CHANGES OF HYDROLOGICAL SYSTEM IN THE LOWER COURSE OF THE KOLUBARA RIVER

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Abstract

Changes of hydrological system, through forming of meanders and cutting the "necks" are recent geomorphologic-hydrological process, which is dominate in the lower course of the Kolubara River. This situation is caused by moving of Kolubara River in riverbed of its tributary Pestan River. The above mentioned situation has been realized during the seventies of last century, in order to provide necessary conditions for undisturbed exploitation of lignite. Reorganizing of Kolubara River into riverbed of Pestan River caused significant and obvious morphologic changes of riverbed of Kolubara River as well as of the mouths of almost all its tributaries. On the base of comparative analyses of historical-geographical and topographic maps as well as satellite images, reconstruction of hydrological system has been done for the periods of the biggest changes. By field investigations during the summer 2007 we have examined consequences of anthropogenic influence not only over this hydrological system but over the entire geographic space. Obtained results may present good base for further geomorphologic, paleographic and hydrologic investigations. Beside its fundamental significance, results of this investigation are applicable before all in the field of water resources management, hydro-technical work as well as in different aspects of the protection and promotion of the environment (particularly within the concept of sustainable development).

Keywords: *Kolubara River, Pestan River, Tamnava River, hydrology, meanders, antropogenic influence.*

1 INTRODUCTION

The influences of natural factors on riverbed morphology in lower parts of Kolubara river valley are fully explained in previous investigations (Jovanovic, 1956; Dragicevic, 2002, 2007; Dragicevic, Nikolic, Zivkovic, 2006). With tectonic movements of sinking lower parts of Kolubara river valley as well as with filling in a riverbed of Kolubara River, significant decrease of stream velocity has happened. That caused turning of the river and forming of meanders. Numerous cut off meanders are located on the left and on the right side of the Kolubara river valley. According to field investigations and to analyses of topographic maps, 28 cut off meanders in total was determined. Total length of all cut off meanders in Kolubara river basin is 23.5km, while total length of abandoned riverbeds is 81.8km, which is near to total length of Kolubara River, 86.4km (Dragicevic, 2007).

The influence of anthropogenic factor is partly solved. There was an analysis of changes in spatial orientation of river system, but without realizing complex consequences of those influences (Ocokoljic, 1993/94; Kostadinov, 2002). Anthropogenic influences on river system could be divided on direct and indirect. Direct influences mean numerous engineering actions of riverbed regulation, and biggest actions were done in the middle of Kolubara River. The aim of those actions was to turn the stream in order to provide space for further lignite exploitation. On the sector between Vreoci and Poljana, Kolubara was changing its natural course passing from winding with meanders to almost straight course. Great morphologic changes on Kolubara River and Pestan River were made in 1976 as a consequence of Kolubara River moving in order to expand surface strip mine of lignite. In this occasion, Kolubara's riverbed was moved for 800m up the river from its confluence with Pestan River. In this way the course of the Kolubara river was turned into a Pestan riverbed which led to fossilization of old Kolubara's riverbed on the sector from Vreoci up to Poljana, as well as to increase of lateral erosion in recent riverbed.

1.1 The consequences of anthropogenic influences

The best parameters of anthropogenic influence on river system changes in the lower part of Kolubara River are numerous degraded riverbanks which are formed by natural process of fluvial erosion. This process was initiated in 1976 by reorganization of the main flow in riverbed of Pestan. In this way, anthropogenic factor modified existing natural conditions. By involving Kolubara riverbed into Pestan riverbed, which morphologically was not predisposed for kinetic energy of stronger flow, provided all necessary conditions for domination of fluvial erosion which is demonstrated in digging the riverbanks, transportation and deposition of eroded material. It is obvious that river system changes in lower part of Kolubara River are demonstrated in domination of fluvial (lateral) erosion on one hand, and in cutting the meanders and fossilization of certain parts of the riverbed, on the other hand.
The analyses of the riverbank degradation level in lower parts of Kolubara River forming as a result of fluvial erosion can be perceived as an immediate (found) state, or as a result of certain chronological actions on this area. If we take in analyses immediate state then the accent should be on analyses of recent fluvial process, which means existence and widening of concave riverbanks, often flooding, riverbed covering. On the other hand, if we take in analyses as a result of certain chronologic actions then we should analyze features of fluvial relief which are formed in the past (fossil forms) which are under the anthropogenic influence considerably degraded (cut off meanders). Because of that, the analyses of degraded areas formed by fluvial erosion should have complex approach then to include all those features which are formed by direct geomorphologic process as well as those fluvial features which are changed or destroyed by anthropogenic actions later on.

Figure 1. Abandoned Kolubara riverbed in Poljane (left) and recent riverbed (right)

According to analyses of topographic maps, satellite images and field investigations it is determined that the biggest number as well as the biggest length of degraded I category riverbanks are located on sector of Kolubara river in following district Poljana, Drazevica and Veliko Polje or in part of former Kolubara riverbed. This evident state can be put in relation to increase of water kinetic energy in riverbed which was formed by natural processes for considerably amount of water flow. Actually, moving Kolubara riverbed into Pestan riverbed caused bigger amount of water flowing through riverbed which morphology is suitable for kinetic energy of small flow. In that way, Kolubara River persistently makes its riverbed wider and cuts alternately its valley sides, which causes lateral erosion, forming of meanders and their cutting.
So, anthropogenic factor in this case modifies the intensity of lateral erosion, more exactly it causes degradation of the banks and the areas by fluvial erosion.

1.2 Spatial changes of the Tamnava river confluence

Forming of meanders and cutting the “necks” are recent geomorphologic-hydrological process, which is dominate in the lower course of the Kolubara River, between Poljana and Veliko polje. According to analyses of topographic map 1:25.000 it is clearly perceived meander of Kolubara river near its confluence with Tamnava river. On the satellite image from 2005, narrow meander in its neck is associated with its recent cutting and changing of Tamnava river course. By field investigations during the autumn of 2007, change of spatial orientation of hydrological system has been noticed.
However, until 1976 (point 1) Tamnava river was empting in into the Kolubara 1.6km southern then in the period after removing Kolubara river into Pestan river *(44˚34'09.3"; 20˚12'22.3").* Pestan River, the amount of water on its previous riverbed (between Vreoci and Poljana) directly depends of Kolubara’s left tributary Kladnica River. During the low flow period there is n significant discharge because it is totally determined by river regime of Kladnica River.

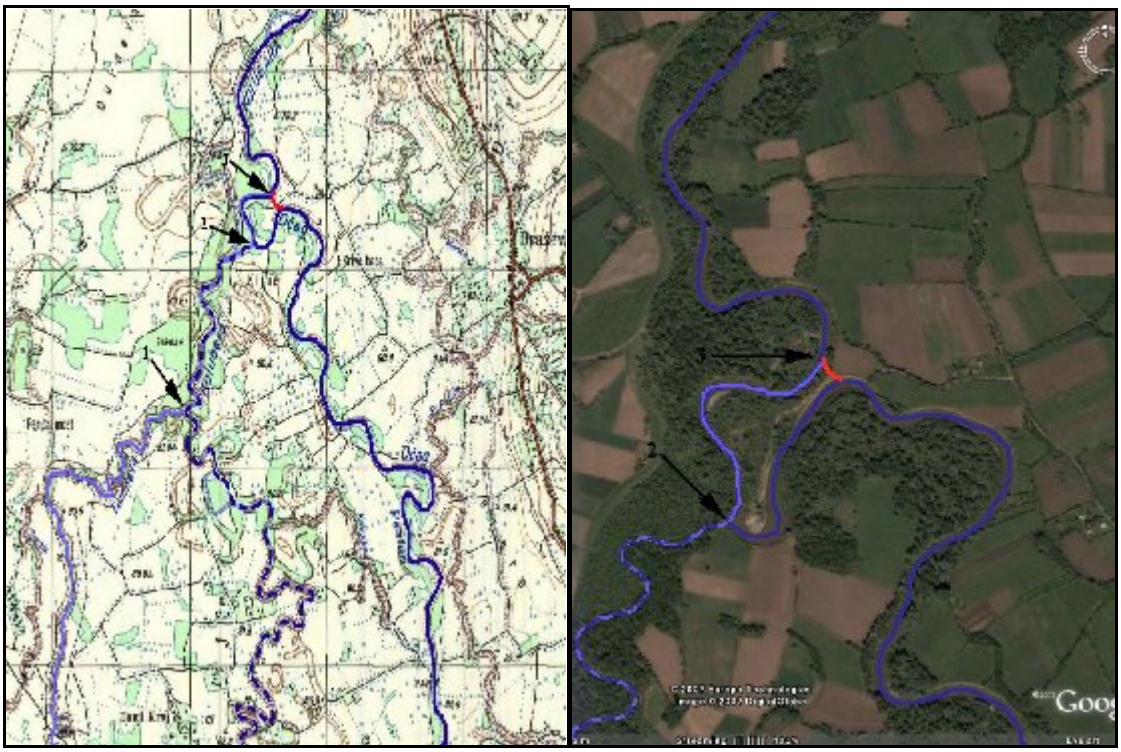

Figure 2. Topographic map from 1983 (1:50.000) and satellite image from 2005 of Kolubara river meander near its confluence with Tamnava river.

Recent riverbed of Kolubara river, previous riverbed of Pestan river до

Previous riverbed of Kolubara river until 1976

Riverbed of Tamnava river

Cutting the neck of meander in 2006

1. The confluence of Tamnava river into Kolubara river until 1976
2. The confluence of Tamnava river into Kolubara between 1976 and 2006
3. Present confluence of Tamnava river into Kolubara in 2006

Because of the above mentioned influences on removing Kolubra riverbed, the flow of Kladnica River made longer for 19.3km. That caused change of situation on the field and Tamnava becomes dominant flow with permanent discharge. According the greater amount of water then Kladnica River, Tamnava takes on the function of the main flow and the old Kolubara River which gets the water from Kladnica River becomes its right tributary. Joined waters of Tamnava river and old Kolubara river (Kladnica river) flow further through fossil riverbed of Kolubara river on the length of 1.6km up to its confluence with former Pestan river (point 2), but present recent riverbed of Kolubara river (44˚34'45.1"; 20˚12'41.6"). Previous described hydrological situation reflected 30 years, from 1976 until 2006. According to telling of local residents in Veliko polje, Kolubara River cut the neck of meander and caused again removing the confluence of Tamnava River to the north. Thus, present condition on the field shows that Tamnava

river flows through western part of the former Kolbara's meander and empties (point 3) into the place of cut meanders (44˚34'45.3"; 20˚12'41.6"). In this way the course of Tamnava River made longer for 500m.

Table 1. The changes of position of the Tamnava River and Kolubara river confluence in last 30 years

Tamnava river confluence	φ	λ	Year
Point 1.	44˚34'09.3"	20˚12'22.3"	До 1976.
Point 2.	44˚34'45.1"	20˚12'41.6"	1976.-2006.
Point a 3.	44˚34'45.3"	20˚12'50.8"	Од 2006.

1.3 Discussion and conclusion

This is only one, investigated in detail and described case of cutting the neck of meander and making longer the course on the area of lower part of Kolubara valley. Every removing of the Kolubara riverbed demanded making longer or shorter of the riverbed of Kolubara's tributaries. In the period of last 80 years, drastic morphologic changes in Pestan riverbed happened several times. Before regulation of Kolubara River, Pestan River emptied water in it near the Drazevac. Its biggest tributary, Turija river, this river was accepting near the Stepojevac. After the regulation, difference in altitude of the bottoms of Pestan and Kolubara rivers was 3.8m. That caused forming of fast course in natural base with length of 150m (Djekovic, 1986). This led to the progress of regressive erosion in Pestan riverbed, which initiated new regulation techniques with new consequences. The total length of abandoned riverbed of Pestan River is 7.2km.

Because tectonic characteristics of lower part of Kolubra valley, removing of hydrological system is expressed to the north and east (savski and pestanski fault). Meanders determined the evolution of the riverbanks, with dominant process of digging and transportation of concave riverbanks. Absence of building strategy, in a term of defense walls has led to removing of river line in historical period.

Considering the existing of concave riverbanks in the lower sector of Kolubara River, it is expected lateral erosion to be followed later by deposition of the eroded material. It can be noticed on the area of Poljana; where along the course through this municipality there is alternating lateral erosion with digging the riverbanks and deposition of the eroded material. By anthropogenic influence on the hydrological system in the lower and middle sector of the Kolubara River there is general riverbed deformation on the majority of the courses. Permanent process of sinking in lower parts of Kolubara valley and existence of Kolubarsko-pestanski fault, as well as permanent change of the length and confluence of the course has led to filling in a riverbed by deposition in order to overcome stage of irregular touch profile and to rich the stage of regular profile.

As an indirect consequence of the anthropogenic influence on the hydrological system in lower part of Kolubara valley, once a year (sometimes twice a year) overflow of Kolubara River happens, and the area of Poljana is endanger of flooding. If we neglect climatic conditions, the main causes of floods in lower part of Kolubara river are the widening course and small depths (riverbed morphology) as a consequence of the of the

filling in a riverbed by deposition. According to previous investigations (Dragicevic, 2002; 2007) it is clearly determined that there is deposition of the material in the middle and lower part of the Kolubara river. Parallel analyses of the carried deposits on Drazevac and Obrenovac profiles during the 2003 and 2004, it is confirmed its decrease down the profile. In 2003 in Kolubara riverbed between Drazevac and Obrenovac was deposited 13.997.3t, and during the 2004 it was 19.605.3t of the deposited material. These facts confirmed that there is intensive filling a riverbed in lower part of Kolubara River.

By detailed analyses of all factors of flood origin in lower part of Kolubara river (Dragicevic, Zivkovic, Ducic, 2007), it is determined unpleasant water regime which is shown in excessiveness of running off waters. The high flows are sudden and short-term and low flows long-term which approaches every year to its biological minimum. As a parameter of unpleasant running off characteristics it is usually taken relation between extreme discharges which put Kolubara River to the top of all our rivers with similar area. With maximal discharge in Drazevac which extends 700m^3/s and minimal around 0.6m^3/s this quotient is around 1200, and even 3400 in Valjevo.

Such hydrological characteristics of Kolubara River are mostly influenced by anthropogenic factors and modification of primary natural conditions in this area. Led by economic calculation which is justified by exploitation of lignite presents strategic interest, it was unknown that removing of Kolubara River can cause such effects on the field. According to well known fact that nature has always prepared answer on anthropogenic factors and balance change in ecosystems, we can expect new balance established. That could be seen today in permanent tendencies of Kolubara River to adapt itself primary riverbed of Pestan River.

As a consequence of digging the riverbanks permanent transportation and degradations of soil resources is creating on the area of Kolubara's lower part. Soil is natural resources and without it life on the Earth is impossible. It is also a necessary base for successful development of certain region. It presents a dynamic environment with numerous physical, chemical and biochemical processes in it which are caused by certain constellation of soil-genetically factors. Development of plant productivity (agricultural and forestry) depends on soil fertility, which is influenced by physical and chemical characteristics of the soil. Lateral erosion of the Kolubara River causes transportation of soil and its overflow causes soil pollution by products left from coal refining.

According to all above mentioned it is totally clear that free exploitation of lignite in Kolubara basin has numerous negative consequences not only on hydrological characteristics of the rivers but on the total degradation of the environment in this area. With anthropogenic influences there is degradation of all natural conditions in this area and negative effects can be either noticed now (hydrological system changes, floods, soil degradation) or in the future.

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