STABLE RIVER REACHES IDENTIFICATION ON AERIAL IMAGE SERIES – A TOOL FOR RIVER REGULATION

IDENTIFICAREA BIEFURILOR STABILE DE RÂU PE BAZA SERIILOR DE IMAGINI AERIENE – INSTRUMENT ÎN REGULARIZAREA RÂURILOR

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Abstract. *Natural river reaches, which show some stability in time, are used in river regulation as models for other unstable reaches. In this context, it is very helpful to find, for this stable reaches, some relationships between riverbed characteristics. These reaches can be considered to be in regime; it means that the parameters which characterize the bed and the flow keep relatively well defined ratio and can be considered to be regime-equation type: parameter = AxQ^n, where A is a coefficient and Q is considered to be the bank full discharge. Starting from this idea we combined field observations with the information available from aerial images taken in 1956, 1971, 1979, 2004 and 2008 and we succeeded to identify such stable reaches on gravel-bed rivers from North Moldavia (Romania). For these reaches we found same regime equation*.
Key words: aerial image series, stable reaches, river regulation

Rezumat. *Porţiunile din râurile naturale relativ stabile în timp sunt folosite ca modele în regularizarea altor biefuri instabile. În acest context, este util de identificat pentru aceste biefuri, relaţii între caracteristicile geometrice ale albiei. Aceste biefuri pot fi considerate în regim; aceasta înseamnă că între parametrii care caracterizează albia şi scurgerea există relaţii bine definite, ce se pot considera de tip regim: parametru = AxQ^n, unde A este un coeficient, iar Q este considerat debitul transportat la albie plină. Pornind de la această idee, în lucrare au fost integrate determinările din teren cu informaţiile provenite din serii de imagini aeriene (1956, 1971, 1979, 2004 şi 2008) pentru identificarea unor porţiuni de râu stabile, cu albia dezvoltată în pietrişuri, situate în nordul Moldovei. Pentru aceste biefuri s-au determinat ecuaţii de tip regim*.
Cuvinte cheie: serii de imagini aeriene, biefuri stabile, regularizare

INTRODUCTION

An essential characteristic of all the forms which directed the flow is that, more than any factor, these generate a continuous modeling of ground surface.

This study is based on the idea that identifying stable channel reaches on natural (or quasi – natural) gravel-bed rivers may be an adequate approach to study the structure of the elements mentioned above.

In this context, an important aspect in river bed morphology approach should be related to a time scale which is fitted on the interdependence between the main variables of the river bed system. This derives from the fact that any adjustments are typical for determining time periods, which are representatives for both the phenomena produced on river bed level and for its characteristic length, as shown in fig. 1. An adequate time-scale approach is also important in establishing the type of variable (dependent or independent).

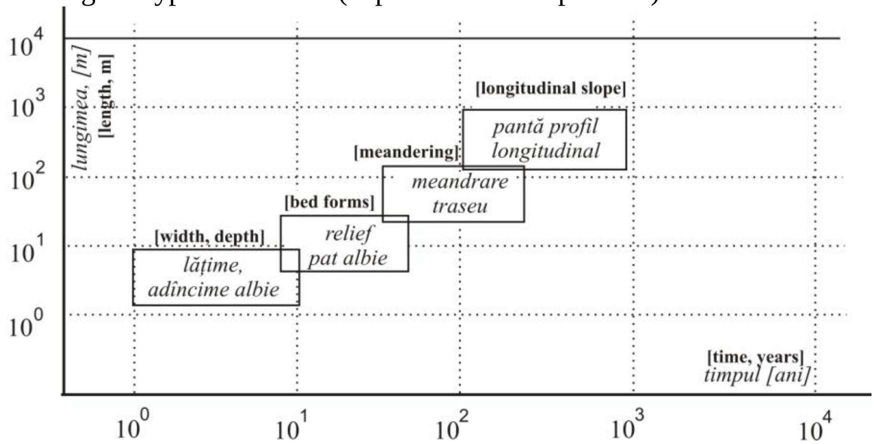

Fig. 1. Diagram of time - length affected by different changes in bed river pattern - dimensions considered for an average hydrographic basin (after Knighton, 1993)

River bed stability approaches were accomplished using empirical regime equations for stable gravel-bed rivers. An important simplification is due to the acceptance of a *dominant* (*characteristic*) *discharge* (Bray, 1982, Inglis, 1947, quoted by Knighton 1993), which is responsible for the major changes of the variables and which is most frequently considered to be the bankfull discharge (Ichim et al,1989).

MATERIAL AND METHOD

Being at aim to identify stable reaches on gravel-bed rivers, we used a series of aerial analogical photographs taken in 1956, 1971, 1979 and digital georeferenced orthophotos (2008). The area taken into account is located in Suceava district, NE of Romania, as shown in fig 2.

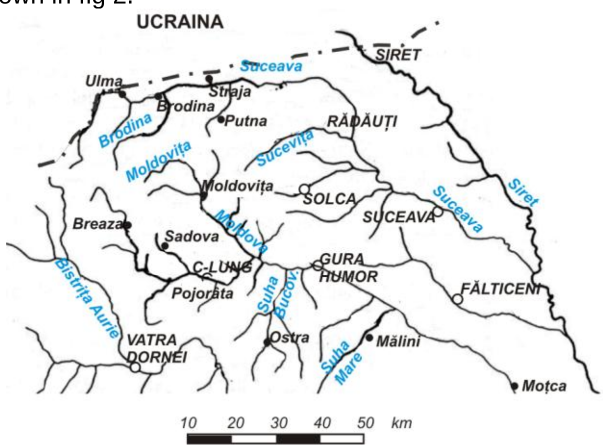

Fig. 2. Hydrographical map of mountain area of Suceava district

In a first step we have identified *natural reaches* river bed, although there are only a few reaches without human interferences. We have direct those reaches without bank protection works, channel reconstruction or flood protection schemes, following river bed stability in time, i.e if the unique thread and some characteristic bedforms (channel bars detectable on aerial images) are maintained. These observations, corroborated with those taken *in situ* shows that in stables transverse and diagonal bars are gathered particularly boulders, increasing the local resistance of channel bed and dissipated hydraulic energy.

Because we founded reaches relatively stable for over 50 years, we assumed that for these a regime state is valid.

Speaking about reaches stability, the author use a new concept called *evolution*, *ev*, defined like the ratio between river length measured along channel axis and the length of the valley, measured along its axis (Iacobescu, 2001):

$$ev = \frac{l_{râu}}{l_{vale}} \left(= \frac{l_{river}}{l_{valley}}\right) \quad [1]$$

Keeping the idea that the river may flow *only* in the available space of the valley, one can also use *evolution coefficient*, c_{ev}, defined bellow:

$$c_{ev} = \frac{l_{râu} - l_{vale}}{l_{vale}} \left(= \frac{l_{river} - l_{valley}}{l_{valley}}\right) \quad [2]$$

The delimitation of the valley was done on the stereoscopic model, obtained from stereo images pairs, arranged under the MS27 stereoscope, eyepiece 3X, connected to stereo pantograph TRA2 Sokkia (fig. 3). Valley characteristics were considered independent variables; every reach slope proved to be continuous and thereby the horizontal projection was considered to be an affine transformation. Valley limits are conspicuous, because in the stereoscopic model heights are about 12 times exaggerated. Further, we supposed that the regime slope was achieved for these reaches. The achievement of equilibrium (regime) state was gradual in time, starting with cross section and planform parameters.

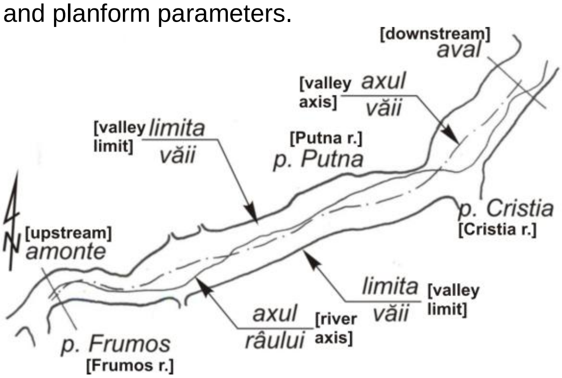

Fig. 3. Example for lining up the axis of the valley and the river (Putna River)

In the study area we found *21 reaches* considered to be stable (table 1). For each reach the author determinates:
- the average scale of the aerial image, using the existing plans 1:5,000,
- valley altitude upstream (z_{am}) and downstream (z_{av}) in the prior mentioned plans,
- the length of valley (l_{valley}) and river (l_{river}) axis, with an electronic curbimeter, adjusted on the scale of the aerial image,
- the slope corresponding to the regime, i_{reg}

$$i_{reg} = \frac{z_{am} - z_{av}}{l_{river}} \quad [3]$$

- river evolution and coefficient of evolution, using [1] and [2],
- cross section area and the local slope of the free surface, by terrestrial measurements done by means of total station,
- bankfull discharge, using Manning relation, with the channel roughness taken from technical books (Kiselev, 1988).

RESULTS AND DISCUSSIONS

For each reach we did outlines and sketches, e.g. for Putna River (fig. 4):

- Pojorâta village, between confluence with Frumos and Modova river,
- pairs of stereo images: 30765 and 30764 / 1956,
- average scale in river bed area: 1:20.980,
- description: single bed, stable banks (wood vegetation),
- valley altitude: upstream = 742 mdMN, downstream = 710 mdMN,
- length of valley axis: 2,47km, length of river axis: 2,53km,
- regime slope = $i_{reg} = l_{râu}/(Z_{am} - Z_{av})$,
- bankfull discharge: 20,0m^3/s

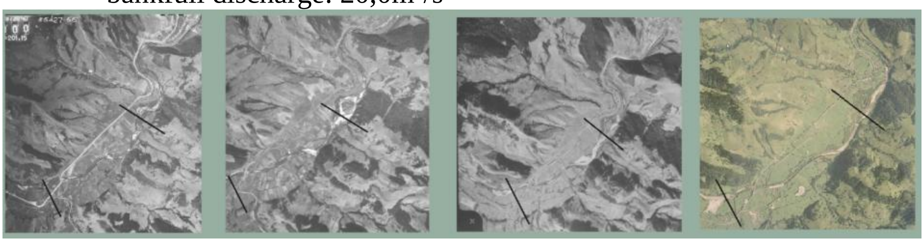

Fig. 4. The same stable river reaches on aerial images series

Table 1 contains the summarized data for all the reaches. Data processing was done in order to obtain the regime slope equation:

$$i_{reg} = 0{,}0501 \cdot Q^{-0.441} \quad [4]$$

Relation [4] shows the variation trend for regime slope. The correlation coefficient is significant for 99% probability (fig. 5).

The table reveals that river length is longer than the valley axis. This means that the river extended his plan form towards valley axis in order to attain the regime slope, i.e. for the valley slope is greater than the regime slope.

$$l_{river} \geq l_{ax} \; ; \; i_{valley} \geq i_{reg} \quad [5]$$

It results that for a stable reach relation [6] is valid:

$$\frac{l_{river}}{l_{valley}} = \frac{i_{valley}}{i_{reg}} \quad [6]$$

and, for a given location, the regime slope depends on river evolution:

$$i_{reg} = i_{valley} \frac{l_{valley}}{l_{river}} = i_{valley} / ev \quad [7]$$

Relation [7] indicate both the slope for a stable reach, and the adequate river length to attain this slope, for a given valley slope, considered an independent variable. The evolution coefficients show low values, meaning that mountains river would rather make deposits in river bed (diagonal or transverse bars) than have a spectacular evolution. Depending on river evolution value, it is possible to predict river behavior in a given period of time.

Tabelul 1

Hydrometric data for stable reaches

	Reach river or brook	Z_{am} [m]	Z_{av} [m]	l_{valey} [km]	l_{river} [km]	i_{reg} (%)	Q_{bf} m^3/s	ev	c_{ev}
1	Moldoviţa (confl. Deia-confl Puşca)	567,0	555,0	2,94	3,20	0,37	171,4	0,09	1,09
2	Moldoviţa (up confl Dragoşa)	617,5	596,0	2,38	3,01	00,72	149,6	0,26	1,26
3	p. Dragoşa (up. confl Moldoviţa)	635,0	599,0	2,93	3,41	1,05	19,2	0,16	1,16
4	p.Sălătruc (up confl Moldova)	564,0	524,0	2,61	2,80	1,43	8,6	0,07	1,07
5	r Moldova (up Prisaca Dornei)	599,0	587,5	2,82	2,93	0,39	130,5	0,04	1,04
6	r Moldova (up C-lung Mold)	701,0	675,0	3,14	3,20	0,81	97,0	0,02	1,02
7	P Dobra (Vama, up confl Moldova	555,0	538,0	1,62	1,94	0,89	11,2	0,20	1,20
8	p. Frumoasa (up confl Moldoviţa)	682,5	595,0	3,85	4,24	2,06	18,5	0,11	1,11
9	p Hurghiş (up confl Moldova)	667,0	600,0	1,53	1,8	3,72	4,1	0,18	1,18
10	r Moldova (up Fundu Moldovei)	727,0	710,0	2,68	2,74	0,63	70,3	0,02	1,02
11	P Sadova (up confl cu Moldova)	701,0	671,0	1,87	1,88	1,58	34,0	0,01	1,01
12	p. Sadova (up Sadova village)	824,0	745,0	4,06	4,86	1,62	27,0	0,20	1,20
13	r. Moldova (up Botuş village)	859,0	790,0	5,07	7,02	0,99	68,2	0,38	1,38
14	r. Moldova (Colacu village)	801,0	770,0	3,17	3,43	0,90	75,5	0,08	1,08
15	Moldova (Breaza – confl r Negru)	831,0	800,0	2,05	2,40	1,30	51,6	0,17	1,17
16	r. Moldova (up. Breaza village)	878,0	835,0	3,78	4,68	0,92	28,1	0,24	1,24
17	r. Moldova (up confl Porcescu r.)	911,0	880,0	2,50	2,65	1,16	9,0	0,06	1,06
18	r. Moldova (down confl Timoi r.)	763,0	735,0	2,80	3,02	0,92	82,8	0,08	1,08
19	r. Moldova (up. confl Putna r.)	709,0	700,0	1,76	1,76	0,52	8,81	0,0	1,0
20	r Putna (up confl Moldova r.)	742,0	710,0	2,47	2,53	1,27	20,0	0,02	1,02
21	r Timoi (up confl Moldova r.)	820,0	740,0	1,93	1,95	4,10	6,2	0,01	1,01

Technical papers in river training quote examples of regime equation, mostly between bankfull discharge and cross section parameters. Bankfull discharge is best related to river bed width and bankfull cross section, which is in agreement with the diagram presented in fig. 1 (Hey, 1982).

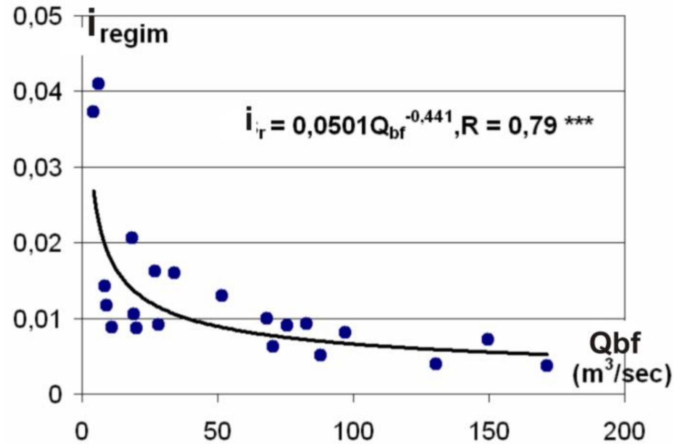

Fig. 5. Correlation between regime slope (i_r) and bankfull discharge (Qbf)

CONCLUSIONS

1. Aerial image series are useful to show channel river behavior in time.

2. The transition from valley slope to regime slope (equilibrium slope) can be made through river evolution, defined like a ratio between river length measured on channel axis and valley ax is.

3. The correlation coefficient *R* is significant (fig. 5), but the number of regime pairs slope – bankful discharge is rather small. For more pairs of data, R can decrease, but maintaining the trend described by [4].

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