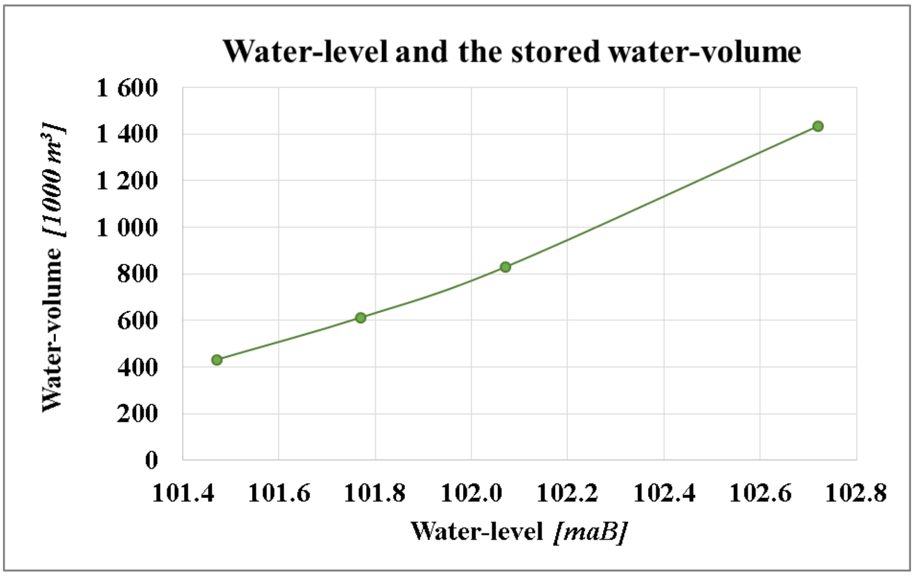


*Figure 3.6. –The relation between the Barcsi-Old-Drava water levels and the stored water volume*

In terms of the characterization of the Barcsi-Old-Drava water regime besides the stored water volumes the water-loss of the evaporation also has to be determined. The approximate estimations were made based on the general evaporation calculation methodology for long-term average values as described in *Hidrológiai számítások [Koris, 2003]* considering the local characters as well. The value of the evaporation loss was calculated according to the methodology described below.

Considering the slight overestimation of the water surface and the water volume, and the limited available data, **the annual rate of evaporation was defined from a map of long-term average evaporation values** *[Koris, 2003]*.

The evaporation rate is 900 mm/year, which – similarly to the precipitation measures – represents the total evaporation of 1 $m^2$ water surface measured in liter ($dm^3$).

As the second step of the approximate calculation **the annual evaporation value (at first without additional water supply) was defined** as a multiplication of the long-term average evaporation rate and the water surface area of the Barcsi-Old-Drava. Different evaporation rate was calculated for each water level, since the surface area varies at the different water levels.

Supposing no water supply the water level would constantly decrease due to the evaporation, therefore the surface area of the oxbow would also decrease, resulting a diminishing evaporation rate.

However regarding the fact that the main objective of the project is to set a constant water level in the oxbow, thus the water level was considered permanent in the calculations for the whole year. For the estimation of the evaporation water-loss the additional evapotranspiration (evaporation of the aquatic plants) also had to be taken into account.

According to the relevant literature, the plants floating on the water surface do not represent supplementary water-loss. With the presence of vegetation stretching high above the water (eg., reeds) in the summer period the combined evaporation of the water surface and the plants can reach **1.5-2.0 times higher summer evaporation rates than the open water surface** *[Koris, 2003]*. The additional evapotranspiration is relevant **only in the summer period**. The related values are summarized in *Table 3.1*.

| **Month** | **IV.** | **V.** | **VI.** | **VII.** | **VIII.** | **IX.** | **Summer term (IV-IX.)** |
|---|---|---|---|---|---|---|---|
| **%** | 6 | 10 | 17 | 27 | 25 | 15 | 100 |

*Table 3.1. – The surplus evaporation of the aquatic vegetation*
*(In percentage of the evaporation prevailing in the summer period)*

As the first step the area of the vegetation-covered water surface was estimated using the findings of the field survey in May 2015 and the combined layers of the available satellite photos and the digital terrain model. **The estimated vegetation-covered water surface is about 45% of the whole surface of the Barcsi-Old-Drava.**

Considering that the evapotranspiration is only relevant in the April - September period, the doubled evaporation rate of the vegetation-covered water surface was projected only to the summer evaporation rate of the open water surface.

86 % (744 mm) of the annual evaporation rate is realized in the summer period, therefore the vegetation covered water surface was considered with 1548 mm evaporation with a monthly distribution as shown in *Table 3.1*.

The combined annual evaporation (winter period + summer period open water surface + summer + summer evapotranspiration) is summarized in *Figure 3.7*.

It has be noted that **without an appropriate water supply the rate of evaporation is almost as high as the stored water volume in the oxbow**.

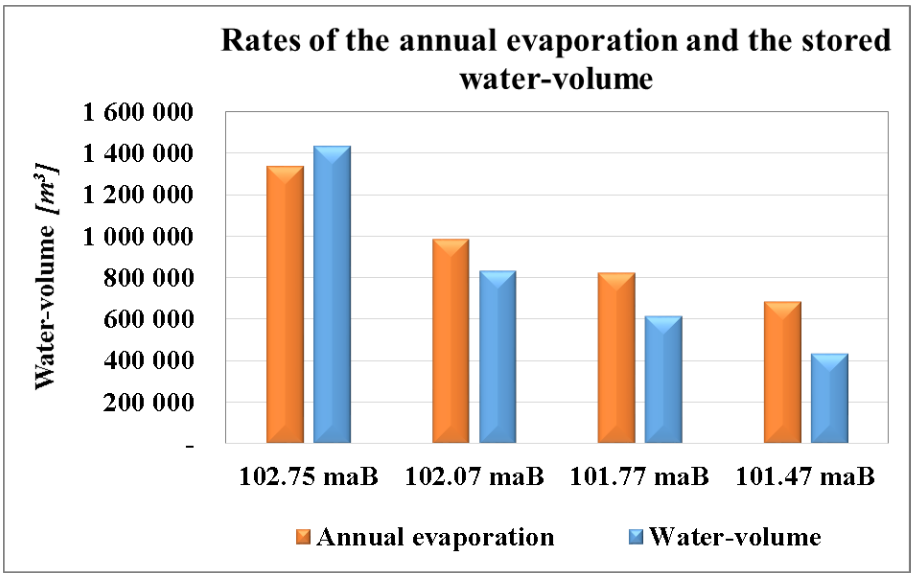


*Figure 3.7. – Annual evaporation rate at various water levels*

**By knowing the evaporation rates, it can be examined whether the planned water supply is sufficient to provide enough fresh water for the Barcsi-Old-Drava,** otherwise the oxbow might became stagnant, which can have adverse ecologic effects (eutrophication, decreased dissolved oxygen concentration, sedimentation, etc.).

To examine this possibility in more details, the characteristic water-flow of the River Babócsai-Rinya was calculated (average value, 90% 50% 10% permanency) based on 50 years of data.

The monthly divided evaporation rate (for each examined water level) and the flow of the River Babócsai-Rinya can be seen on *Figure 3.8.* It is remarkable that even the 90% permanency water flow is 20 times higher than the evaporation. Therefore it can be concluded that **applying the River Babócsai-Rinya alone as a water supply for the oxbow, the proposed water level and the higher water volumes can be sustained at high probability**.

However the total water-loss is higher than the evaporation since the filtration from the riverbed into the ground also has to be considered. **For the estimation of the potential infiltration the required data was not provided**, indicating the need for further studies and measurements. **In order to define the relation between the groundwater level and the oxbow's water level a groundwater monitoring well should be installed near the riverside.**

On the other hand the calculation showed that **the water flow of the River Babócsai-Rinya is significantly higher than the evaporation loss**, therefore these partial losses does not significantly compromise the relevance of the findings.

*Note: Figure 3.8.* illustrates both the evaporation loss and the water flow data. It is noted that the scales of the two data series are different.

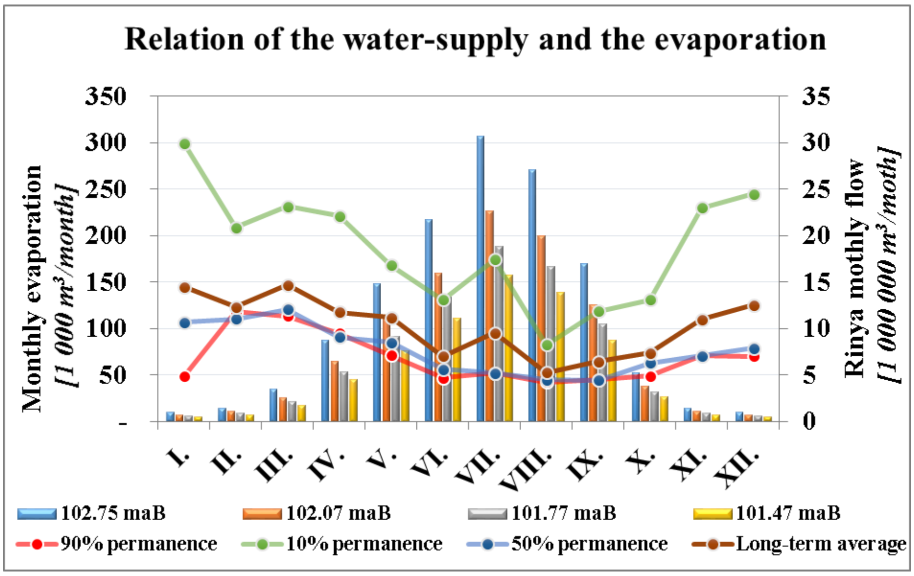


*Figure 3.8. – The evaporation rate and the characteristic monthly flow of the River Babócsai-Rinya*

## *3.1 Expected changes in water quality*

For the preparation of the water retention measurements, it is important to define the residence time of water of the Barcsi-Old-Drava.

**With longer residence time, the probability of the water quality degradation processes increases** (eutrophication, sedimentation, deterioration of dissolved oxygen household, etc). In order to examine this sceanrio the residence time for each proposed water level and for different water flows (LQ, MQ and HQ) of River Babócsai-Rinya was estimated (*see Table 3.2.*).
For the calculation a simplified formula was applied (which did not consider the water loss and the precipitation). The residence time was defined as the ratio of the stored water volume and the flow.

| Residence time | Water flow [$m^3/s$] |
|---|---|
| **Water flow with 90% permanency** | 1.21 |
| **Water flow with 50% permanency** | 3.13 |
| **Water flow with 10% permanency** | 9.70 |

*Table 3.2. – Characteristic water flow rates for different permanency used as boundary condition for the applied model (The data was measured between 1969-2015 at Babócsa river-gauge)*

*Note*: Residence time can be defined as a period of time which a single water particle spends in the system, in this case in the oxbow.

*Table 3.3* summarizes the estimated residence time for different water flows.

| Water-level | Water volume | Residence time | | | |
|---|---|---|---|---|---|
| | | 90% permanency | 50% permanency | 10% permanency | Long-term average |
| *[maB]* | *[m³]* | *[day]* | *[day]* | *[day]* | *[day]* |
| **102.75** | 1 434 100 | 14 | 6 | 2 | 4 |
| **102.07** | 829 500 | 8 | 3 | 1 | 2 |
| **101.77** | 613 200 | 6 | 3 | 1 | 2 |
| **101.47** | 432 400 | 4 | 2 | 1 | 1 |

*Table 3.3. – Residence times for different water level and water flow permanency*

It is notable that with the given water supply the residence time related to the proposed water levels is 3-4 times higher than the values of the summer low water level period. Therefore **in case of a permanently higher water level the multiplication of the residence time has to be taken into consideration**.

As described in the water quality analysis on the lower section of the River Babócsai-Rinya, below Nagyatád the nutrient concentration is several times higher than the standard limit value, and along the river section at Babócsa the nutrient concentration is more favorable but still relatively high, therefore the risk of eutrophication in the oxbow may increase.

**It has to be examined that the high concentrations of nutrients along the feeding the stream and the high water levels the increased residence time can significantly increase the trophic level of the oxbow. Especially given that the otherwise limiting factor the orthophosphate-ion with the longer residence time is available in larger amounts.**

Therefore with the increased residence time the risk of the unfavorable water quality changes is further increasing. **Thus in case the interventions are realized, it has a key importance to improve the water quality of the River Babócsai-Rinya (filtration, pond, regular harvest of the reed, etc.) in order to avoid and moderate the unfavorable ecologic effects (decreased dissolved oxygen, fish mortality, dense vegetation in riverbed. etc.)**.

In case the eutrophication process enhances due to the higher water level, the expected favorable ecologic effect of the intervention will diminish (in an adverse case even worse conditions can develop than the present basic state).

It is to be noted that with the execution of the pollution control measures of the National Water-Management Plan, the water-quality of the River Babócsai-Rinya is expected to improve.

**It is recommended to install and operate a surveillance monitoring system, and regularly analyze the hydraulic and water quality parameters of the oxbow in order to observe and follow up the effects of the interventions.**

# 4 Studies on water supply alternatives for the period of 2009-2015

Based on water level data between 2009 and 2015 we have determined the number of days during which the water supply of the oxbow can be provided directly from the River Drava, considering the proposed water levels. The evaluation of the water levels of the River Drava was carried out on the basis of the following data (*Chapter 2.2.*):

- **Water level data of the gauge of Barcs between 1970 and 2015;**
- **The water level slope indicated in the Drava Atlas between the gauge of Barcs and the planned connection point of the Barcsi-Old-Drava and the River Drava for water supply.**

*Figure 4.1.* shows water levels of the River Drava in 2009. extrapolated to the connection point. Beside the various water levels, the altitude of water levels (level of inflow) can be read. Water supply is possible when the water level developing in this section of the River Drava exceeds the proposed water level of Old-Drava. The water level determined by the experts of DDNPD as 102.75 maB (green line).

The figure clearly shows that the days suitable for water supply around the year do not form a longer, continuous period, the **water supply would have been possible only at one few days long period**. Based on *Figure 4.1.* it can be concluded that in 2009, supposing a water level of 102.22 maB (zero point of the gauge) water supply would have been possible only at four times, of which only one is considered permanent (2 weeks).

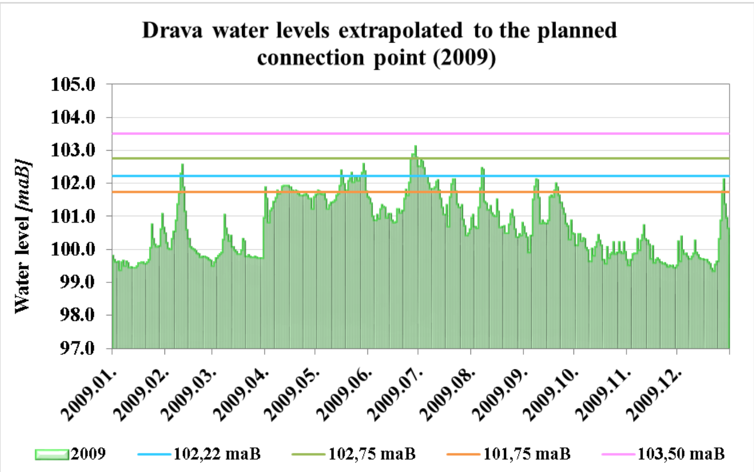


*Figure 4.1. – Extrapolated water levels of River Drava at the planned connection point with the water levels for different inflow cases (2009)*

As in the year of 2009, the periods suitable for water supply in 2010 were determined as well. It can be seen on *Figure 4.2.* that in order to achieve the planned water level of 102.75 maB, **water supply would have been physically possible only for a short period from the River**

**Drava**. The water level of the River Drava in the given section exceeded the 102.22 maB altitude only for a few days.

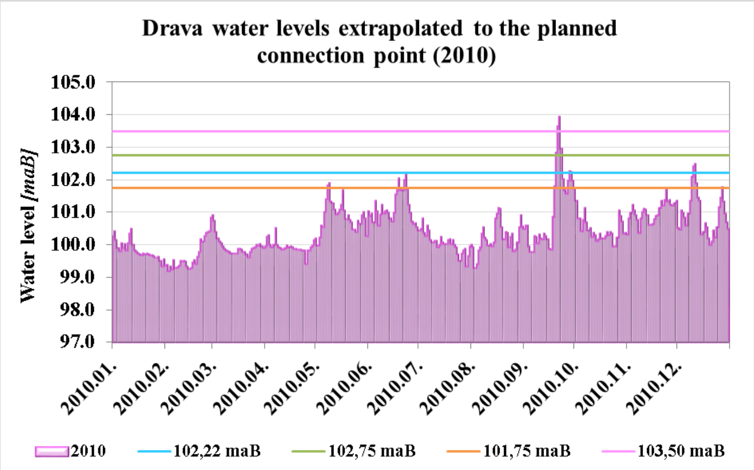


*Figure 4.2. – Extrapolated water levels of River Drava at the planned connection point with the water levels for different inflow cases (2010)*

**In 2011, the water level of the River Drava would not have allowed the water supply** in the case of 102.75 maB, nor in the case of 102.22 maB water level (*Figure 4.3.).*

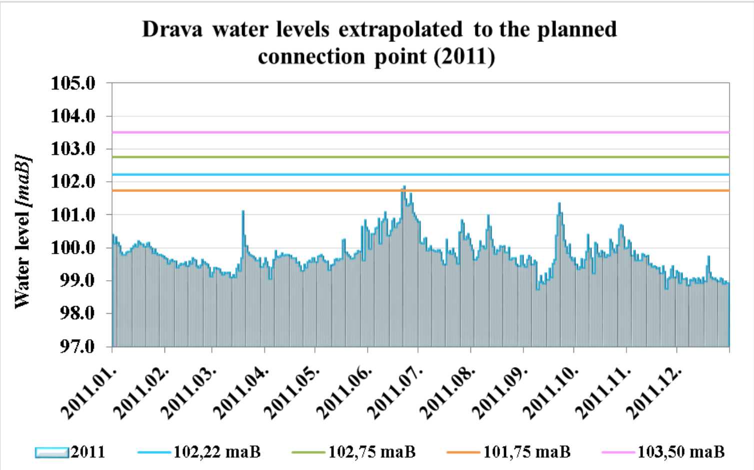


*Figure 4.3. – Extrapolated water levels of River Drava at the planned connection point with the water levels for different inflow cases (2011)*

**In 2012 the 102.75 maB water level of the Old-Drava could have been maintained only for one longer period** (*Figure 4.4.*).

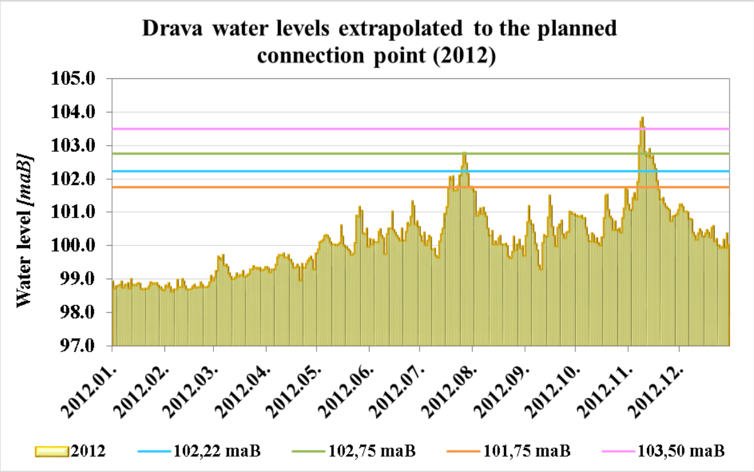


*Figure 4.4. – Extrapolated water levels of River Drava at the planned connection point with the water levels for different inflow cases (2012)*

In 2013, resembling conditions were experienced to that of 2009. During the year, only **3 shorter periods were suitable for water supply of the Old-Drava** to maintain 102.75 maB water level (*Figure 4.5.*).

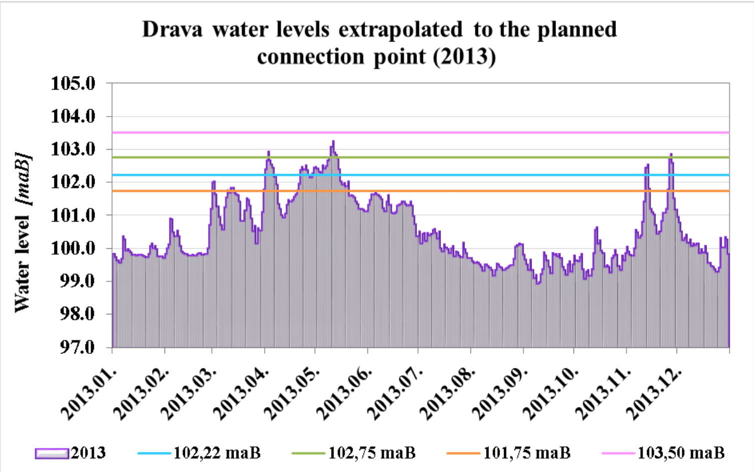


*Figure 4.5. – Extrapolated water levels of River Drava at the planned connection point with the water levels for different inflow cases (2013)*

Based on the extrapolated data to the planned connection point, the highest water levels of the River Drava were seen in 2014 of the examined years. However, **for maintaining a 102.75 maB water level in the Old-Drava only two longer period** (six and ten days long) **would have been suitable** (*Figure 4.6.*).

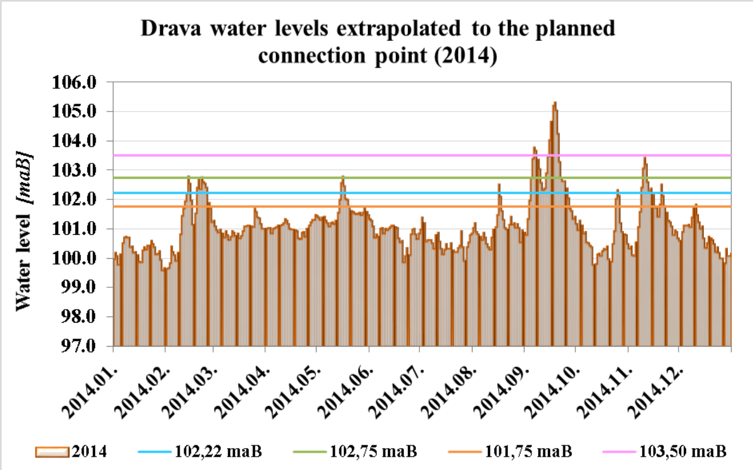


*Figure 4.6. – Extrapolated water levels of River Drava at the planned connection point with the water levels for different inflow cases (2014)*

Similarly to the year of 2011, **in 2015 the water level of the River Drava would not have allowed the water supply** neither in the case of 102.75 maB, nor in the case of 102.22 maB water level (*Figure 4.7.).*

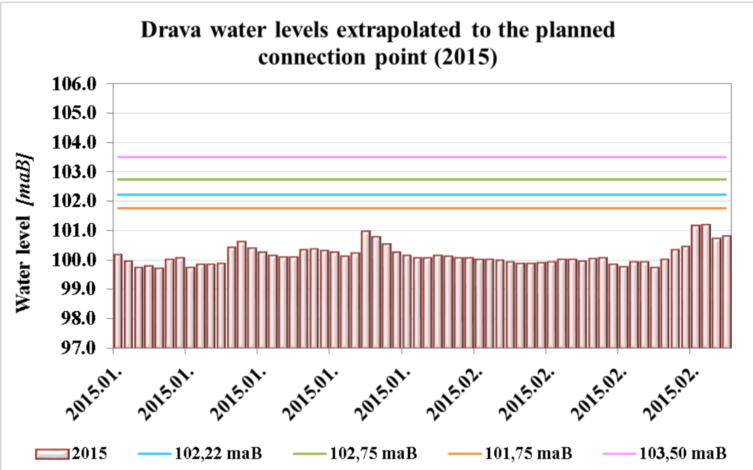


*Figure 4.7. – Extrapolated water levels of River Drava at the planned connection point with the water levels for different inflow cases (2015)*

Under a suggestion of the DDNPD and the STWMD (South-transdanubian Water Management Directorate) we have investigated an other possible alternative path of the discharge between the River Drava and the Barcsi Ó-Dráva. The investigated discharge alternatives are shown on the *Figure 4.8.*

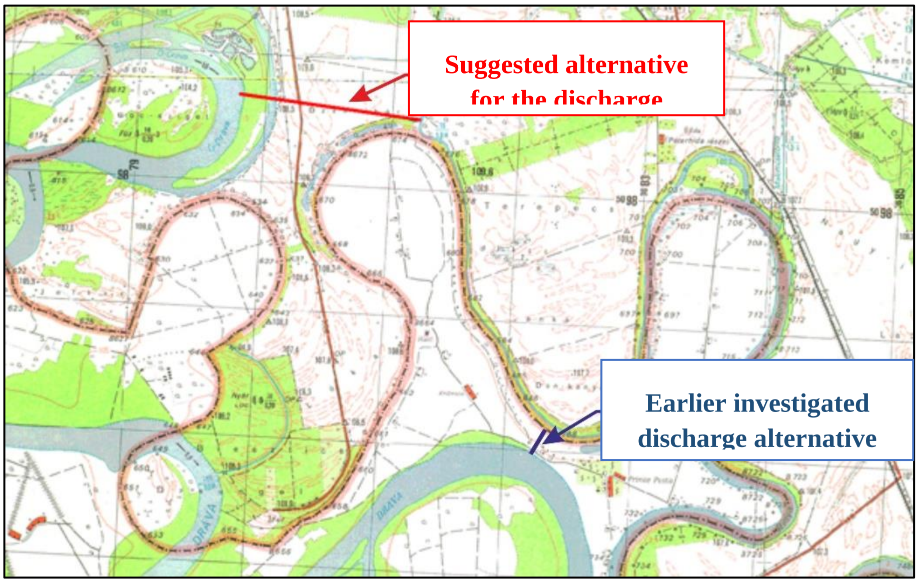


*Figure 4.8. – Suggested alternatives of the discharge between the River Drava and the Barcsi Ó-Dráva*

Regarding the results of the investigations, the alternative suggested by the STWMD is not recommended, due to the significantly higher investment costs and the low efficiency by lower water levels of the River Drava.

# 5 Introducing the water retention alternatives

Based on the terrain model developed by the Hydroing Ltd. the required height of the planned weir, capable to ensure the proposed at 102.75 maB water level, was defined.

**In order to determine the specific and most ideal location of the weir a detailed riverbed survey (at least in the surrounding area of the possible locations) and a geotechnical survey is required. The current study focusses only the conceptual plan.**

In the following **three cross-sections with different geometry as alternative locations** (see *Figure 5.1.)* **for the planned weir were examined.**

**The required height of the weir was calculated by using the 50% permanence flow rate of the River Babócsai-Rinya. The water levels at 90% and 10% permanence flow were also examined.**

It should be noted that at the time the terrain model was built, detailed data of the riverbed was not available, therefore the model was built up from several cross section data. **It is recommended to carry out a more detailed survey in order to fully explore the geometry of the riverbed. The accurate knowledge of the channel geometry (at least around the proposed structure) is a key requirement for the project planning.**

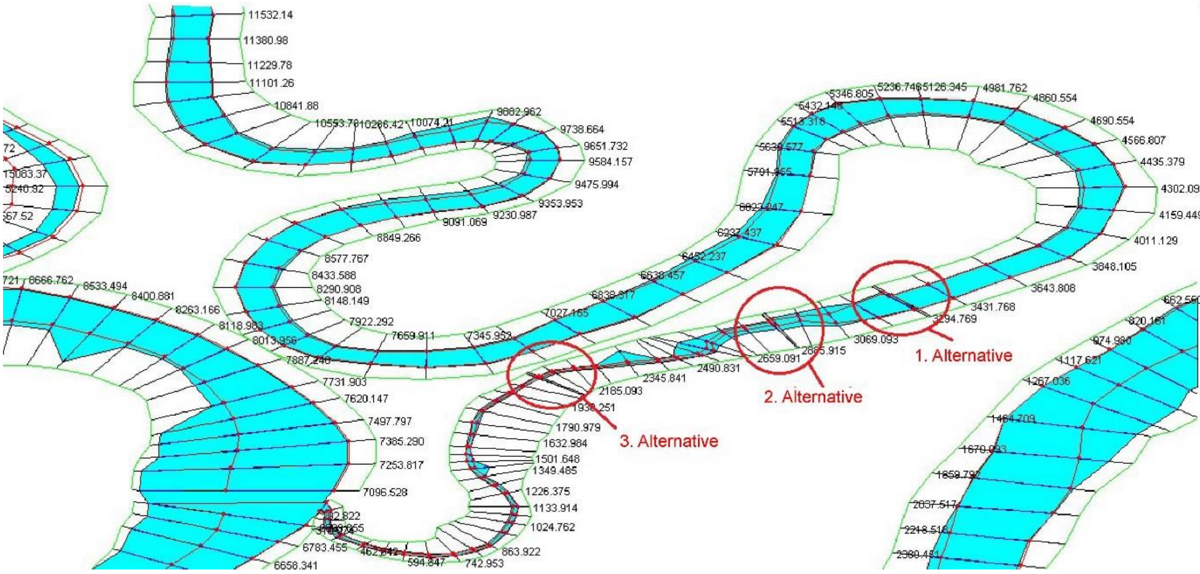


*Figure 5.1. – Proposed weir location alternatives along the Barcsi-Old Drava*

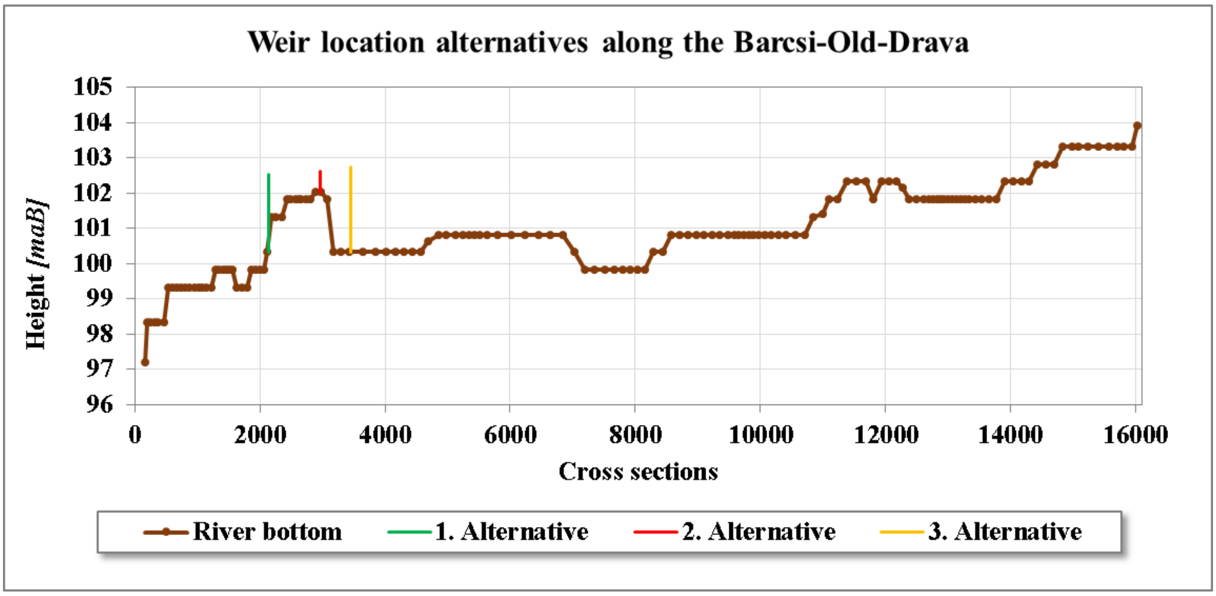


*Figure 5.2. –Proposed weir location alternatives along the Barcsi-Old Drava*

As a result of placing the weir in different cross-sections, the following figures illustrate the evolving water level along the oxbow.

As the calculations showed all the three different locations are suitable to construct a weir capable to stabilize the water level at the proposed 102.75 maB, irrespectively to the flow conditions of the Babócsai-Rinya. According to the 1st alternative a weir with a 102.7 maB crest was placed to the 3+295 rkm, in the 2nd alternative was set with a the crest 102.6 maB at 2+886 rkm and in the 3rd alternative it was placed to 2+118 rkm with a 102.5 maB crest. Compared to the height of the terrain these parameters require the installation of a 2.4 m, a 0.6 m and a 2.2 m high weir.

The water level calculations are referring to the cross section of the gauge, but it can be seen on the figures that in most sections of the oxbow the impacts of the water level rise are prevailing. It has to be emphasized that the HEC-RAS model leaves the possible water-losses out of consideration.

As it was described in *Chapter 3.* there can be considerate water losses because of the evaporation and infiltration, therefore the actual water levels can be slightly lower than the water levels indicated by the model.

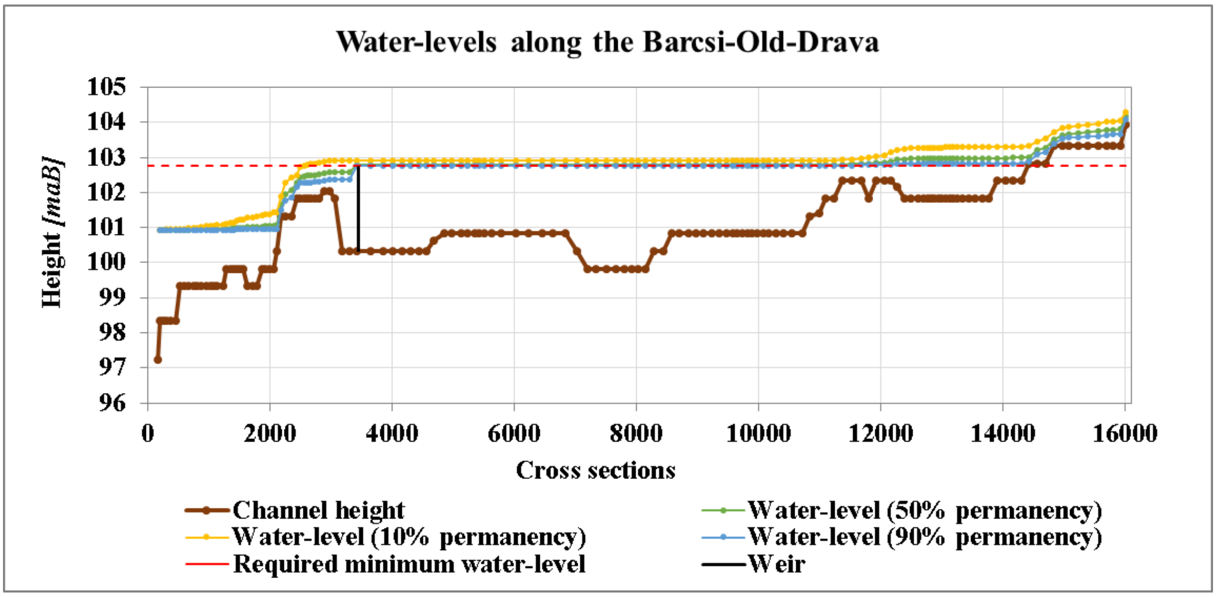


*Figure 5.3. – Water-levels along the oxbow's longitudinal profile – 1st alternative (3+295 rkm)*

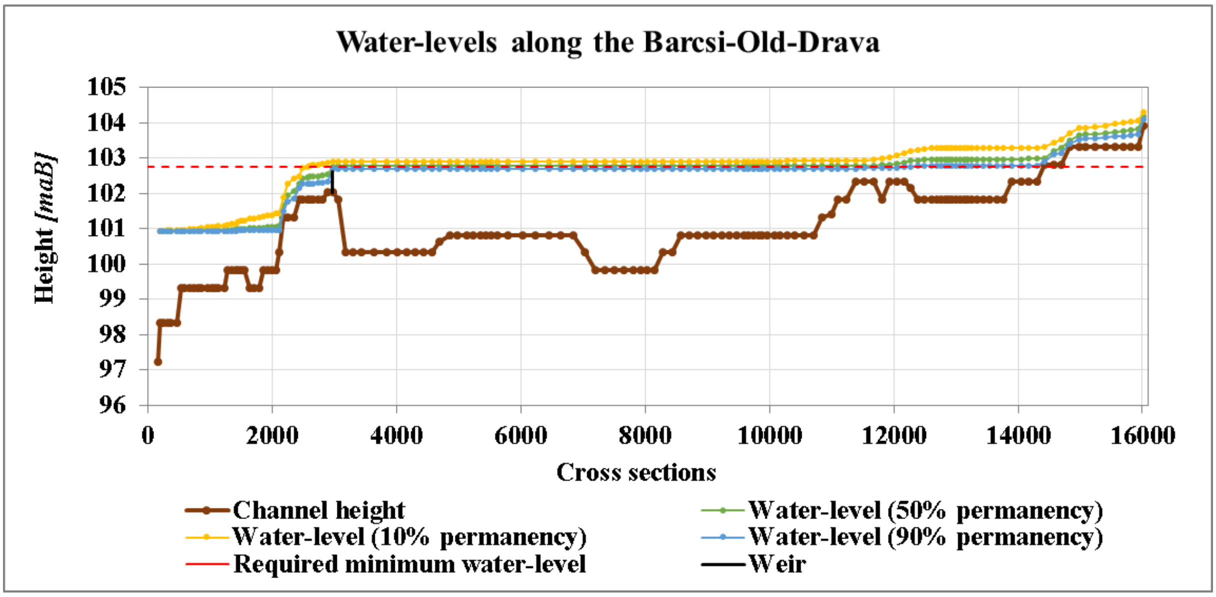


*Figure 5.4. - Water-levels along the oxbow's longitudinal profile – 2nd alternative (2+886 rkm)*

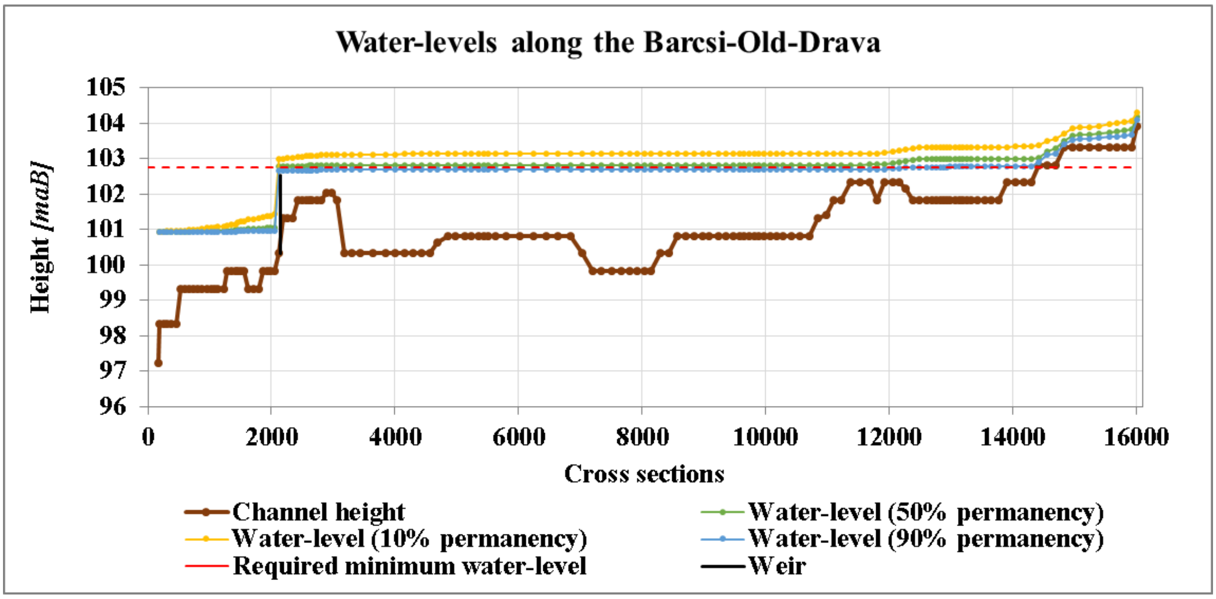


*Figure 5.5. – Water-levels along the oxbow's longitudinal profile – 3rd alternative (2+118 rkm)*

Flow velocity along the oxbow was calculated for each alternative with special regard to the vicinity of the weir. *Figure 5.6.-5.9.* illustrate the characteristic flows and the calculated values can be found in *Table 5.1*. The flow velocities along the Barcsi-Old-Drava were determined for different flow conditions of the River Babócsai-Rinya (for 10%, 50% and 90% flow permanency).

**Rather high velocities develop in the vicinity of the weir, especially on the downstream section. In order to ensure the stability of the weir the increased flow velocities have to be respectively considered for the structure design and construction.**

According to the model calculations significant change in flow velocity is not expected upstream of the weir. The construction of the weir do not extensively change the flow on the upstream section, however the flow cross section of a higher water level with the identical volume of water supply results in a slight decrease in flow velocity (the value can be defined as a function of the exact water level).

The retention time is expected to increase, however the main reason instead of the slowing velocity is the significantly increased water volume of the oxbow.

It has to be noted that the flow velocities are estimated values since for every alternatives a 10 meter the thick (parallel with the flow) weir was assumed for the calculations. Knowing the exact measures and geometry of the structure is indispensable for the simulation.

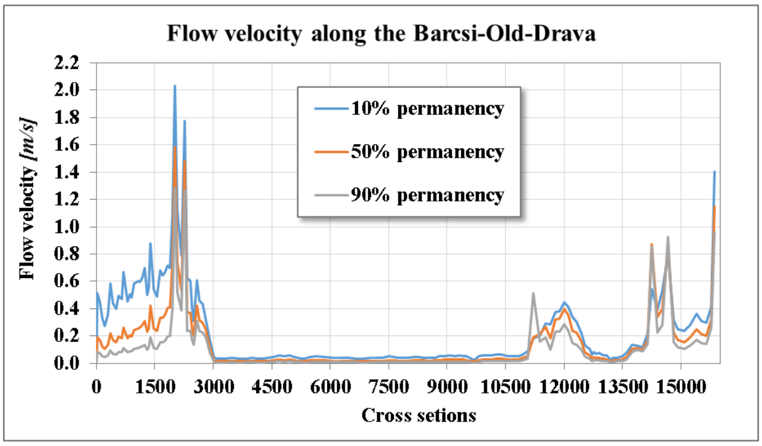


*Figure 5.6. – Flow velocity along the longitudinal section of the Barcsi-Old-Drava - 0. alternative (without a weir)*

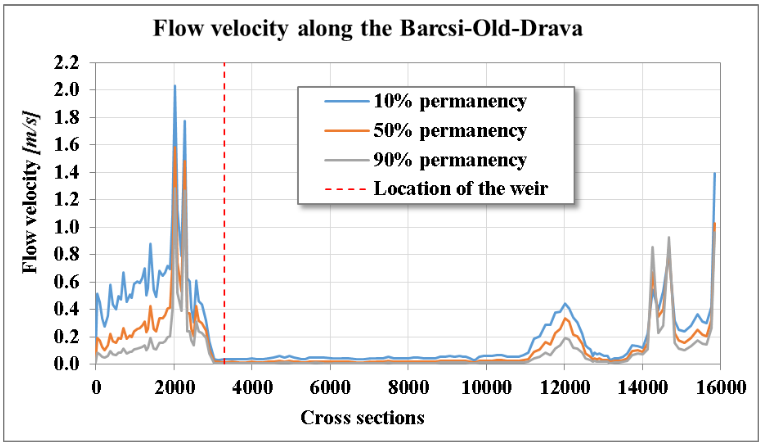


*Figure 5.7. – Flow velocity along the longitudinal section of the Barcsi-Old-Drava - 1. alternative (3+295 rkm)*

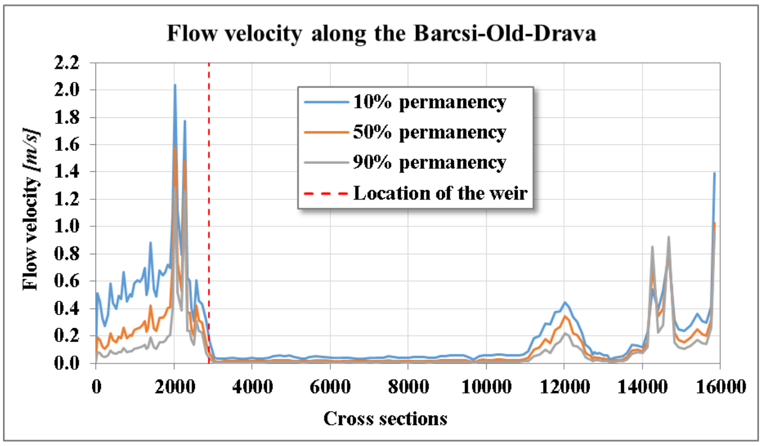


*Figure 5.8. – Flow velocity along the longitudinal section of the Barcsi-Old-Drava - 2. alternative (2+886 rkm)*

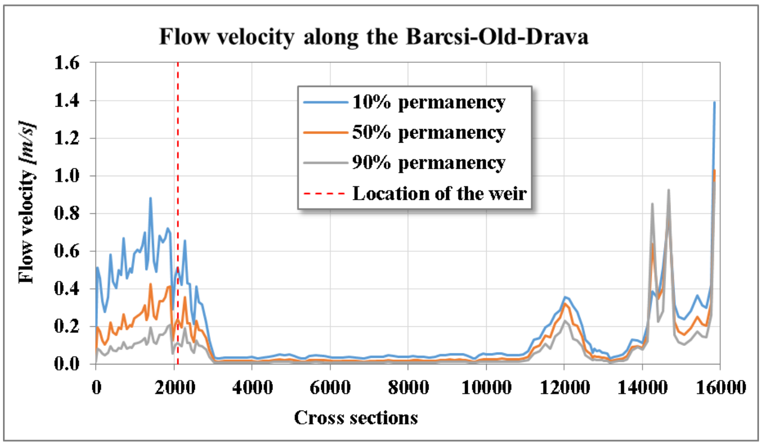


*Figure 5.9. – Flow velocity along the longitudinal section of the Barcsi-Old-Drava - 3. alternative (2+118 rkm)*

| **0. alternative (no weir is applied)** | | **Flow permanency** | | |
|---|---|---|---|---|
| | | **10%** | **50%** | **90%** |
| **Flow velocity at the gauge** | ***[m/s]*** | 0.04 | 0.02 | 0.01 |
| **Maximal flow velocity on the downstream section** | ***[m/s]*** | 2.03 | 1.58 | 1.29 |
| **Water-level at the gauge** | ***[maB]*** | 102.9 | 102.6 | 102.4 |
| **1. alternative (3+295 rkm)** | | **Flow permanency** | | |
| | | **10%** | **50%** | **90%** |
| **Flow velocity above the weir** | ***[m/s]*** | 0.37 | 0.36 | 0.27 |
| **Flow velocity directly under the weir** | ***[m/s]*** | 0.03 | 0.01 | 0.01 |
| **Flow velocity at the gauge** | ***[m/s]*** | 0.04 | 0.02 | 0.01 |
| **Maximal flow velocity on the downstream section** | ***[m/s]*** | 2.03 | 1.58 | 1.29 |
| **Water-level at the gauge** | ***[maB]*** | 102.9 | 102.8 | 102.8 |
| **2. alternative (2+886 rkm** | | **Flow permanency** | | |
| | | **10%** | **50%** | **90%** |
| **Flow velocity above the weir** | ***[m/s]*** | 0.65 | 0.51 | 0.40 |
| **Flow velocity directly under the weir** | ***[m/s]*** | 0.41 | 0.30 | 0.23 |
| **Flow velocity at the gauge** | ***[m/s]*** | 0.04 | 0.02 | 0.01 |
| **Maximal flow velocity on the downstream section** | ***[m/s]*** | 2.03 | 1.58 | 1.29 |
| **Water-level at the gauge** | ***[maB]*** | 102.9 | 102.8 | 102.7 |
| **3. alternative (2+118 rkm)** | | **Flow permanency** | | |
| | | **10%** | **50%** | **90%** |
| **Flow velocity above the weir** | ***[m/s]*** | 0.96 | 0.70 | 0.53 |
| **Flow velocity directly under the weir** | ***[m/s]*** | 0.70 | 0.41 | 0.20 |
| **Flow velocity at the gauge** | ***[m/s]*** | 0.04 | 0.02 | 0.01 |
| **Maximal flow velocity on the downstream section** | ***[m/s]*** | 1.39 | 1.03 | 0.96 |
| **Water-level at the gauge** | ***[maB]*** | 103.1 | 102.8 | 102.7 |

*Table 5.1. – The evolving flow velocities at the 3 weir alternatives and the water levels by the gauge*

As the results shown above a weir (depending on the exact location) can significantly increase the flow velocity along the direct downstream section.

However it is important to point out that on the account of the natural changes of the riverbed heights, velocity increase can be observed even without the installation of a weir (along the riverbed there is a naturally elevated point, and on its downstream section the flow velocity tend to be higher resulting riverbed erosion).

**The locally increased flow velocity can accelerate the erosion along the concerned section of the Barcsi-Old-Drava. In order to avoid any adverse effect preventive measures have to be taken. To assure the riverbed stability more small weirs could be installed, which do not play role in the water-retention measures.** *Figure 5.10.* illustrates an example for this case.

*Note*: The 3rd alternative has similar effect, placing the artificial structure after the damming natural height-elevation, can reduce the emerging velocity peak.

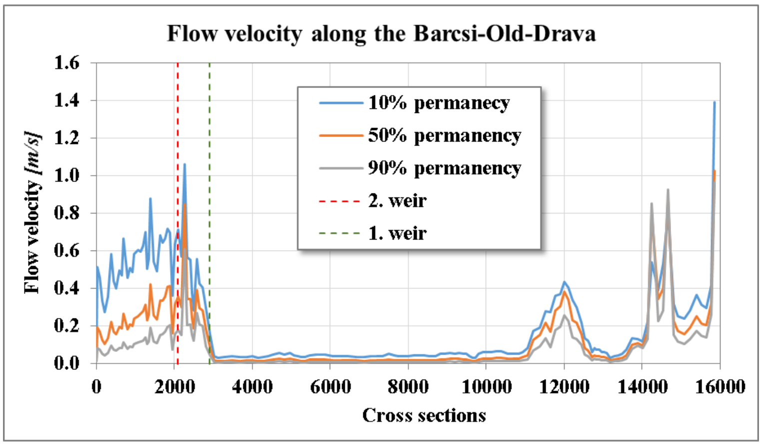


*Figure 5.10. – Flow velocity along the longitudinal section of the Barcsi-Old-Drava - 2. alternative (2+118 rkm) with two weirs*

In addition, **different other engineering solutions (e.g., riverbed cover with stones) can also be considered as a possible solution to ensure the riverbed. These measures also have to be calibrated as part of the technical preparation of the project**.

The different water-retention alternatives have different construction material demand and financial implications, therefore **estimations were made for the geometry of each weir alternatives in order to illustrate the possible differences.**

For the calculations the cross sections of the HECRAS model were used (since more detailed riverbed geometry data was not available) therefore these estimations may depart from the actual required material volumes.

However the presented calculations still properly illustrate that the material demand among the different weir location alternatives can be rather significant. The results can be found below in *Table 5.2.*

| Cross section | Cross profile * | Crest width* | Weir height | Thickness (parallel with the flow) *[m]* | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 5 | 7 | 9 | 11 | 13 |
| | *[m²]* | *[m]* | *[m]* | Volume *[m³]* | | | | |
| 3+295 (1. alternative) | 201.84 | 125.2 | 2.4 | 1009 | 1413 | 1817 | 2220 | 2624 |
| 2+886 (2. alternative) | 11.14 | 23.72 | 0.6 | 56 | 78 | 100 | 123 | 145 |
| 2+118 (3. alternative) | 20 | 15.05 | 2.2 | 100 | 140 | 180 | 220 | 260 |

*Table 5.2. – Geometry measures of the different weir alternatives*
*(*perpendicular to the flow)*

**Precise estimates of the construction costs and the material can only be made after selecting the location of the weir and defining the detailed geometry.**

**The construction of wing-walls, the assurance of the bottom stability on the two sides of the weir, and riverbed stability measures on the downstream section (stone scatter, weirs, etc.) may be required as well. The exact parameters of these structures have to be calibrated as a part of the technical design of the project.**

**On the behalf of the cost-effectiveness the whole detailed geodetic survey of the riverbed (or at least the 1+500 to 3+000 rkm) is recommended. Knowing the bed geometry and the soil-mechanic conditions the most suitable weir location can be selected.**

# 6 Possible water retention and water supply alternatives evaluation summary

In the previous chapters the possibilities of rehabilitation of the area were evaluated in detail, during which the key aspects and concerns were taken into consideration.

Essential conclusions and main comments are summarized of the feasibility study in similar topic on target area made by the Croatian Hydroing Ltd. in 2008 are summarized below *[Hydroing, 2008]*.

- **The Barcsi-Old-Drava water supply now primarily provided by the River Babócsa-Rinya. *Based on our own analysis the Babócsa-Rinya can be considered as the only water supply.***
- **Water transfer from the Drava is a possible alternative to solve water supply which can be resolved with a 101.8 maB base level connecting tunnel or tube. The 102.75 maB water level can not be guaranteed with the currently proposed solution.**
- **Riverbed dredging is a planned intervention in the riverbed of Barcsi-Old-Drava. B*oth the Hungarian and the Croatian party rejected the implementation of this project element, therefore we don't consider this action.***
- **It is recommended to install a filter field on the first section of the river in order to reduce the eutrophication in the area. *It is necessary to monitor the water quality of the River Babócsai-Rinya and the Barcsi-Old-Drava which ensures the supply of water, and to examine the alternatives to prevent an increase in eutrophication.***
- **It is necessary to build a sluice or a dam on the lower section of the Barcsi-Old-Drava which would ensure the water level control along the entire length of the Old Drava. According to preliminary plans it is a ~107 maB high dam with flood gate (the upper part of the high banks is ~108 mBf high). *It is recommended to build a dam/weir to retain the water, but it must fit into the landscape and if possible it should be low height and diameter and built from natural materials.***
- **There was no specific resolution in the study regarding the water level, 103 maB water level was suggested as a possible option.**

Based on discussions with the experts of DDNPD, the Hungarian partners had considered the rehabilitation of Barcsi-Old-Drava feasible following these criteria which we acknowledged as boundary conditions during the making of this study:

- **The dredging of oxbow would seriously damage the area ecologically, therefore the implementation of this version is not recommended; the Croatian partner also rejected this option.**
- **The water level of 102.75 maB in Barcsi-Old-Drava should be maintained.**

- **Solutions including engineering structures for water retention that requiring no human intervention or continuous operation and little maintenance should be preferred. It is a priority that the most natural solutions come to application.**

Tests carried out on the basis of data and information provided by the Croatian and Hungarian partners can be summarized as follows:

- **Water level of the River Drava in the vicinity of water transfer point was examined and the feasibility of the water supply from the River Drava was evaluated considering the water level of Barcsi-Old-Drava.**
- **The elevation data of the area in the vicinity of the oxbow and the extent of the area potentially flooded due to water level increases was examined.**
- **The typical flow of the River Babócsai-Rinya was examined which guarantees the water supply of the backwater.**
- **Based on the available data, rates of evaporation and evapotranspiration were determined for each proposed water level of the oxbow which was compared to the flow data of the River Babócsai-Rinya applying different occurrence probabilities (permanency).**
- **The water replacement times for each proposed water level and characteristic water regimes was examined using the retention curve of the oxbow.**
- **Water quality of rivers in the area was assessed and the potentially emergence of adverse effects of water storage was investigated.**
- **A literature summary was prepared about what passive structures could be used for water retention which was capable providing the desired water level in the oxbow.**
- **Using a model drawn up by the Croatian partner proposals for the possible alternatives to damming were developed. The required dimensions of the weir/dam in three potential cross-sections and the developing water flow rates in the vicinity of the structure was examined.**

Based on the results the following statements and suggestions can be provided.

For the water replenishment of Barcsi-Old-Drava it can be stated that **in case of 102.75 maB water level suggested by experts of DDNPD, water supply from the River Drava is phisycally possible only for few days in a year therefore it is not recommended on the basis of cost efficiency** (see *Chapter 4.*). The development of water transfer may affect the water level of Barcsi-Old-Drava because the water level of the River Drava in the vicinity of the point of discharge is typically much lower (1.5-2.0 m). Based on the alternative presented in the Croatian study, the highest point of the pipe transferred bottom level is situated at the height of 101.8 maB. **If the pipe for water supply is passive design and is not closed with sluice, during periods in which the water level of the River Drava is lower than the planned 102.75 maB, the water coming from Rinya will flow to Drava instead of Barcsi-Old-Drava.** As a result, the Barcsi-Old-Drava water supply disappears; according to present data this can happen at 95 % of the year. It has to be considered that the riverbed of this section of the River Drava is 3.5 cm/year whereupon the desired water level will develop more and more infrequently. **It is recommended – if authorities decide to build water transfer – to adjust the development and the bottom level of the water transfer to the planned water level of the Barcsi-Old-Drava and implement a way to close the transfer to prevent the water flow in the opposite direction in case of low water level in Drava.**

**The dredging of the Barcsi Old Drava riverbed is not recommended due to cencerns related to environmental protection and nature conservation.**

Considering water quality of the River Babócsa-Rinya – which is currently providing the water replacement of Barcsi-Old-Drava – **we recommend exemining interventions in order to prevent escalation of eutrophication, for example wetland or filtration zone establishment and/or systematic removal of aquatic vegetation in the upper sections of the Barcsi-Old-Drava** in agreement with Hydroing study. Based on the results diffuse and point source pollution both alters the quality of the River Babócsai-Rinya, primarily in terms of high nutrient concentrations.

**Considering typical water flow rates of River Babócsai-Rinya the oxbow's water exchange time will be 2-14 days in case the of 102.75 maB water level (**in the case of 90% permanence flow: 14 days). The current water exchange time varies between 1-8 days, depending on the water level (see *Chapter 3.1.*). **Evaporation and evapotranspiration loss are an order of magnitude lower than the amount of most likely coming water this time of year, therefore the River Babócsai-Rinya will be able to ensure the proper water recharge of the oxbow.**

Analyzing the area's altitude conditions in the vicinity of oxbow **as a result of applying the 102.75 maB water level recommended by the experts of the DDNPD, inundation in the surrounding areas is not expected to occur**. Based on the expert views the stabilized 102.75 maB water level would be higher than the normal water level (end of May: 0.7 m, June-July: 0.9-1.1 m, August: 1.3 m). *Remark: The modeling did not take into account water loss (leakage, evaporation), so the reported values in case of „0" alternative model may be higher than the actual water level.*

There are many technical solutions to developing structure for the impoundment of water. Based on a Croatian study ~ 107 maB of altitude characterized by reinforced concrete dam would be built. The top of the dam height would be so close to a high-shore (108 m maB). The water level of the Barcsi-Old-Drava would be controlled by opening and closing the sluice of the structure, which would be set at approximately 102.75 maB, about 4 m lower than the top of the dam based on current plans. The structure is needed to be operated to allow adjustment of the desired water level, and closed state of the lock the water flow stops in the oxbow. Due to the above, **the development of large reinforced concrete structure(s) is not recommended.**

In addition to the formerly suggested Croatian solution of the concept plan many other structure allows to stabilize water level of the Barcsi-Old-Drava water level. **Gabion dams,**

**pile lines or combined dams/weirs in addition to a number of advantages can be implemented as a passive system, which is capable increase the water level of the Barcsi-Old-Drava without operation.**

**Water permeability of the structure can be designed**, the full-impermeability or the desired degree of water permeability can be ensured with appropriate design. **The loose stones formed gabion dams are increasingly used, thanks to a more favorable environmental and ecological properties** (*Figure 6.1.*). These structures **somewhat permeable by the water and the sediment and organic suspended solids**, thus minimizing sedimentation and eutrophication of the dammed section of the river.

*Figure 6.1. – Stones formed gabion dam [source: http://www.gabionbaskets.co.za]*

*Figure 6.2. – Stones formed weir with center of pile line*

Among the stones bacteria break down a portion of the organic matter, thereby contributing to clean a river or canal water, as kind of a water purification and wastewater treatment process. Due to the particulate medium the turbulent flow supports aerobic decomposition processes, whereas the air-water mixing promoted.

**The stability and water resistance can be increased by using pile line as center of dam. The special profile along a side weir is suitable for measuring water flow.**

We developed several alternatives with the HEC-RAS model, which was submitted by the Croatian partners, in order to determine which portion of the oxbow and what size of dam or weir would be needed to establish, so that the water level is kept 102.75 maB vicinity of the gauge. In the calculations we took into account the River Babócsai-Rinya 10%, 50% and 90% permanence discharge data. The required heights were determined to the weir would be set at approximately the determined value of the oxbow water level for all characteristic water flow (see *Chapter 5.*). **Based on the analysis the construction of the water retention structure was recommended at the lower section of the oxbow, the current impoundment (2 + 886) surroundings. A more accurate survey of the basin geometry is necessary to determine the exact position of the structure and validation of cost efficiency, at least in the vicinity of the planned structure cross section, furthermore making geotechnical survey.**

**The most important aspects to be considered during the planning phase are summarized in the following *Chapter 7*.**

# 7 Main conclusions and suggestions based on the preparation work carried out by Inno-Water Ltd.

According to the available information and the results of the current preparation work the following key findings and recommendations are summarized regarding the revitalization of Old Drava:

1. **The planned water level at the river-gauge of the Old-Drava is 102.75 maB (53 cm).**
2. **In order to fit into the landscape the planned water retention structure should be made of natural materials. It should be operated as a passive object (regular maintenance-free operation) to avoid any greater natural disturbances. Only wood, natural stone or gabion building blocks should be used for the construction.**
3. **The geodetic survey of the oxbow's riverbed is required to accurately determine the ideal location of the planned dam and weirs (preferably the whole longitudinal profile of the oxbow should be surveyed, but at least the 1+500-3+000 rkm section).**
4. **The dam should be placed into a narrow cross-section, in order to decrease the required dimensions of the constructed structure. Therefore a shorter and tighter dam can ensure the required water level.**
5. **According to the currently available information, the suggested location of the dam construction is situated within the broader surrounding of the existing weir at the 2+895 rkm.**
6. **Protective measures have to be taken along the downstream section of the weir, in order to avoid further erosion and riverbed sinking. The length of the sections and the protection methods (stone scatter, chain of weirs, etc.) should be defined on the basis of geodetic and geotechnical studies.**
7. **As the exact location of the planned dam is defined, further geotechnical drilling and investigations has to be performed.**
8. **For the applied dam structure the Inno-Water Ltd. proposes the following recommendations: The core of the dam should be an adjusted row of wooden piles dimensioned based on the geotechnical data. As protection and cover layer gabion blocks should be applied, which also allow the passage through the top of the dam. The possibility should also be provided to place a water-load measuring weir into the pile row. The permeability of the dam can be evolved by an additional foil cover.**
9. **Preventive measures have to be considered that can help avoiding the enhanced eutrophication. A possible solution could be the set up of a free surface wetland or root zone area on the upstream section. The plants have to be regularly removed in order to permanently draw out the extra plant**

**nutrients. The wetland/filtration zone should be placed in the area of the Babócsai-Rinya outlet. The required dimensions and the exact location of the wetland should be defined as part of the planning procedure (on the basis of the current water quality, ownership and nature protection aims of the area) considering cost-efficiency. As an alternative solution the regular removal of the inhabited vegetation should be examined as well.**

10. **The water diversion during the construction should be carefully planned in order to avoid any possible environmental harms and distractions but to provide safe building conditions at the same time. It is not allowed to completely sluice down the oxbow! The minimal water level has to be determined. The demarcation of the building site and the applied water divertion depends on the determined minimum water level that should be kept during the construction period.**
11. **The possible fish pathways through the dam have to be investigated.**
12. **According to the data available the Inno-Water Ltd. takes the view that the discharge of the River Babócsai-Rinya is sufficient for the water recharge of the oxbow (considering the evaporation/evapotranspiration as well).**
13. **Water recharge from the River Drava (on 102.75 maB water level) can only be realized in case of extreme high water levels of the River Drava (which occur annually only for a few days). Therefore this water recharge solution is not recommended.**
14. **In case the source of the water recharge is yet the River Drava, a suitable engineering solution has to be implemented that prevents the water from the oxbow to flow back into the River Drava in the upstream section of the Old-Drava. The structure has to be protected (for example with dampers) against any adverse unwanted human intervention.**
15. **The Inno-Water Ltd. recommends the installation of a permanent surveillance type monitoring system (water quantity, water quality).**

# 8 Base data for the planning

The draft version of the concept plan was discussed several times with the involved organizations and experts. During the project meeting at Drávaszentes in 13.10.2015. **the representatives of the project partners together the experts and the design engineers involved in the preparation (planning) phase of the project have agreed on the following base data and conclusions, which should have been considered in the planning procedure.**

1. The planned target water level is 102.75 maB regarding the current water gauge of the Barcsi-Ó-Dráva (53 cm water level).
2. The planned weir for the water retention will be constructed in the vicinity of the currently existing, not regulated bottom weir, at the 2+886 rkm cross section of the Barcsi-Ó-Dráva (2$^{nd}$ alternative) (due to cost-benefit, approachability and other reasons). There are private lands on the designated area based on the preliminary studies, whose expropriation should be carried out by the Croatian project partner.
3. The planned structure of the weir allows the water flow also in case of low water levels (with manually operated sluice planks).
4. The planned weir is natural and fits into the landscape. It will be constructed of gabions mainly, using other additional natural material (rock, gravel, wooden logs for the foundation). The water proof condition will be provided using geotextile (geomembrane).
5. The geodetic survey of the riverbank section of the oxbow has to be performed near to the planned construction site (in order to the detailed planning of the weir, the additional riverbank fixation and the causal wing-walls). The selection of the survey performing subcontractor is in progress.
6. The drillings and the soil mechanic investigations also have to be carried out, in order to the design and construction of the weir.
7. The protection of the river bed bottom must be provided at the section behind the artifact, i.e. the deepening of the riverbed section should be prevented. During the geodetic and soil mechanic investigations the protected sections, and the method of the protection have to be determined (weir cascade system, riprap, etc.).
8. The minimization of the implementation costs should be pursued during the planning stage.
9. It can be concluded as the result of the preliminary investigations, that the recharge from the River Drava at 102.75 maB can be performed only by extremely high water levels of river, therefore this alternative was rejected by the project partners (due to cost-benefit reasons mainly).
10. Dredging will not performed during the project.
11. It is suggested to setting up a monitoring system including 1 or more groundwater monitoring wells, in order to collect baseline data, and follow the effects of the future implementations.

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