MUREŞ RIVER MIDDLE COURSE RIVERBED DYNAMICS BETWEEN THE ARIEŞ AND STREI CONFLUENCES

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ABSTRACT. Mureş River middle course riverbed dynamics between the Arieş and Strei confluences. The Mureş River is the most eloquent model regarding the alternation of characteristic river courses. In this alternation presents a special interest the course between Arieş and Strei, where due to the morphological and geological conditions we find lower course characteristics. The analysis of the river bed dynamics is carried out in two ways, vertically and horizontally. To evaluate the aggradation and degradation we used hydrometrical data found in the discharge measurements. The difference between the water gage height and the maximum depth indicate the evolution of the thalweg compared to the zero stage of the gage. The analysis of the horizontal dynamics is based on the cartographic method, in which we compare the topographic outlines of the river from three cartographic sources (1911, 1978 and 2005). The horizontal evolution was followed at first on the entire course of the river and then in three separate case studies. The case studies were chosen to illustrate different evolution types of meanders. The significant variations of different morfometrical parameters highlight the lower course character in the analyzed river sector.

Keywords: river channel dynamic, meander, aggradation, degradation, Mureş River

1. INTRODUCTION

The Mureş River is one of the most complex hydrological entities of Romania. This is due to its length (716 km), its watershed size (27830 km^2) and mainly the consequence of crossing a large variety of landforms. The Mureş River is the most eloquent model regarding the alternation of characteristic river courses. One can distinguish the following sequence:

– upper course characteristics, from its spring to the Giurgeu Depression,
– middle course characteristics in the Giurgeu Depression,
– upper course characteristics in the Topliţa – Deda Gorge,
– middle course characteristics from exiting the gorge and the confluence with the Arieş River
– lower course characteristics between the Arieş an Strei confluences
– upper course characteristics in the second gorge, between the Metaliferi Mountains and the Poiana Rusca Mountains
– middle course characteristics until the border

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– lower course characteristics in Hungary (modified by regularizations).

In this alternation presents a special interest the course between Arieş and Strei, where due to the morphological and geological conditions we find lower course characteristics: small speed and slope, accentuated horizontal erosion, meandering, diminution of competence and capacity, sedimentation phenomena, wide valleys with terraces. All these on a friable substrate, a grooved depression, also the threshold set by the downstream gorge and probably influenced by neotectonic movements.

2. METHODS AND DATA

The analysis of the river bed dynamics is carried out in two ways, vertically and horizontally. To evaluate the aggradation we used hydrometrical data found in the discharge measurements. Monthly we picked a measurement, where the difference between the water gage height and the maximum depth indicate the evolution of the thalweg compared to the zero stage of the gage. In the analyzed river sector there are four hydrometric stations: Ocna Mureş, Alba Iulia, Acmariu and Gelmar. For each we used approximately the same period: from the 70's until 2010. The advantage of this method is that at gauging stations the measurements are frequent and precise. The disadvantage is that the vertical dynamics can only be studied in the gauge cross section.

The analysis of the horizontal dynamics is based on the cartographic method, in which we compare the topographic outlines of the river from the Austrian topographic measurements from 1911, the Romanian topographic maps (1:25000) from the second part of the last century (1978) and the recent orthofotoplans (2005). So the analyzed period contains almost one hundred years.

The length of the chosen river sector is 162 km. In the morphometric analysis of the meanders we used, besides the wavelength and amplitude the following parameters: sinuosity index, length of the meander chord, meander loop length (i), chord arc length (k) and the relation $\lambda = i/k$.

To vectorise the data bases (maps) we used the Esri ArcMap G.I.S. software group, and for the measurements we used the cartographic Ocad9 software. There were chosen three conclusive situations, with case study role, to present the different evolution types of the meanders (Fig. 3). The selected sectors have the same length on the different maps, so the comparison between them makes possible following the horizontal dynamics of the riverbed in the chosen time period.

3. RESULTS

The vertical characteristics of the riverbed dynamics at the four stations were analyzed on the hp=f(T) graphs. We also overlaid the 5-month moving average, hp5=f(T), which removes the eventual irrelevant variations arising from the measurement picking or from measurements errors. The analysis was carried out on both curves.

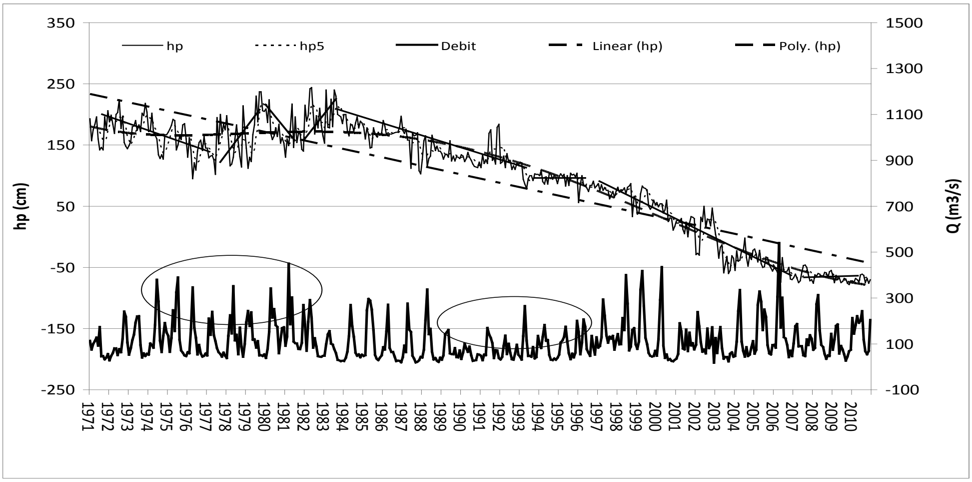

Fig.1. ***Chanel bed dynamic at Alba Iulia hydrometric station***

At Ocna Mureş the river bed is relatively stable. The oscillations are frequently between 15 and 25 cm. In 1998 there is an unexplainable rupture of 40 cm due to anthropic interferences. At Alba Iulia the riverbed stability is significantly weaker (Fig.1). The oscillations are between 60 and 100 cm, particularly in the first half of the analyzed interval. After the riverbed enters a constant degradation process the amplitude of the oscillations decreases significantly. At Amariu cross section (Fig.2) the oscillations doesn't exceed 20 cm, with exception in the last period, when they amplify to 30-40 cm. At the Gelmar gauging stations alternate the periods with high oscillations, of 40 cm, with other small ones, around 10-20 cm. we can conclude that the gauging stations cross sections are optimal for following hydrometrically the evolution of hydric phenomena.

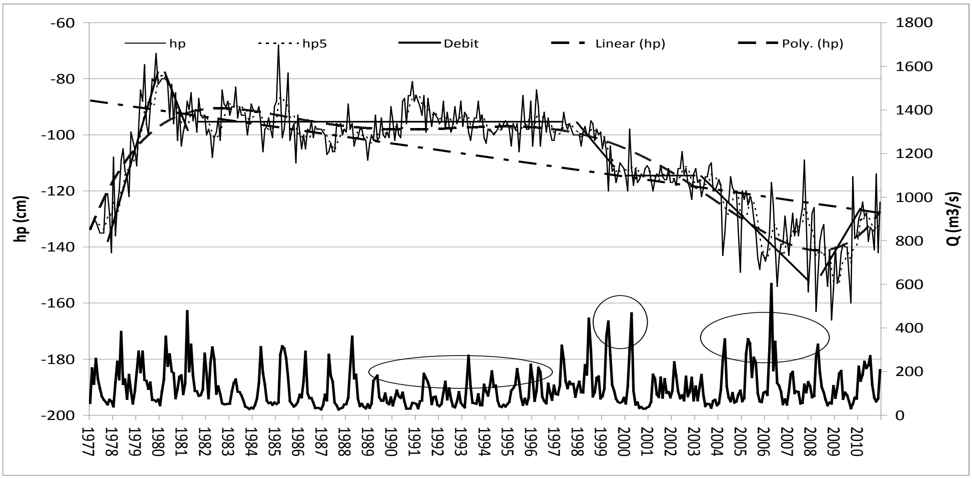

Fig.2. ***Chanel bed dynamic at Acmariu hydrometric station***

The characteristic period's analysis shows an accentuated dynamic of the riverbed vertical variations. The phenomena justified in a river sector is characterized by small slope, insignificant active energy and friable sandy substrate.

There is a succession of periods at all stations (Table 1.), some with pronounced degradation or aggradation. Their length is small, generally 2-5 years, which means that the river bed regains relatively quickly its dynamic equilibrium. Between these we find intercalated relatively long periods of stability (Acmariu 16 years, Ocna Mureş 7 years, at Gelmar twice 6 years).

We denote the years 1978-1980 when at three stations there was a concomitant aggradation. In the periods between 1980-1981 and 1985-1990 at two stations the degradation was simultaneous. The end of the study period was stable at three stations.

The river bed natural dynamics causality, by comparing it to the average monthly discharge, is hard to follow. Years with accentuated discharge cause a significant dynamic (Ocna Mureş 1974-1981, Alba Iulia 1974-1982 şi 1998-2000, Acmariu 2004-2008, Gelmar 1980-1981 şi 1984-1988). In periods with poor discharge the riverbed dynamics are reduced (Alba Iulia 1989-1996, Acmariu 1989-1996, Gelmar 1989-1992).

Table 1. ***Periods of the river bed vertical dynamics***

Hm. Station	Total period	Ye ars	Aggradation period	Ye ars	Degradation period	Ye ars	Stability period	Ye ars
Ocna Mureş	1971-2010	40	1971-73	3	1974	1	1982-85	4
			1975	1	1976-78	3	2004-10	7
			1979-81	3	1986-87	2		
			1988-89	2	1990-92	3		
			1993-97	5				
			1998-03	6				
			Total	**20**	**Total**	**9**	**Total**	**11**
Alba Iulia	1971-2010	40	1977-79	3	1971-76	6	1993-95	3
			1981-83	3	1980	1	2007-10	4
					1984-92	9		
					1996-06	11		
			Total	**6**	**Total**	**27**	**Total**	**7**
Acmariu	1977-2010	34	1977-79	3	1980	1	1981-96	16
			2008-10	3	1997-98	2	1999-02	4
					2003-07	5		
			Total	**6**	**Total**	**8**	**Total**	**20**
Gelmar	1978-2010	33	1978-80	3	1981	1	1987-92	6
			1982-86	5	1993-96	4	1998-03	6
			1997	1	2004-06	3	2009-10	2
			2007-08	2				
			Total	**11**	**Total**	**8**	**Total**	**14**

The correlations don't constitute a permanent rule. Some of the riverbed modifications are due to anthropic activities close to the gauging stations, so is the strong degradation at Ocna Mureş from 1998 or the almost continue degradation with high amplitude at Alba Iulia.

The general trends of variation are different. However we remark the negative slope linear trend at la Alba Iulia, Acmariu and Gelmar. The amplitude of degradation is maximum at Alba Iulia (almost 300 cm) and smaller at the other two stations (40 cm respectively 50 cm). Only at Ocna Mureş the linear trend has a small aggradation path of 20cm. The sixth grade polynomial trends doesn't show periodicity but embrace significantly the allure of the changes.

The horizontal evolution was followed at first on the entire course of the river (Table 2.). According to the classification of Brice (1964) the analyzed sector fits to the meandering channels characteristics (Ks>1.5). The meandering index (Ks) rises from 1.690 to 1.726 and then returns almost to the initial value. The entire length of the sector doesn't change significantly in the analyzed period, 162-165 km, representing only a 2% change. However the number of meanders decreases almost to the half, from 20 in 1911 to 11 in 2005, due to the general dynamics of the riverbed, meander migration and anthropic interventions. Most active periods of this evolution are those with significant discharge, mainly the periods with important floods. They are only known exactly in the intervals when there were hydrometrical measurements at the river gauges.

Table 2. ***Meandering length and sinuosity index***

	Total		1st Case		2nd Case		3rd Case	
Year	Ls (km)	Ks	Ls (km)	Ks	Ls (km)	Ks	Ls (km)	Ks
1911	162.4	1.690	8.406	2.4	6.749	2.1	5.495	2.3
1978	165.9	1.726	9.894	2.9	7.308	2.3	5.519	2.3
2005	162.8	1.694	6.905	2.0	7.386	2.3	4.623	1.9
Average	163.7	1.703	8.402	2.433	7.148	2.233	5.212	2.166

Ls –sinuous sector length, Ks-sinuosity index

The case studies were chosen to illustrate the different evolution types of the meanders (Ichim et. al., 1989). In the first case we see a natural cutoff of a meander and the formation of an ox-bow lake; in the second we follow the natural evolution of the meander (wandering and sweeping) without cutoff and in the third case a relatively stable course. The case studies morphometric parameters vary from an interval to other, emphasizing the fact, that are continuous changes in the river channel.

So, in the first case (Fig. 3) near Rădeşti, the sinuosity index decreases to two (Table 2) after the two meanders were cut off through natural breakthrough. Together with these the sector length was over 10 km an after the cutoff it decreases to only 6.9 km. Highest sinuosity index (2.9) was measured on the 1978 topographical maps when the two meanders were still active.

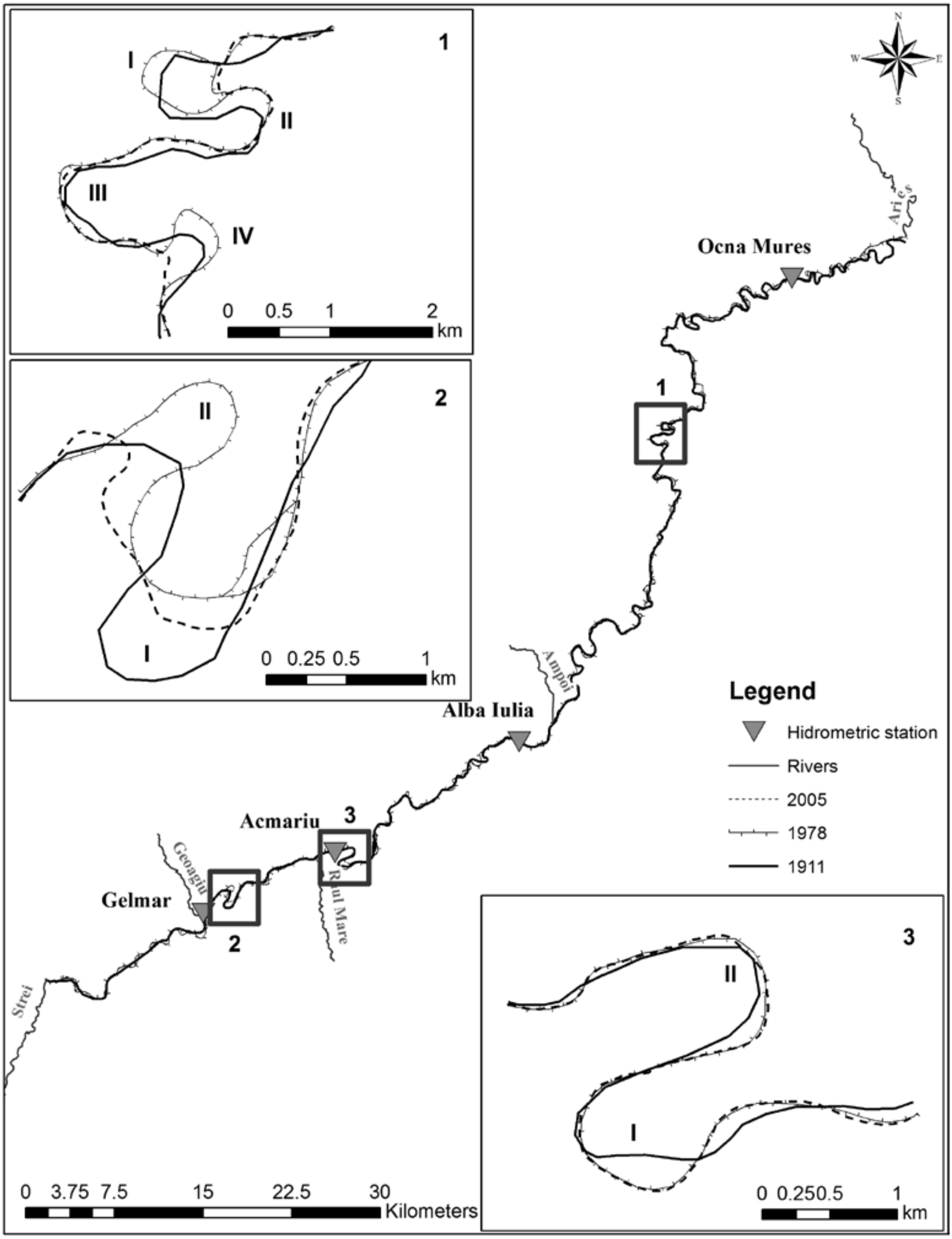

Fig. 3. ***Horizontal dinamics of the Mureş River between the confluence with Arieş and Strei and the case studies***

This is a typical example of ox-bow lake formation, after cutting off the meander by natural breakthrough, when it reached the gooseneck form. In case of booth meander loops (I., IV.) appears the ox-bow lake which has no direct contact to the river.

Table 3. *1st meandering case morfometrical characteristics*

	Meander I			Meander II			Meander III			Meander IV		
Year	1911	1978	2005	1911	1978	2005	1911	1978	2005	1911	1978	2005
Wave-length	1.00	0.85	1.20	1.15	0.81	1.68	1.43	1.25	1.62			
Amplitude	1.08	1.28	0.60	1.98	1.53	1.42	1.36	1.29	1.27			
Meander chord (km)	0.44	0.29	0.50	0.31	0.27	0.55	0.78	0.69	1.15	0.59	0.31	0.82
Loop length (i)	2.06	2.03	1.19	2.11	2.16	1.52	3.09	3.25	3.21	1.37	1.65	1.15
Chord arc length (k)	0.67	0.84	0.81	0.49	0.96	0.81	1.22	1.39	1.81	0.93	1.48	1.30
$\lambda = i/k$	3.08	2.41	1.47	4.33	2.26	1.88	2.53	2.34	1.78	1.48	1.12	0.89

The analysis of the other morphometric parameters, from this sector, shows the same flattening trend of the river allure. Comparing with the year 1911, in 2005 the wavelength increases at every meander loop and in the same time the amplitude decreases (Table 3). We can observe that the meander chord length (i) increases at every loop and the loop length only in case of the 3th loop because of the flattening of the last loop. The disappearance of the last loop (IV.) can be followed very well also in the evolution of the loops morphometric parameters. The λ relation only in this case drops under de unit (0.89) which according to Schoklitsch, A. (1962) (Borsy, 1998) means the return to a simple bend from the meander.

Table 4. ***2nd meandering case morfometrical characteristics***

	Meandre I			Meandre II		
Year	1911	1978	2005	1911	1978	2005
Wavelength	1.51	1.34	1.51			
Amplitude	1.31	1.18	0.69			
Meander chord	0.64	0.45	1.06	0.87	0.37	0.35
Curvature length (i)	3.06	3.18	2.95	2.37	1.78	0.91
Chord arc length (k)	1.00	0.72	1.66	1.37	0.59	0.56
$\lambda = i/k$	3.06	4.44	1.78	1.73	3.00	1.63

The second case is near Aurel Vlaicu (Hunedoara). Here the meander was not cut off, but instead it changes its form continuously by meander migration. In 1911 it was evolved towards South-West, in 1978 it was elongated towards North-East and then returned to an intermediate position (Fig. 3). This trend is underlined also by the values of λ (Table 4.), which are smaller in 2005 (1.78) than in the other moments (3.06 in 1911 and 4.44 in 1978). In case of the first loop we recognize the meanders sweeping and wandering phenomena and in case of the second loop the transformation of the meander (Ichim. et al., 1989). We can observe a continuous decrease of the amplitude and from the data we can also conclude that the meanders are losing their sinuosity.

The third case study presents a particular stable situation; in the 100 year period there are sectors where the changes are almost undetectable. The small difference of 600 m regarding the length it may occur due to the map projection transformations or as a result of mapping errors. The shape differences between the years 1911 and 2005 represent the local evolution of the meanders in stable areas.

4. CONCLUSION

The special characteristics of the middle course of the Mureş River are well illustrated by the riverbed dynamics. Periods of aggradation, degradation and stability, the evolution trends, the amplitude of vertical and horizontal dynamics, the morphometric characteristics, all play a part in the differential evolution of the meanders. The significant variations of the vertical and horizontal morphometric parameters highlight the lower course character of the analyzed river course.

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