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CHANNEL DYNAMICS ON THE HUNGARIAN SECTION OF RIVER MAROS

Theses of Dissertation

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INTRODUCTION, AIMS

The study of River Maros can serve further understanding on channel dynamics, the relation of form and process in a send bedded semi-anthropogenic, close to natural environment. River Maros is the fourth largest water flow of the Carpathian basin with a length of 765 km and a discharge varying between 31 and 2420 m^3/s. Channelisation works of the 19th century had significantly changed the pattern of the river. The artificial form induced the realm of new channel processes. At present the studied reach can be divided into two different units. The upstream has almost been untouched since the regulations, however the lower unit is maintained with revetments and groins.

The research addressed two main questions: What forms and processes determine the present morphological setting of the studied reach? How do present dynamics reflect the response of the morphological system to the great scale human impact experienced approximately one and a half century ago? As a result of answering these questions the stability and equilibrium of the studied river reach can be evaluated, and the prospected morphological changes can be outlined. Besides, during the analysis of the different forms the need for classification at different spatial scales has also arose, which helped in determining general relationships and processes acting within the studied morphological system.

APPROACH AND METHODS

The aims could only be fulfilled with the help of a multiscale, multitemporal analysis, applying various methods. The research was performed mainly on macro scale (bars, islands) and mega scale (braids, river reaches) morphological features. Analyses were made at three separate time scales. Short term investigations focused on changes occurring due to one flood or low stage event. Mid term analyses assessed the effect of a series of events, usually in a several decade time span. The long term approach was concentrating on the comparison of pre-regulation and present forms and processes.

For the short term investigations firstly cross-sections were applied. Fairly high temporal resolution cross-section data were available for the Makó gauging station, dating back to the 1988–2004 period. Approximately 120 cross-sections per survey were gauged by us during five measurement periods, recording the spatial effects of different discharges on bed processes. In addition, morphological mapping was also applied to increase the understanding of processes.

Mid term investigations involved GIS, dendro-geomorphology, and hydrological calculations. The mid term GIS data were mainly derived from aerial photographs and military surveys. Changes were evaluated on the basis of geo-corrected images and maps. Dendro-geomorphology was applied for assessing sedimentation processes in terms of two vegetated islands and a point bar. Hydrological calculations primarily aimed at determining channel forming discharge, and energy levels of certain periods.

For long term analyses data from the period of regulation works were collected. These mainly include contemporary engineering maps, and military surveys. Some of the resources contained pre-regulation cross sections too. The maps were attached to the original GIS, however in some cases the analysis was limited due to failure in adequate geo-correction. These problems were overcome by the comparison of dimension-less, relative morphological values.

RESULTS

1. Cross-sectional changes at the Makó gauging station

1.1. Analyses were made at two temporal scales. Longer term, 20 year long, detailed analysis of mean depth did not resemble any unidirectional changes in morphological processes. I.e. no obvious signs of incision or aggradation were detected. The observed 54 cm decrease in mean water levels can be related then to other, possibly climatic factors.

1.2. In the short run however, morphological parameters (mean depth, maximum depth, form roughness) show great variations in any of the analysed hydrological situations. During the rising limbs of floods the bed material is torn up, and form roughness increases sharply. Besides, depth values also increase (mean depth with a few 10 cm, maximum depth by 1 m). Sediment is first transported in the form of dunes, then during peak flow mid channel bars develop, and convey a large amount of sediment. The falling limb can be characterised by thalweg fill, decreasing form roughness and depth values.

1.3. During a flood the maximum form roughness and the size of bed forms depend on the rate of water level increase and the extent of relative water level rise. The thalweg fill and the value of mean depth decrease in the falling limb are in relation with the peak water level height, and the rate of water level decrease.

1.4. Low water periods do not cause dramatic changes, however sediment transport, bar migration and thalweg shift are continuous. During low stages form roughness decreases further. Only slight mean depth changes can be observed due to the redeposition of bed material. In all, low stages are responsible for the smoothing of the riverbed, and the slow but continuous outwash of sediments.

2. *Development of bar forms*

2.1. Underwater sand bars were assessed at different water levels, during a two year period of short term analysis. The investigated 6 study sites exhibited compound and highly variable bar morphology. General and local processes were both identified. Processes of the first type are mainly determined by the actual hydrological situation, while those of the second type are dependent on the morphological setting of the sites. Due to flood events bar systems completely change. Falling discharges then have strong and direct effect on the elevation (decreases), size (decreases), number (increases) and migration rate (decreases) of bar forms. However, they do not directly determine morphological features such as length/width ratio or bar surface slope. These are mainly influenced by the surrounding morphological environment (e.g.: location of islands, channel width).

2.2. The identified underwater bar forms were classified based on their situation, degree of freedom and hierarchy. The main types, differentiated on the basis of their position relative to the banks (chute-less sidebars, chute sidebars, mid channel bars), have represented well separable morphological parameters. During the different hydrological situations the ratio of mid channel and side bars stayed nearly the same (30 % and 70 %).

2.3. In any situation the most elongated forms are chute-less sidebars (length/width = 3,6). They are followed by chute sidebars (2,7) and finally by mid channel bars (2,0). In terms of surface elevation mid channel bars are the first, chute-less sidebars the second and chute sidebars the third. In several cases further parameters are also in relation with the main morphological types, but differences cannot be generalized for all situations.

2.4. Subsequent to the drop of water level, exposed sand bars appear, experiencing further changes. These determine their shape, and erosional state. Surface bars were analysed with the help of aerial photographs. Based on their position in the channel, mid channel bars, side bars and point bars were distinguished.

2.5. In terms of surface bars – similarly to underwater bar forms – mid channel bars were characterised by the lowest length/width ratios (2,4). Side bars were more elongated (4,7), while the longest forms were point bars (8,3).

2.6. The morphology of surfaces bars (shape, position, area, length/width ratio) was evaluated in order to provide a form and process based classification. Exposed bar surfaces were assessed primarily according to their shape (convex front, concave front, double-arc, semi-arc, rhomboid, triangular, and scroll shaped forms). The qualitatively distinguished classes reflect different stages of surface bar evolution driven by primary accumulation, secondary accumulation and lateral erosion.

3. Formation and development of islands

3.1. The initiation and further development of islands is a complex process, determined by hydrological and vegetational factors. Their formation is due to the colonisation of elevated bar surfaces, reaching well above the mean water level. The success of stabilisation is highly affected by the oncoming hydrological situations. If no great floods occur, and low stages last long, Salix and Poplar species need 4–5 years to create an island resistant to larger floods too.

3.2. With the increase of area, the relative growth and migration speed of islands is decreasing, forms become static. However, the area of small islands (under 0,5 ha) might show a two or threefold increase in a decade, and the migration speed of their centre-point can reach 7 m/year.

3.3. Island formation on the managed reach is greatly influenced by the fact that the elevation of bars here is not as high as on the upper reach. Thus the chance for developing larger vegetated surfaces is much lower.

3.4. According to dendro-geomorphological surveys and regime analysis, the further development of islands is greatly determined by the variation of low and high energy periods. The highest bar surfaces attached to the islands are formed during high energy years, and colonised during low energy years. However, if low energy years do not occur, the upstream erosion can overwhelm downstream accumulation, leading to the degradation of forms. Contrary, in the lack of high energy control, the vegetation may occupy side branches, leading first to the coalescence of islands and later to their amalgamation with the bank.

3.5. Long term analyses have shown that before the regulation works of the 19th century islands were formed dominantly by avulsion, the role of mid channel, small islands were not significant. The realm of smaller, braided features followed the cutting off of meanders and consequent bank erosion. If long term changes are considered, the continuous increase in total and average island territory has to be highlighted. The process was accelerated by the low water years of the 1980s and 1990s.

4. Role and development of braided units

4.1. Braided units – representing the next spatial scale – were put under a short and a long term analysis. The effect of different hydrological situations on braid morphology is obvious. The total mean depth of study sites is primarily determined by discharge. Floods can result a several 10 cm decrease in the total mean depth data, suggesting intensive bedload pulses and aggradation during high discharge events. During low water periods the braid systems are emptied by lateral erosion of the meandering thalwegs.

4.2. The spatial distribution of sediment in braids was also assessed. The greatest accumulation during floods was observed mainly in upstream sections. Its value is determined by the morphological setting of the braid, i.e. the number and situation of islands. Based on the spatial variation in channel fill, morphological zones (accumulation, transportation, erosion) were identified in the studied braids.

4.3. In general, two types of braids were separated. One which blocks bed load pulses, and another which lets them pass through the system. The first is a lower energy, stable system, while the second is at a higher energy level, being more prominent to changes.

4.4. Based on the lateral migration of islands inside the braids, cyclical states in braid evolution were recognised. These states are in due connection with the above mentioned morphological types. The three states are juvenile (island initiation), mature (well developed islands) and senile (amalgamation of islands into the banks). The first and the third are representing the higher energy morphological type, while the second is the stable form.

4.5. Concerning the long term processes, the slight decline of braids were detected during a fifty year long period. Recently, the number of juvenile braids is increasing, meaning that less energy is consumed on the whole river reach.

5. Changes of channel pattern

5.1. Prior to the regulations four morphologically separable sections characterised the studied reach. A (1) meandering–braided and an (2) anastomosing section were situated upstream, while a (3) low sinuosity and a (3) high sinuosity meandering downstream. The first two developed on the elevated alluvial fan surface, while the later ones developed right in front of the fan border. In a close to natural state morphological parameters (sinuosity, total sinuosity, bend curvature) had shown a great temporal variance (8–10 % in 30–40 years).

5.2. Due to anthrpogenic interventions (several cut offs), the pattern of the study reach changed dramatically, braided units appeared on the previously anastomosing and low sinuosity meandering reaches. In the past 50 years morphological values showed insignificant changes compared to pre-regulation processes, however, these very slight changes are unidirectional (decrease of total sinuousity, increase of sinuousity).

5.3. Subsequent to cut offs the channel widened significantly, however, mid term investigations reflected channel narrowing (20 m in average between 1953 and 2000). The greatest changes were recorded in terms of braids located on unmanaged sections. Nevertheless, mean channel width is still higher here, than pre-regulation values.

5.4. Meanwhile, average hydrological data plot the river in various functions to the meandering region. Similar results are achieved, if total and specific stream power, or the ratio of suspended and bed load are considered.

EVALUATION OF MORPHOLOGICAL STABILITY

Assessing the most important morphological changes at different spatial and temporal scales, it was proved that from a morphological point of view dynamic equilibrium processes dominate the studied morphological systems and subsystems. Values are usually oscillating, no accelerating change was detected. In this respect, from the point of view of physical interpretation (dynamics) the system is in a stable equilibrium, where negative feedback is a key process. Instability can only be observed in short term morphological changes. Steady state was not identified on any of the spatial or temporal scales, the system is in a continuous change in terms of the averages, too.

Considering the regulations we can state that in the short term the river gave a sensitive answer, as new morphological units had appeared. However, based on the present processes a slight trend of restoration can be perceived, which can indicate a robust response on behalf of the system in the long run. Meanwhile, changes identified recently do not threaten morphological stability. Any kind of river metamorphosis at the present equilibrium processes should take a comforting span of time from the aspect of management strategies.

According to our investigations, the most important independent variables in sustaining dynamic equilibrium processes on the lowland section of River Maros are the high volume of sediment load and vegetation. If morphology is considered, the role of widened, braided units has to be highlighted, since these are ultimately significant in regulating energy conditions in the riverbed. Changes in these factors could result accelerated morphological processes on the river reach.

PUBLICATIONS IN RELATION WITH THE DISSERTATION

Sipos Gy, Kiss T. 2006. The role of braids in the morphological stability of lowland rivers, on the example of River Maros (A medertágulatok szerepe a síksági folyók morfológiai stabilitásában, a Maros példáján). *3rd Conference on Hungarian Geography*, Budapest. Abstract volume (p. 201) and CD-publication ISBN: 963-9545-12-0. *(in Hungarian)*

Sipos Gy, Kiss T. 2006. The classification of underwater bar forms in braided rivers. (Fonatos medrű vízfolyások felszín alatti zátonyformáinak osztályozása). *3rd Conference on Hungarian Geography*, Budapest. Abstract volume (p. 200) and CD-publication ISBN: 963-9545-12-0. *(in Hungarian)*

Kiss T, Sipos Gy. 2006. Braid-scale channel geometry changes in a sand-bedded river: Significance of low stages. *Geomorphology* (in press).

Sipos Gy. 2004. Channel pattern and bar formation on a sand-bedded lowland river reach (Medermintázat és zátonyképződés homokos medrű síksági folyószakaszon – Maros 31-50 fkm). *8th Conference for Postgraduate Geographers in Hungary,* Szeged. CD-publication ISBN: 963-482-687-3. *(in Hungarian)*

Sipos Gy, Kiss T. 2004. Evaluation of morphological stability on the lower reaches of River Maros, Hungary. *Geomorphologia Slovaca*,**4/1**: 52–62.

Sipos Gy, Kiss T, 2004: Recent changes of the channel and bedforms on the Hungarian section of River Maros (A meder és a mederformák recens fejlődése a Maros magyarországi szakaszán). *2nd Conference on Hungarian Geography*, Szeged. Abstract volume (p. 188) and CD-publication ISBN: 963-482-687-3. *(in Hungarian)*

Sipos Gy, Kiss T. 2003. Island establishment and island development on River Maros (Szigetképződés és fejlődés a Maros határszakaszán). *Vízügyi Közlemények* **85/4**: 225–238. *(in Hungarian)*

Kiss T, Sipos Gy. 2003. Investigation of channel dynamics on the lowland section of River Maros. *Acta Geographica, Szeged* **39**: 41–49.

Sipos Gy, Kiss T. 2001. The investigation of the morphological dynamics in an island braided unit of River Maros (Egy szigetrendszer morfodinamikájának vizsgálata a Maros apátfalvi szakaszán). *1st Conference on Hungarian Geography*, Szeged. Abstract volume (p. 93) és CD-publication ISBN:963482544-3. *(in Hungarian)*

Kiss T, Sipos Gy. 2001. The relationship of morphology and heavy metal distribution in the channel and on the floodpalin of River Maros. (A morfológia és nehézfémtartalom kapcsolatának vizsgálata a Maros medrében és hullámterén). In *A táj megértése felé, Tanulmányok a 75 éves Pinczés Zoltán professzor tiszteletére*, Keményfi R, Ilyés Z (eds). DE–EKF, Debrecen–Eger; 63–83. *(in Hungarian)*