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Inland waterways regulation and river restoration in Croatia

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ABSTRACT: Croatia has signed in 1997 the *European agreement on major international inland waterways (AGN) contract*, which took affect in 1998. Based on *Contract*, Croatian inland waterways on the rivers Danube, Drava and Sava are implemented in the European inland waterways network (E-pp). Current class state of navigable rivers is not satisfied at this moment, and only 24% of the whole length fulfils international waterways requests. There are several activities according to the AGN, which are mainly making project documentation and readjustment of critical segments for navigation.

On these rivers modification of riverbed geometry are clearly caused by human activities. Due to stabilized river banks, geometric changes are indicated in river bed degradation. Additional problem on the river Sava is the water level degradation, which is caused by river bed degradation. River bed degradation is caused by gravel exploitation and dredging due to waterway depth increase.

Furthermore, Croatia is in the process of integration into the European Union, and as other EU members has a duty to align its water politics with the Water Framework Directive EU. According to the named document Member States shall protect, enhance and restore heavily modified water bodies of water, with the aim of achieving good surface water status. By using technical measurements stated goal and navigability requirement will be accomplished.

KEYWORDS: Inland waterways, river bed degradation, Water Framework Directive EU

1. Introduction

In the Republic of Croatia inland navigation occurs on three major rivers: Danube, Drava and Sava. Besides being major water recipients of large Croatian areas, water management moment of these rivers is great. For that reason they where in the past (and today but less) a subject of regulation actions through changes in water body and water regime.

In the past the river Drava was a subject of human activities for various water management purposes. Regulation of the river has begun in 18 century. Throughout 20 century a few hydropower plans have been build in the upstream section, and now days energetic value is generally employed. In Austria until 1988 it was constructed 12 weirs, in Slovenia until 1978 8 weirs, and in Croatia until 1999 3 weirs.

There were also significant regulation actions, mainly meander cutting and bank protection. The result is a significant decrease of river length (cca. 40% of the whole watercourse). The progression of this process is shown in Table 1. Now days there are great commercial appropriation of the river Drava related to sand and gravel exploitation.

It is indisputable that constructed energetic and regulation structures have disturbed watercourse natural balance. Now days banks of the river Drava are relatively stable and their

Table 1. Length change of the river Drava from mouth to Osijek.

Year	1784	1830	1842/46	1860	1886	1904	1966/68	1987/88
Length [km]	32	31,2	29,1	20,4	23,6	22,2	21,2	20,9

morphological change shows river bed degradation process. The example of the depositional zone of the river Drava, near the mouth into Danube, is presented on Figure 1.

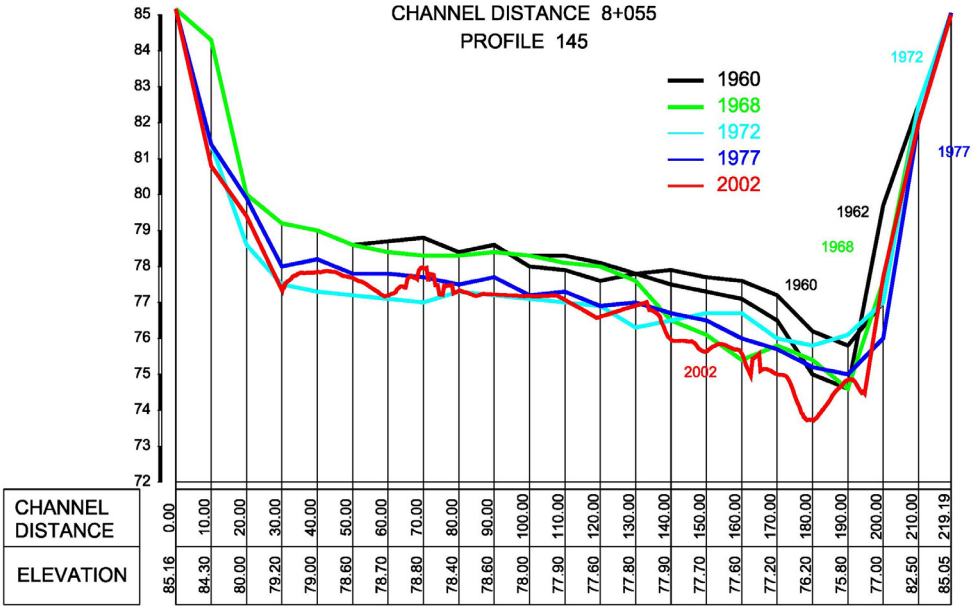

Figure 1. Characteristic profile on the river Drava.

On this section the water level is strongly influenced by backwater of the river Danube. And erosion process is still evident. Morphological changes made strong influence on hydrological changes of the watercourse and its ground waters. According to long-term measurements on water ganges there are continuous decreases of low waters and minimal discharges (Figure 2).

There are similar hydromorphological changes on the river Sava. In the middle 70žs significant changes were registered on a serial number of water ganges. During a period of 20 years (1970-1990) the mean annual change is showing permanent decrease of low, mean and also high water levels. In that period changes of a cross-section area have also been recorded. This 20-years-change was estimated according to cross-section soundings [2] and is shown in Table 2.

This behavior trend is explained by many hydrotechnical actions on the river Sava, mostly done in the 70's and 80's of the last century, which main purposes were flood protection and partially the use of water for thermo and nuclear plant. The exploitation of construction materials (sand and gravel) from the river banks also made a significant influence.

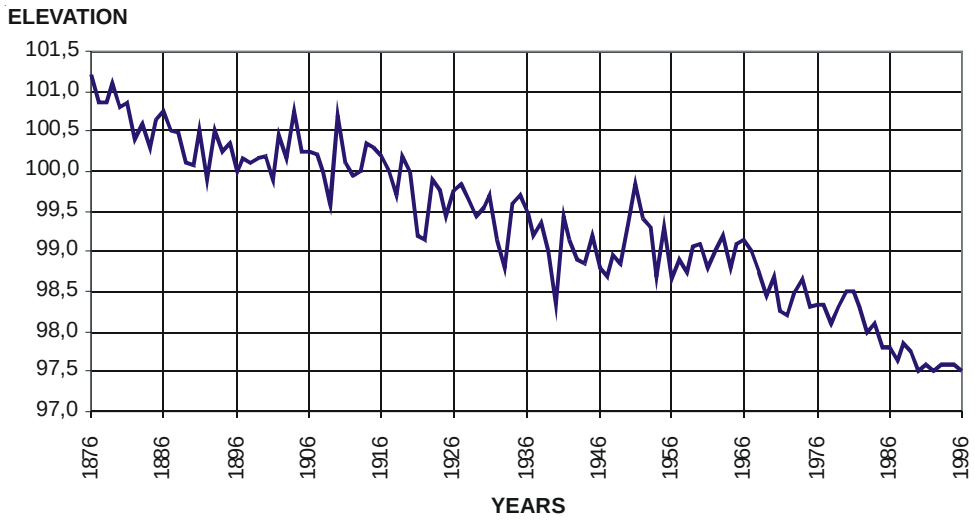

Figure 2. Annual low water levels on water station Terezino polje [1].

Table 2. Mean annual change of water level and water area for the period 1970-1990.

Water meter	Minimal annual water level [cm]	Mean annual water level [cm]	Maximum annual water level [cm]	Estimated increase of wetted area [m^2]
Jasenovac	-8,4	-7,0	-3,5	250
Mačkovac	-3,5	-5,2	-3,0	920
Sl. Kobaš	-3,0	-5,2	-4,2	290
Sl. Brod	-2,7	-5,8	-4,1	300
Županja	-4,8	-7,1	-4,5	96

2. AGN contract projection and current projects

Croatia has signed in 1997 the *European agreement on major international inland waterways (AGN) contract*, which took affect in 1998. Based on *Contract* [3], following Croatian inland waterways are implemented in the European inland waterways network (E-pp):

- E 80, river Danube, class VI.c,
- E 80-08, river Drava from mouth to Osijek, class IV., and
- E 80-12, river Sava from Jamene to Sisak, class IV.

Current class state on navigable rivers is not satisfied at this moment, and only 24% of the whole length fulfils international waterways requests.

Long-term goals of the inland navigation in the national development documents, are set a level or two above the current state (class V.b). According to the named duties and nacional plans, now days in Croatia there are several activities, which are mainly making of project documentations and readjustment of critical segments for navigation.

Project on the river Sava:

- Water depth condition for class IV is not satisfied on 30% of length and current waterway state is class III.

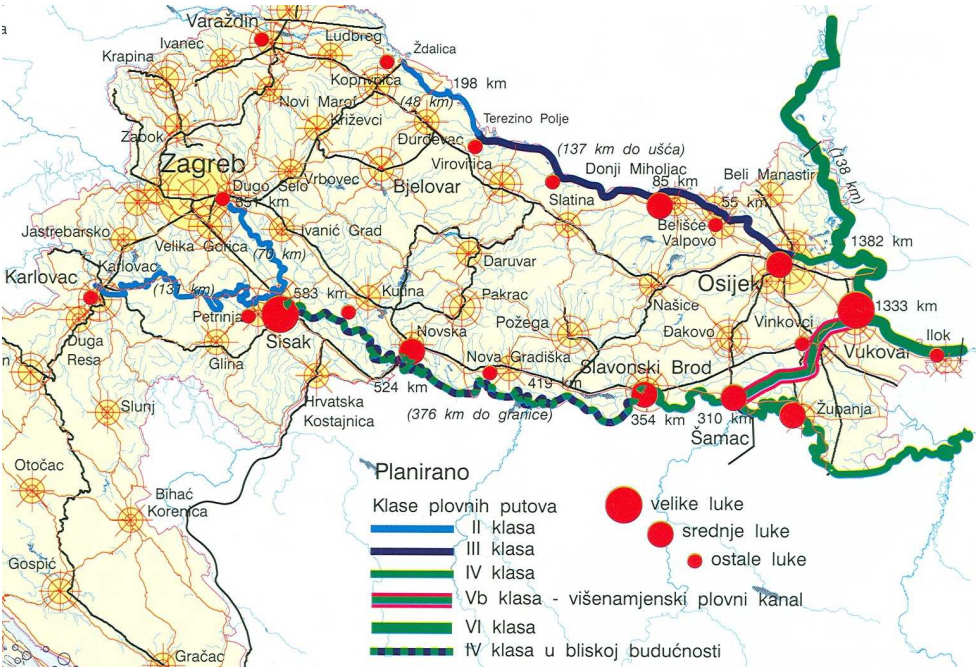

Figure 3. Waterway plans in Croatia [4].

- Curve condition is not satisfied on 10% of waterway length.
- Regulation project has been done for waterway class IV. Geometric project elements are profile 70x2.2 m and minimal curve radius R_{min}=360 m.

Project on the river Drava:

- As a part of the international waterway, in the first phase of Drava's regulation (rkm 0-22) maintenance work has been done, concerning sedments dredging from the river bed.
- Regulation project has been done. Geometric project elements are profile 50x2.4 m and minimal curve radius R_{min}=550 m.

For achievement of the necessary navigation profile, technical measures in Croatia mainly consider increase water depth in waterway zone. That increase of a wetted area of the river profile influnces water level decrease. Based on dredging volume that water level decrease have different value with decereasing trend moving upstream from the dredged place. Water table drawdown effect makes difficulties in the upstream section, with degradation of the river bed and groundwater level decrease, and also negative impact on navigability as primary demand for regulation actions.

3. Water Framework Directive projections

Achievement of the navigability purpose should not be confronted with principles of the integrated water resources management, which are implemented in general water management. Republic of Croatia is in the process of rapprochement to the European Union and should align its water politics to the Water Framework Directive EU. One of the stated tasks and goals in water management are environmental objectives. Applying

environmental objectives from *Directive* to the river watershed, EU member states may designate a body of surface water as heavily modified (HMWB). According to the *Directive* [6] (Article 4.) HMWB designation is possible when the changes to the hydormorphlogical characteristics of that body which would be necessary for achieving good ecological status would have significant adverse effect on:

- the wider environment
- navigation; including port facilities or recreation
- avtivities for the purpose of which water is stored
- water regualtion, flood protection, land drainage

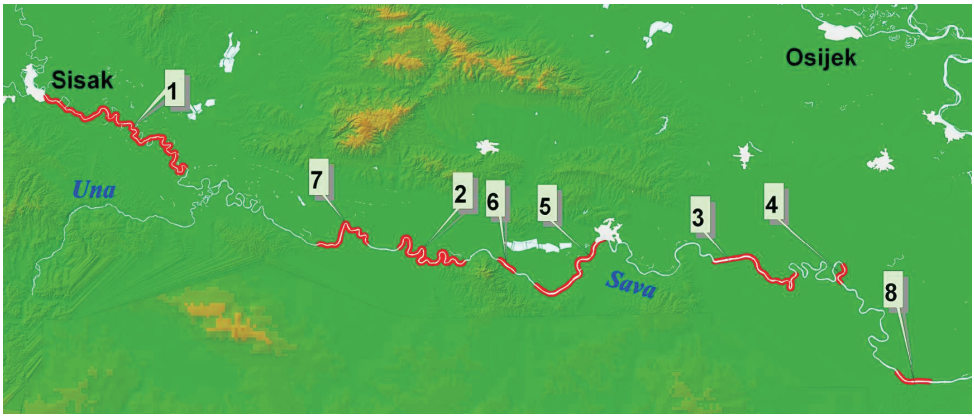

Figure 4. Regulation project of the river Sava [5].

For implementation environmental objectives from *Directive*, representatives of the Danube Basin countries came together to the international workshop *Identification and designation of heavily modified water bodies (HMWB) in the Danube River Basin*. Technical criteria for provisionally identifying HMWB are leaded though hydromorphological changes of the watershed.

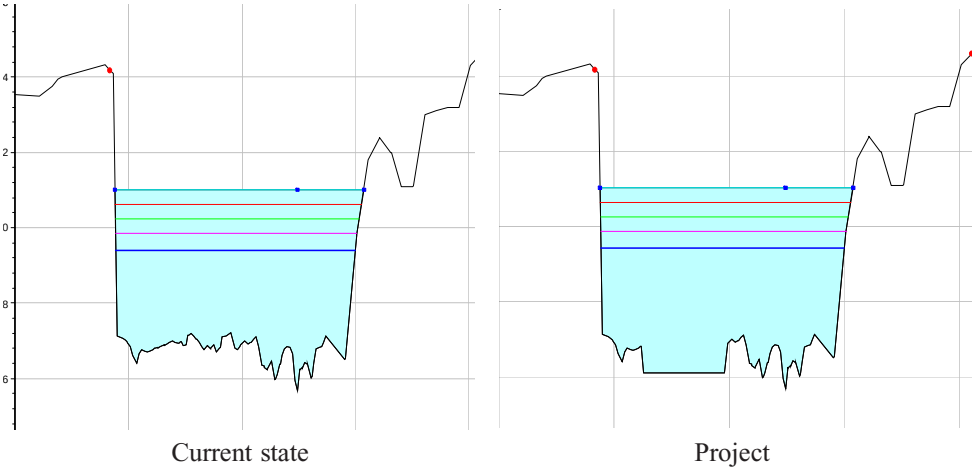

Figure 5. Example of a depth regulation on the river Drava cross section.

Taking into account guides from *Directive* and International workshop [7] and existing regulation level of rivers Sava and Drava, it can be councluded that they belong in HMWB river group.

4. River boundary regulation for navigation and river restoration

The initial issue is to specify influence level of above mentioned regulation actions for navigability purpose on good surface water status changes. A start point should be relevant current watershed condition. All of three major navigable watercourses in Croatia (Sava, Drava, Danube) had in the past significant hydromorphlogical changes related to the human activities on the river boundary and watershed. Furthermore, these watercourses are main streams in large watersheds with a great importance in water management. Now days, a new dynamic balance is accomplished but with different state from desirable one.

Objectives of the river restoration is to accomplish previos good ecological state considering river renatularization principles. To achive that goal on above mentioned rivers, knowing current condition and very intensive explotation in future, is not realistic and should be set differently. The actions on rivers should have multipurpose character. Beside improvements of the ecological system and biological variety improvements, future actions should also enable river exploitation. This task seems to be very contradictory and still it is only acceptable one.

The position of designers dealing with the river regulation for navigation purpose is very unenviable. Their technical solutions should at first satisfy demands of navigation authorities and on second may not drastically change river hydromorphological state. Furthermore, demand to accomplish better river ecological state is also present. This task can be solved only through gradually and cautiously implementation of technical measures, with accompanied suitable monitoring and corrections of the basic idea based on obtained effects.

The solution can be found within iterative procedure with implentation of the initial state on expensive pilot sections. In regulation actions of croatian rivers as part of international waterways following considerations are necessary:

1. depth corrections should be done only on necessary sections of the river boundary,
2. total length of the correction reach may not be longer than 30% of the total section length,
3. average width of the channel corrections may not be greater then 1/3 of the whole river width,
4. depth corrections should be combined with a grain application.

In our oppinion, only by applying these limitations three main requests could be accomplished (navigation, hydromorphology, ecological condition improvement). Obviously, previously mentioned considerations have to be proved on pilot river sections with application of proper monitoring system. After evaluation of the examined technical measure its advantages and disadvantages are demonstrated, and also ecological condition improvements.

5. Conclusion

Signing the AGN contract Croatia set objective to insure international navigation on major rivers: Drava, Danube and Sava. Rivers Sava and Drava do not suffice the requirements and should be regulated for navigation. In the past those three rivers have significant hydromorphological changes, conditioned by various human actions on river

boundaries and watershed. Republic of Croatia is in the process of rapprochement to the European Union and should align its water politics to the Water Framework Directive EU. According to the named document Member States shall protect, enhance and restore heavily modified water bodies of water, with the aim of achieving good surface water status.

The position of designers dealing with the river regulation for navigation purpose is unenviable. Their technical solutions should at first satisfy demands of navigation authorities and on second may not drastically change river hydromorphological state. Demands to accomplish better river ecological state are also present. The recommendation is to input technical measures to experimental sections with appropriate monitoring system and correction of the main idea depending on obtained effects.

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