CONSIDERATIONS ON THE SEDIMENTS TRANSPORT IN RIVER BEDS

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Abstract. The solid flow carried by a river is a dynamic overlapping contribution of the upstream catchment and the contribution due to the sediment entrainment effect of the liquid flow by river bed, respectively the deposit of sediment in suspension. The solids content of surface water bodies is related to the physical, morphological and hydro-climate characteristics of the basin to which they belong. The paper presents the assessment of alluvial sources in relation to the processes manifested in the river bed specific an flood event.

Keywords: *suspended sediment, flood, processes of erosion and transportation, rainfall regime.*

Introduction

The intensity of the washing and erosion phenomenon is directly dependent on the destructive factors, rains and drainage, and resistant factors, soil and vegetation. Following these phenomenons result large quantities of solid material on the slopes who arrived in the beds of water courses can lead to significant changes in riverbeds, when the river has not a sufficient transport capacity.

As a result of water flow on the slopes and in river beds, in specific terms the nature of hydro-morphological, pedological and vegetation, the suspended solid flow at a time of a water course is confirmed to be a function of many factors distributed throughout the basin. The statistical character of the laws then succeed while suspended solid flows requires adequately addressing the problem of conditioning discharges of suspended solid by water flows (Beciu, 2010).

The large quantities of sediments are transported during the floods production. The flash floods are the peak moments in the evolution of a river flow. They are characterized by spectacular growth, very fast (in matter of hours) of the water level and thus of the flow, until reaching a maximum level, followed by a very fast decreasing in water by returning to normal parameters.

The flood genesis is mainly related to climatic conditions, as a result of intense rainfall, melting sudden of snow or mixed. Other influencing factors are soil permeability, moisture degree and soil temperature, vegetation, river beds slopes, shape and surface watersheds and river beds characteristics.

The characteristic elements of flood waves are shown of the following parameters: the base flow (Q_b) which is recorded before and after the flood, the maximum flow or peak flow (Q_{max}), is the maximum flow which waters reached him during the flood, the increase time (T_c hours) represents the duration of the flood start time and that of the peak flow recording, the decreasing time (T_d hours,) expressed during withdrawal of water from the production times at the maximum flow and return to base flow, the total flood time ($T_t = T_c + T_d$), represents the number of hours when the water flow was higher than the basic flow, the flood volume (W) is played by water quantity rolled during the flood and is determined of based on hydrographer or using the relationship:

$$W = Q_{max} \cdot T_t \cdot y \cdot 3600$$

where: W, the maximum flood volume (in m^3), Qmax , peak flow (in m^3 / s), Tt, total time (in hours), Y, form factor of the flood.

Another parameter is the drained water layer (h), it illustrates the thickness of a uniform layer of water (in mm) and is obtained by dividing the water volume of flood (W, in m^3) on the surface-basin (F, in km^2) in the upstream of the considered section:

$$h = W/1000 \cdot F$$

The flood form coefficient (γ) is expressed follows as:

$$\gamma = W/(Q_{max} - Q_b) \cdot T_t$$

During the floods, many rivers carry significant volumes of sediments in suspension and the tarate, which, mostly, is deposited at the estuary of causing an advancing of the delta, which can reach over 100 m / year, depending on the amount deposited.

The researchers determined that during the large floods, the sediments flow grows exponentially, so that the relationship between water flow and sediment flows is represented by curves with a large broadening into the right.

From measurements made during the floods it has been found that for a liquid flow rate Q correspond two discharges of suspended solids R and these two are: one for the ascending branch of the flood R_c and one for the descending branch of the flood R_d (Giurma et al., 2003).

The conditioning analysis of the flow of sediments in suspension starts from the assumption that, in a given profile, for the same water flow, the flow of suspended sediments is very different at certain times, covering a wide spacing.

In the growth phase of the floods there is a high increase of slopes and flow velocity, therefore, the erosion and transport capacity manifests the same. In the descending phase of the floods the slopes and the speed are decreasing and along with that the river competence is reduced and the alluvial processes of the river are intensified (Dumitriu D., 2003).

The objective of this paper is to analyze the temporal variation of the suspended sediments flow in relation to the manifested processes in the river bed during a flood.

The hydro-morphological characteristics of the hydrographic basins and the water courses of the Prut river

The Prut River is the second major river in the eastern part of Romania. This originates from the Forest Carpati Cernogora (Ucraina) and is flowing into the Danube River from the left bank at a distance of 164 km from the mouth of the river, at a distance of 0,5 km from Giurgiulesti. At the beginning the course river passes the Cernauti region (Ukraine) that is represents a natural boundary between Romania and Republic of Moldova. The river basin shows an asymmetric shape, with a greater development in the northern half and a very sharp narrowing to the south of Ungheni with the confluence of the Danube, up where its width decreases to less than 20 km.

The Prut River is 953 km long and the catchment area is 27540 km^2. The river fall is 1577 m, the average slope is 1,63‰ and the river tortuosity coefficient reaches the value of 2,1 (Figure no.1).

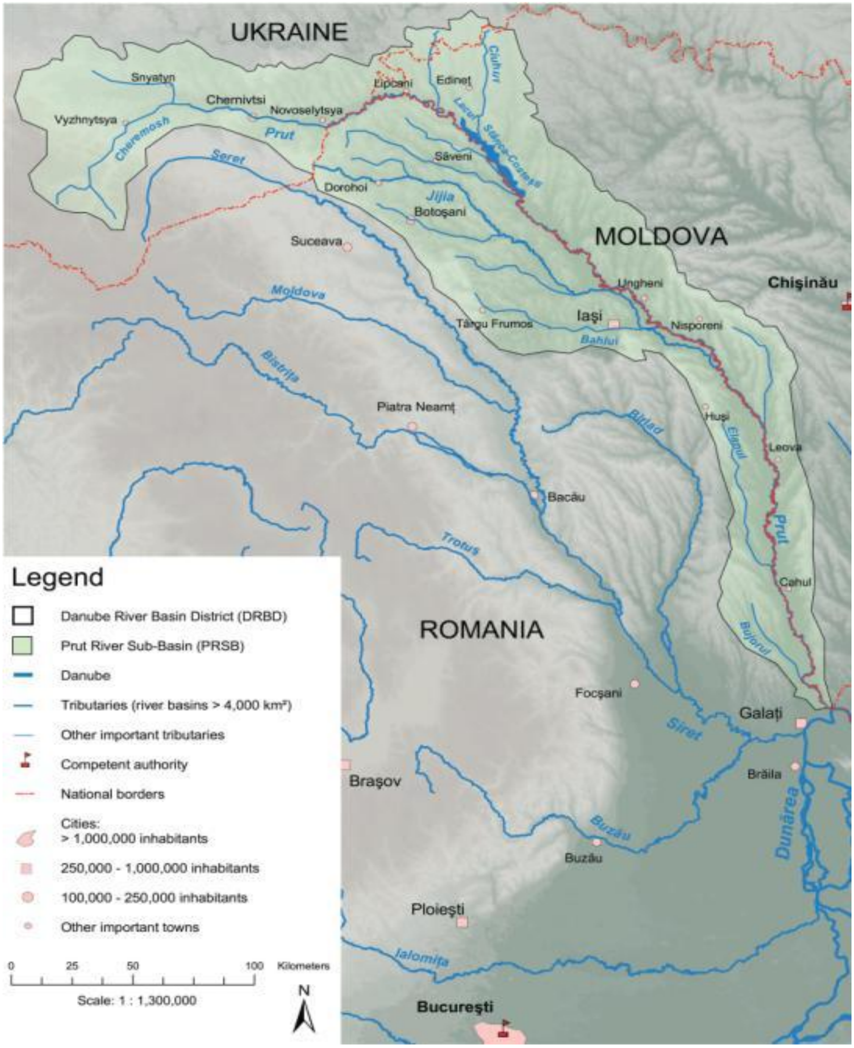
The Prut hydrographic space is situated in North-Eastern part of Romania, neighbouring at west and south Siret basin, comprises integrally: Botosani (90 %), Iasi (83 %) and Vaslui (100 %) counties and partially: Neamt, Bacau, Vrancea and Galati.

The hydrographic network has a total length of the cadastral waters from Prut hydrographic basin of 4,183 km, of an average density 0.38 km/km^2 (Administrația Bazinală Prut-Bârlad, 2007).

The Prut riverbed material is dominated to 80% of friable rocks of the Moldavian Platform and the alluviums derived from the remobilisation deposits of the perimeter beds, especially in downstream to Stanca- Costesti reservoir. This way, to the upstream of the lake dominates a gravel with a diameter d50 of 15 mm to Oroftiana and 7 mm to Mitoc.

The dam and the Stanca-Costesti lake creates a threshold in the distribution of liquid flow and solid flow of suspended sediments. The changes in the transport of suspended sediments is dramatic, values recorded at 55 kg/s upstream the lake up to 2.28 kg/s downstream of the lake.

The river channel reflects the geological and geomorphological conditions in the superior basin of the Prut River, where crystalline schists and rocks on flysch outcrop on almost 40% of the basin's surface up to this point, with an energetic potential of the landscape capable of transportation of rough materails to the minor channel (Radoane et al., 2007).



Source:Icpdr/iksd

Figure 1 The map of the Prut River basin

The liquid flow of the Prut River is influenced by the rainfall and the functioning of the hydrotechnical works of Stanca- Costesti reservoir. The multiannual average discharge of Prut River increases from 78.1 m^3/s (2,462 $mn.m^3$) in Radauti section at 86.7 m^3/s (2,736 $mn.m^3$) in Ungheni section and of 105 m^3/s (3314 $mn.m^3$) at the confluence with the Danube. The main tributary of Prut river, Jijia, brings in 10 m^3/s (316 $mil.m^3$).

The minimum flow of the Prut hydrographic basin tributaries is reduced, the most part of them have a temporary character. The minimum monthly average discharges of 95% and the minimum average daily of 95 % is registered between 0 and 0.5 m/s on the majority of Prut tributaries (Administrația Bazinală Prut-Bârlad, 2007).

Below we present aspects of the solid transit in the Prut River Basin during the flood of July-August 2008.

The regime of the suspended sediments flow during the flood in 2008 on the Prut river

It is known that while the size of liquid flow in a flood depends mainly on the duration, size and intensity of rainfalls, in the case of solids flow, besides the water flows, an important role plays the basin lithology and the lithology of the river bed, its stability as well as the slope evolution during the flood.

The flood in July-August 2008 was generated by the rainfall in the upper basin of the Prut River, which amounted values between 91-305 m and caused a great increase in the river levels and flows in the period after July 22, 2008. The maximum levels were recorded on July 26, between 12 to 15, near the border with Ukraine and on July 27, between 17 to 20, at the hydrometric station Rădăuți Prut.

It is noted that the flood caused had a probability of exceeding of approximately 0.4%, being much higher than that considered at the formation of the Stanca-Costeşti reservoir. This way, the flood in July-August 2008, when it reached its highest level in the Stanca-Costeşti accumulation, was characterized by:

- ❖ the initial elevation in the lake 90.75 mdMN ;
- ❖ maximum elevation in the lake 98.75 mdMN ;
- ❖ the accumulated volume 558 hm^3;
- ❖ the discharged volume, the total volume 840 hm^3;
- ❖ the maximum flow tributary 3380 m^3 / s;
- ❖ the increase for 66 hours;
- ❖ total time 120 hours and form factor 0.63 (Ovidiu G., Ion H., 2008).

The flows of suspended sediment, which occurred during the flood, on the Prut River Basin were very high. It is known that solid medium flow, maximum average and minimum average are dependent on liquid flow. The phenomenon of the solid flow are elevated and this ensures to the Prut river a rich supply of suspended sediments. Water turbidity (ρ, în g/m^3) in the river is on average about 1000-2500 g / m^3.

In the Table no.2 are shown the rates of the liquid flow and suspended sediments flow in 2008 (between 23.07-31.08) when there is an increase of the influence of control factors and also the maximum values of the flow of liquids and solids.

Table no. 2 Flows of water and sediment in suspension produced in some sections, during the flood of the Prut River Basin, 2008.

DATE	STATIONS									
	H.S. Sipote		H.S. Tg. Frumos		H.S. Victoria		H.S.Ungheni		H.S. Carjoaia	
	Q m^3/s	R kg/s	Q m^3/s	R kg/s	Q m^3/s	R kg/s	Q m^3/s	R kg/s	Q m^3/s	R kg/s
23.07	0,063	0,169	0,070	0,006	2,40	0,142	81,5	3,94	0,002	0,005
24.07	0,407	0,252	11,8	133	2,76	0,048	82,3	11,5	4,99	63,4
25.07	5,91	123	15,9	241	4,57	0,164	85,1	10,4	15,2	348
26.07	23,3	542	0,494	1,07	7,44	0,280	88,7	11,0	0,236	0,482
28.07	11,7	217	1,40	4,69	14,3	0,397	177	35,0	0,610	2,48
29.07	13,1	274	0,611	1,50	17,3	0,513	346	141	0,718	3,05
30.07	6,70	104	5,57	35,1	21,6	0,603	446	233	0,900	5,67
31.07	2,97	32,2	0,834	2,32	26,9	0,693	488	275	0,557	1,91
1.08	1,01	3,820	0,158	0,136	11,3	0,690	537	324	0,162	0,268
2.08	0,698	1,320	0,138	0,219	8,91	0,598	565	353	0,152	0,248
3.08	0,585	0,850	0,106	0,302	7,84	0,506	595	384	0,152	0,248
4.08	0,425	0,252	0,082	0,385	5,85	0,413	621	411	0,152	0,248
5.08	0,475	0,252	0,114	0,262	5,04	0,437	627	417	0,142	0,008
6.08	1,84	16,5	0,138	0,140	4,42	0,461	606	395	0,105	0,008
7.08	1,47	0,115	0,120	0,017	4,19	0,485	579	367	0,081	0,007
8.08	0,529	0,133	0,120	0,200	3,37	0,444	561	349	0,069	0,007
9.08	0,372	0,120	0,186	0,383	3,06	0,404	545	332	0,072	0,006
10.08	0,358	0,108	1,01	0,567	3,54	0,363	535	349	0,135	0,006
11.08	0,343	0,095	0,249	0,750	3,16	0,322	533	332	0,087	0,006
12.08	0,313	0,083	0,122	0,503	3,98	0,295	540	322	0,079	0,005
13.08	0,291	0,071	0,106	0,256	4,93	0,269	547	320	0,069	0,005
14.08	0,250	0,058	0,104	0,009	4,37	0,242	551	327	0,059	0,005
15.08	0,218	0,052	0,120	0,008	3,66	0,191	552	334	0,057	0,004
16.08	0,165	0,045	0,107	0,007	3,39	0,140	553	338	0,049	0,004
17.08	0,111	0,039	0,105	0,006	3,68	0,090	479	339	0,043	0,004
18.08	0,131	0,032	0,138	0,006	3,80	0,039	297	340	0,045	0,003
19.08	0,239	0,026	0,124	0,006	3,54	0,030	224	266	0,049	0,003
20.08	0,211	0,020	0,120	0,006	1,72	0,021	204	102	0,035	0,002
21.08	0,165	0,013	0,107	0,006	0,302	0,011	192	56,7	0,031	0,002
22.08	0,134	0,013	0,101	0,006	0,809	0,026	158	46,7	0,028	0,002
23.08	0,098	0,013	0,105	0,006	1,33	0,042	144	41,3	0,027	0,002
24.08	0,125	0,012	0,114	0,006	2,46	0,058	141	28,0	0,022	0,002
25.08	0,427	0,012	0,169	1,26	3,70	0,073	141	22,6	0,068	0,002
26.08	0,367	0,011	0,092	0,840	4,27	0,175	139	18,7	0,036	0,002
27.08	0,376	0,011	0,092	0,420	9,36	0,278	136	14,7	0,028	0,001

28.08	0,308	0,010	0,092	0,004	5,04	0,380	135	10,8	0,024	0,001
29.08	0,155	0,010	0,092	0,004	4,21	0,384	134	10,8	0,024	0,001
30.08	0,145	0,009	0,092	0,003	4,38	0,388	133	10,9	0,030	0,001
31.08	0,162	0,008	0,092	0,002	4,15	0,393	110	11,0	0,025	0,001

Source : Prut – Bârlad Water Basin Administration

It is observed that the maximum flow of suspended sediments, at Ungheni hydrometric station, reached the value of 421 kg / s on 4th of August, with a turbidity of about 0,290 kg/m^3 and a liquid flow of 630 m^3 / s.

Table no.3 The monthly average characteristic turbidity measured at five hydrometric stations in the Prut River Basin in 2008

MONTH	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
S.H. Sipote												
Q_{med} m^3/s	1,22	1,02	0,43	7,96	2,50	1,33	2,22	0,41	0,34	0,79	0,46	0,83
R_{med} kg/s	28,5	6,19	0,04	2,79	49,9	32,1	42,1	0,78	2,82	50,6	0,03	0,02
ρ kg/m^3	23,4	6,07	0,08	35,1	20,0	24,1	19,0	1,93	8,25	64,0	0,06	0,02
S.H. Tg. Frumos												
Q_{med} m^3/s	0,16	0,09	0,09	0,51	0,51	0,14	1,26	0,15	0,12	0,11	0,13	0,13
R_{med} kg/s	0,02	0,01	0,02	2,85	6,20	0,59	13,5	0,22	0,01	0,06	0,02	0,05
ρ kg/m^3	0,09	0,06	0,16	5,60	12,1	4,30	10,7	1,46	0,10	0,49	0,22	0,41
S.H. Victoria												
Q_{med} m^3/s	4,76	6,10	4,16	19,3	15,2	4,04	5,44	4,31	5,44	7,79	4,60	4,52
R_{med} kg/s	0,45	0,63	0,64	2,79	2,08	0,29	0,23	0,28	0,24	0,62	0,31	0,09
ρ kg/m^3	0,09	0,104	0,15	0,14	0,14	0,07	0,04	0,07	0,04	0,08	0,07	0,02
S.H. Ungheni												
Q_{med} m^3/s	62,5	61,7	54,6	176	174	110	131	381	104	163	114	59,8
R_{med} kg/s	1,67	2,96	2,37	35,9	19,6	4,64	38,0	225	12,8	17,4	8,55	1,59
ρ kg/m^3	0,03	0,048	0,04	0,20	0,11	0,04	0,29	0,59	0,12	0,11	0,08	0,03
S.H. Carjoaia												

Q_{med} m^3/s	0,06	0,053	0,06	0,43	0,07	0,11	0,77	0,07	0,03	0,04	0,04	0,06
R_{med} kg/s	0,01	0,002	0,02	0,48	0,06	0,28	13,7	0,04	0,00 1	0,02	0,00 3	0,00 2
ρ kg/m^3	0,13	0,034	0,34	1,11	0,83	2,53	17,9	0,52	0,04	0,63	0,08	0,03

Source : Prut – Bârlad Basin Administration

At the other hydrometric stations the evolution of alluvial flows and liquid flows is presented as follows:

- ❖ at the hydrometric station Sipote (at Miletin river) the maximum liquid flow was 61.2 m^3 / s, the flow of suspended sediments was 4182 kg / s (4.04) and the average turbidity 35.1 kg/m^3 (Table 3);
- ❖ at the hydrometric station Tg.Frumos (at Bahluet river) the maximum liquid flow was 95 m^3/s, the flow of suspended sediments was 2950 kg/s (24.07) and the average turbidity 10,7 kg/m^3;
- ❖ at the hydrometric station Victoria (at Jijia river) the maximum liquid flow was 67,2 m^3/s, the flow of suspended sediments was 11 kg/s (26.04) and the average turbidity 0,144 kg/m^3;
- ❖ at the hydrometric station Cârjoaia (at Măgura river) the maximum liquid flow was 83,1 m^3/s, the flow of suspended sediments was 2812 kg/s (25.07) and the average turbidity 17,9 kg/m^3 (Table 3).

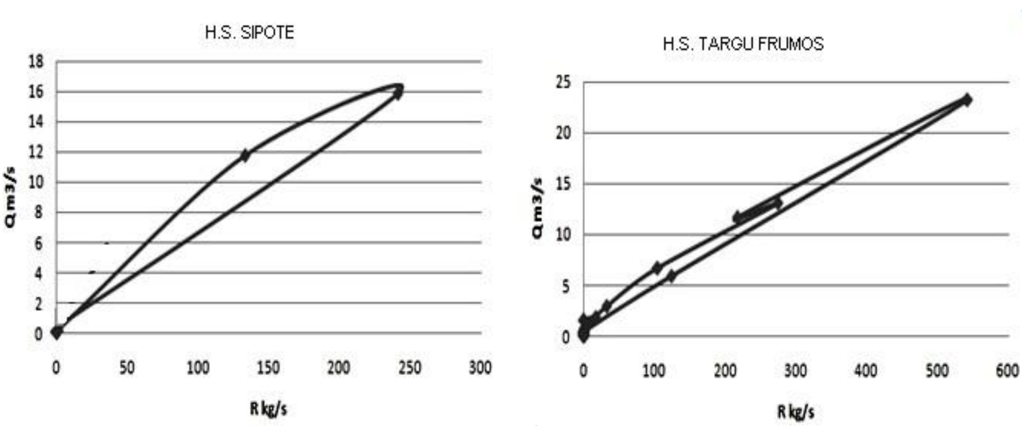


Figure 2 The link between liquid flow (Q m^3 / s) and suspended solids flow R (kg /s) determined at the five hydrometric stations in the Prut river basin during the flood (07/23/2008 to 08/31/2008).

The year 2008, at the hydrometric stations monitored, was characterized through a minimum liquid flow, manifested in the winter period, ranging between

0.001 m^3 / s at Cârjoaia, 0.037 m^3 / s at Sipote, 0052 m^3 / s at Tg.Frumos, 0.280 m^3 / s Victoria and a value of 39.5 m^3 / s at Ungheni. The minimum flows of suspended sediments ranged between 0,001 kg / s at Sipote, Cârjoaia and Tg.Frumos, 0,011 kg / s at Victoria and 0.716 kg/s at Ungheni.

The link between fluid flow (Q m^3 / s) and suspended solids flow R (kg /s) determined at five hydrometric stations in the Prut river basin during the flood (07/23 to 08/31/2008) is shown in Figure no 3.

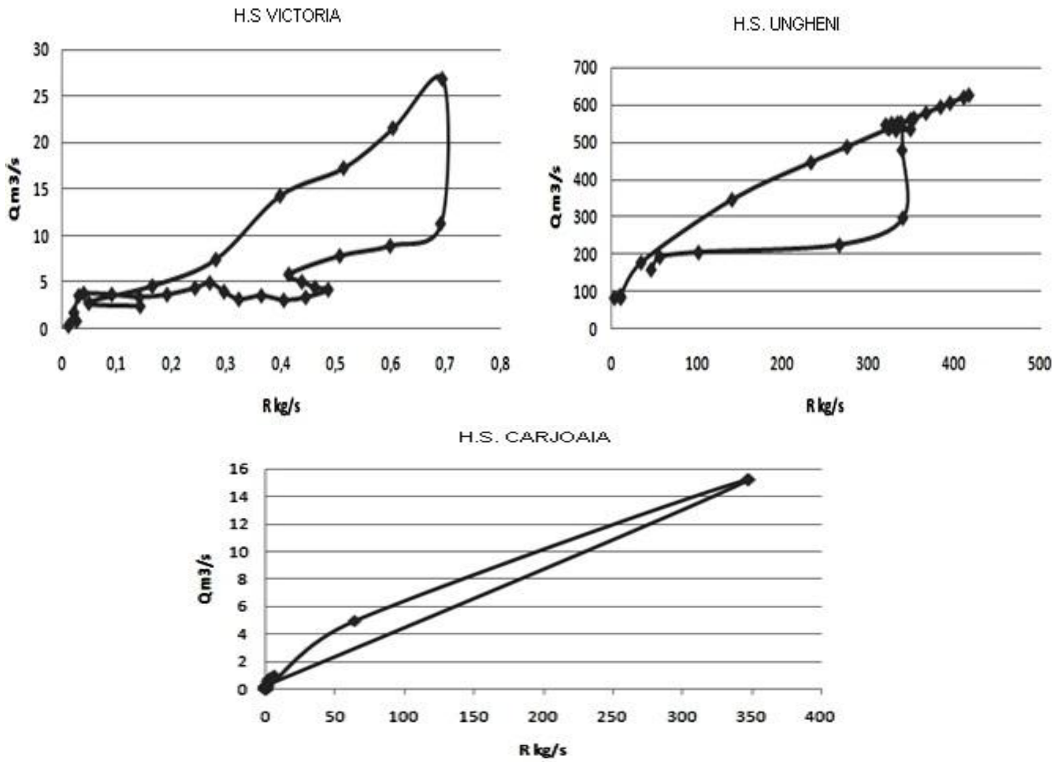


Figure 3 The link between liquid flow (Q m^3 / s) and suspended solids flow R (kg /s) determined at the five hydrometric stations in the Prut river basin during the flood (07/23/2008 to 08/31/2008).

The existence of several monitoring sections of the suspended sediment on the Prut river, and in general on all the rivers, contribute positively to the changes occurring in the evolution of river bed, of processes of erosion and height increasing, of stability and of the quantity of sediment carried by tributaries in the Prut River and, in after, into the Danube.

Conclusion

In this paper were analyzed some aspects of the transit of the sediments during the flood in the Prut River Basin.

The hydrological data processing has revealed that: the granulometry of sediments deposited in the bed of a river is actually the expression of lithology and geological structure of that river basin, of the rainfall regime and of the drained liquid flow which caused erosion and transportation, the liquid flow is the main and indispensable factor of formation of the solids flow regime and the control factors of alluvium spill are very numerous and acts in a continuous interdependence.

Using the statistical data measured in 2008 at the five hydrometric Posts in the Prut River Basin it has been emphasised the regime of suspended sediments flow during the flood (between 23.07-31.08). They resulted some correlations on the transport of sediment (R = f (Q)), with which it is distinguished the intensity of the flows of solid growth compared with the liquid flow, that is more pronounced in the case of floods and less relevant in the case of low flow.

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