

HYDRO METEOROLOGICAL INSTITUTE OF MONTENEGRO
- Hydrology Division -

Preliminary Technical Report

for profiles of small (mini, micro) hydro power plants (sHPPs)
on tributaries of main watercourses in Montenegro, (second stage)

This analysis of hydrology was performed as a result of an agreement reached with Elektroprivreda Crne Gore A.D. Niksic in accordance with programe with Norwegian Directorate for Water and Energy (NVE), Oslo

Responsible author:

Milan Bošković, M.Sc. Civil. Engineer

Authors:

Mirjana Popović, B.Sc. Civil Engineer

Nevzeta Alilović, B.Sc. Civil Engineer

Director

Luka Mitrović, M.Sc. geography

Podgorica, June, 2008

A. Introduction

The sequence of selected profiles with corresponding watercourses (tributaries) is as follows:

	Name of station	Watercourse	Catchment area (km ²)	Tributary level	Catchment of river
1	Požnja	Požanjska Rijeka		I	Morača
2	Rijeka	Ibrištica		I	
3	Zavraca	Ratnja Rijeka		I	
4	Gornja Ljuta	Vrelo		I	
5	Bjelojevići	Bjelojevička Rijeka		I	Tara
6	Pojišta	Bukovica		I	
7	Štitarica	Štitarica		I	
8	Majstorovina	Bistrica		II	Ljuboviđe
9	Kuti	Kutska Rijeka		II	Zlorečica
10	Jošanica	Peročica		II	
11	Lješnica	Lješnica		I	Lim
12	Kaludra	Kaludarska rijeka		I	
13	Dapsići	Dapsička Rijeka		I	
14	Šekular	Šekularska Rijeka		I	
15	Ljuta	Vinicka		I	

Out of these 15 profiles, two stations HS Šekular on the river Šekularska Rijeka and HS Ljuta on the river Vinicka, were washed away by high waters in October 2007. On that occasion the profile where these stations were placed was so damaged that it was not possible to have them installed again, and finding another profiles would not have been useful due to limited duration of research works of 15 months and because it would not be possible to have sufficient number of measurements and monitorings.

B. Overview of parameters of hydrographic and physical-geographic characteristics of catchment areas

These indicators are reflecting spatial, topographical and relief position of selected sites, with parameters which are used as input data for regional analysis of homogeneity of run-off regimes in catchment areas and for implementation of same procedures for their analysis.

1. Catchment area ----- F (km²)
2. Length of watercourse ----- L_t (km)
3. Length of catchment area ----- L_s (km)
4. Perimeter of catchment area ----- S (km)
5. Average width of catchment area ----- B = F/L_s (km)
6. Rectilinear distance river source - confluence- L_i (km)
7. Rectilinear distance between brunt centre of the catchment and the river confluence - U_t (km)
8. Watershed spreading factor ----- K_s
9. Elongation of catchment factor ----- K_σ
10. Concentration of catchment factor ----- K_c
11. Tortuousness of flow factor ----- K_l
12. Maximum elevation in the catchment area --- H_{max} (m.a.s.l.)
13. Minimum elevation in the catchment area -- H_{min}(m.a.s.l.)
14. Average head in the catchment area ----- I_{sr} (%)
15. Maximum head of slope of valley ----- I_{max} (%)
16. Average altitude of the catchment area ----- H_{sr} (m.a.s.l.)
17. Average difference in altitude of the catchment area ----- ΔH (m)
18. Levelled out head of watercourse ----- I_t (%)
19. Maximum head of the watercourse ----- I_{t1} (%)
20. Averaged maximum head of the watercourse- I_{t2} (%)

In brief, we shall list necessary assumptions used to obtain this information. Catchment area, length of watercourse, length of catchment area and perimeter of catchment area are all straightforward.

Medium width of the catchment area is a parameter calculated by applying the following formula $B = F/L_s$ and it represents a ratio between surface and length of catchment area.

Watershed spreading factor $K_s = \frac{S}{3.54\sqrt{F}}$ is a ratio between perimeter of of catchment area (S) and circumference of a circle with a same surface as the analysed catchment area (S₁)

$$F = r^2 \pi \rightarrow r = \sqrt{F/\pi}$$

$$S_1 = 2r \pi = 2\sqrt{F/\pi} \times \pi = 2\sqrt{F\pi} = 3.54\sqrt{F}$$

Elongation of catchment factor $K_e = \frac{l_t^2}{F}$

Concentration of the catchment area factor is calculated based on the following formula $K_c = \frac{2F}{S \times U_t}$

Average head of the catchment area is also calculated by applying the following formula $l_s = \sum_{i=1}^N \frac{h_i}{\check{s}_i} \times \frac{f_i}{F}$

h_i - equidistance between contour lines

f_i - surface between two neighbouring contour lines

\check{s}_i - average width of a strip of land between two contour lines

$$\check{s}_i = \frac{f_i}{L_{sr}}; \quad L_{sr} = \frac{L_{i-1} + L_i}{2}; \quad L_{i-1}; L_i - \text{lenght of contour lines}$$

$$l_s = \frac{0.5h \times \sum_1^n (L_{i-1} + L_i)}{F}$$

Average altitude of the catchment area is calculated based on the following formula:

$$H_{sr} = \frac{f_1 H_1 + f_2 H_2 + \dots + f_n H_n}{F}$$

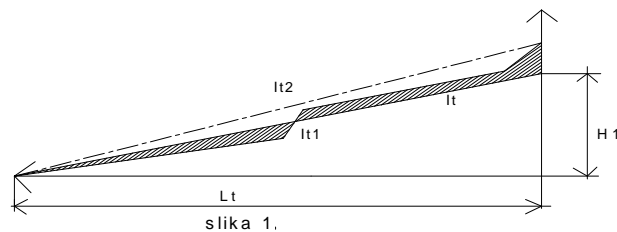
f_1, f_2, \dots, f_n - surface of the catchment area encompassed between two contour lines,

H_1, H_2, \dots, H_n - average altitude between two neighbouring contour lines.

Average difference in altitudes in the catchment area $\Delta H = H_{sr} - H_p$

H_p - altitude of confluence of a river or altitude of a profile for which difference in altitudes is calculated.

Overview of characteristic heads in the watercourse



$$F_{\Delta} = \frac{L_t \times H_1}{2} \quad \text{from condition} \quad F_{\Delta} = F \rightarrow H_1 = \frac{2F}{L_t}$$

$$\text{i.e. } I_t = \frac{H_t}{L_t} \times 100 \text{ (\%)}$$

For the purpose of this Preliminary Report only basic parameters shall be given, i.e. five of them, as well as schematic longitudinal profile of watercourses. Others will be elaborated and will be given in the final Technical Report which shall be prepared after expiration of time envisaged for research works, i.e. 15 months.

C. Partial water balance for selected measurement profiles

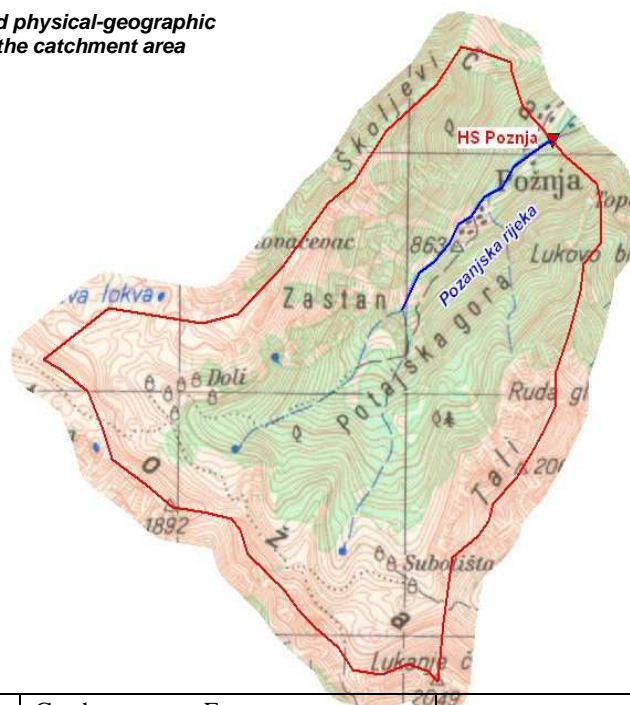
Preliminary balances for the analysed period which is finalised by the time of preparation of this report, as well as for those profiles where performed hydrometric measurements ensure flow curve to be sufficiently covered by required measurements, with at least 70% of actual water level amplitude, shall be given here.

On the most of watercourses there were 12 series of hydrometric measurements, which were not of the same quality on all the watercourses. On some HS coverage of water level amplitude goes even up to 95% and there are some HS with 35% coverage, in which case additional measurements would have to be performed during high waters.

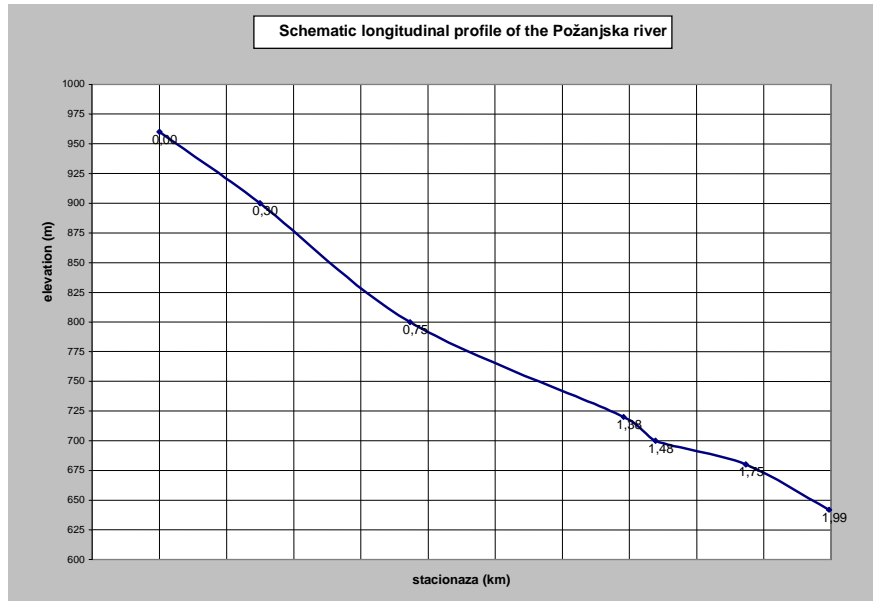
C1. WATERCOURSE: POŽNJA HS: POŽNJA

The river Požanjska rijeka is right tributary of the river Gornja Morača downstream from Dragovića Polje. The river has a catchment area of 12.5 km² and length of watercourse is 1.99 km. Maximum elevation in the catchment area is 2063 m.a.s.l. and minimum elevation is 642 m.a.s.l. Perimeter of catchment area is 15.9 km. As stated in the introduction of this Report, only five basic hydrographic and physical-geographic characteristics of the catchment area shall be given as well as a schematic longitudinal profile of the watercourse (Figure 1).

Hydrographic and physical-geographic characteristics of the catchment area



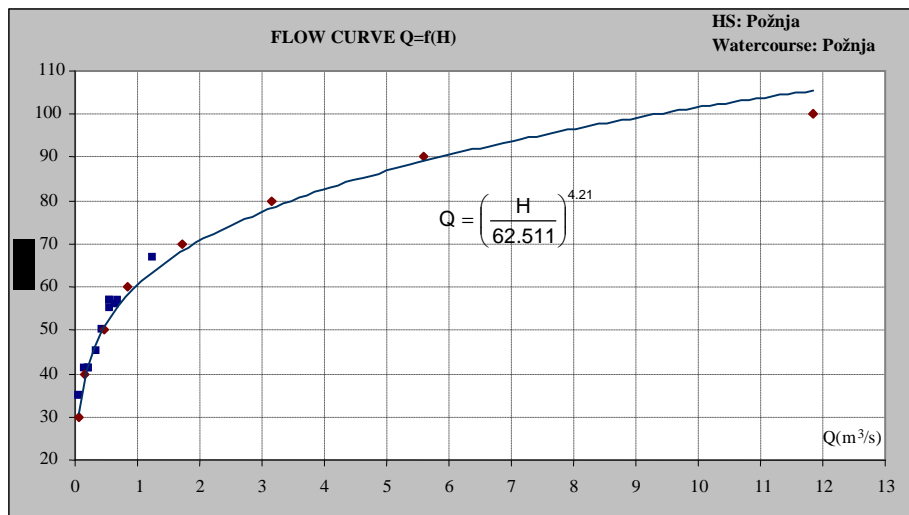
1	Catchment area F	12,5	[km ²]
2	Length of watercourse L _t	1,99	[km]
3	Perimeter of catchment area S	15,9	[km]
4	Maximum elevation in the catchment area H _{max}	2063	[m.a.s.l.]
5	Minimum elevation in the catchment area H _{min}	642	[m.a.s.l.]



(Figure 1)

Available data base for this hydrology station was 348 days, from 1.07.2007 until 12.06.2008. There were 11 hydrometric measurements of velocity of flow on this profile, and coverage of water level amplitude with measurements was 68%. Flow curve was created based on performed measurements, which was then extrapolated and discharge curve was expressed as the following function $Q = \left(\frac{H}{62.511} \right)^{4.21}$, figure. Based on this curve a balance for analysed period was made.

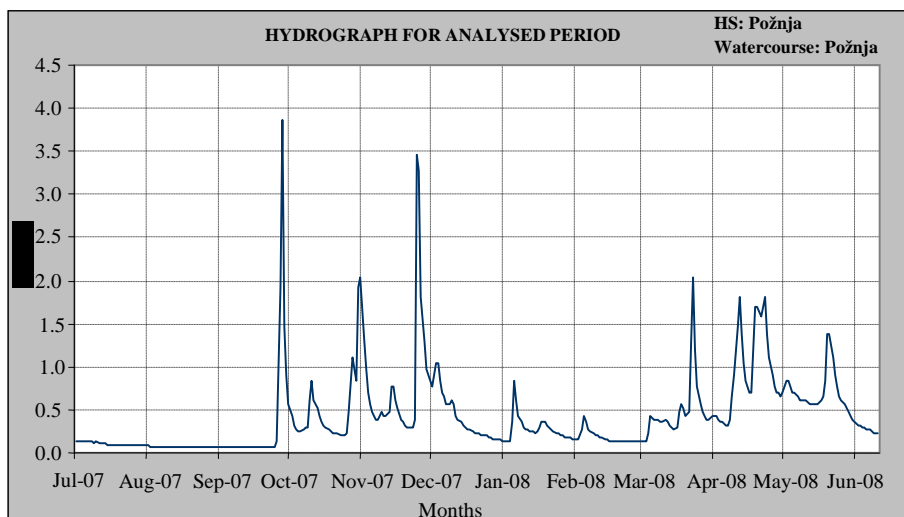
Average flow in analysed period is 0.433 m³/s.



(Figure 2)

Minimum flow is registered as 59 lit/sec, and maximum was 7.1 m³/s and was recorded in September 2007 and it was 73% higher than the average daily discharge. This big oscillations may be registered through automatic stations which register water levels at every 15 minutes.

Hydrograph is given on the Figure 3.



(Figure 3)

For this HS, it was estimated that average flow in the analysed period lasted around 20% of time, i.e. 70 days. Duration curve with duration of average monthly flow as well as with other characteristic durations shall be also given in the final Report.

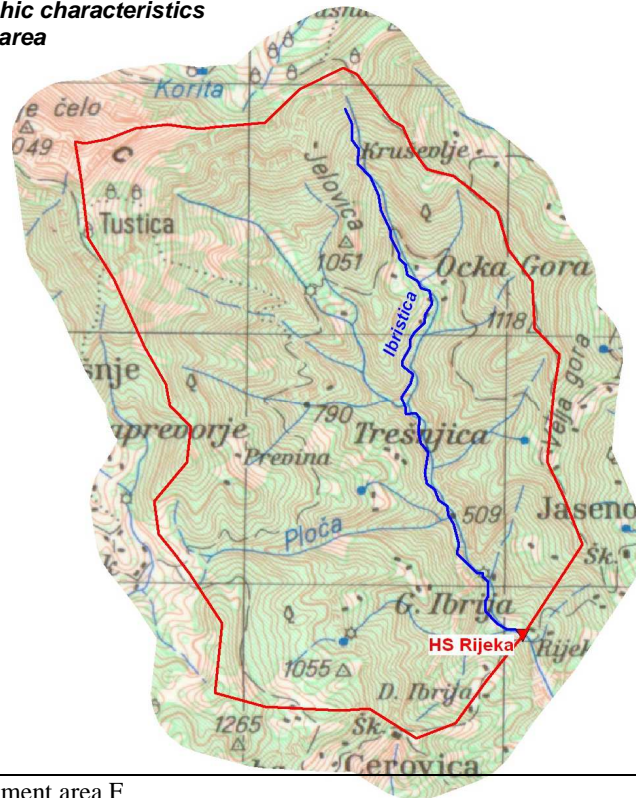
Review of flows for available period with average decade, average monthly, minimum and maximum flows are given in the Table below.

WATERCOURSE: POŽNJA HS: POŽNJA							WATERCOURSE: POŽNJA HS: POŽNJA					
REVIEW OF FLOWS - 2007							REVIEW OF FLOWS - 2008					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1	0.143	0.088	0.068	0.898	1.917	0.898	0.160	0.160	0.127	0.431	0.657	0.394
2	0.143	0.088	0.068	0.558	2.042	0.832	0.143	0.160	0.143	0.431	0.712	0.359
3	0.143	0.078	0.068	0.431	1.288	0.770	0.143	0.160	0.143	0.431	0.832	0.327
4	0.143	0.078	0.068	0.327	0.967	1.041	0.143	0.160	0.143	0.394	0.832	0.327
5	0.127	0.078	0.068	0.270	0.712	1.041	0.143	0.270	0.220	0.359	0.770	0.297
6	0.127	0.078	0.068	0.244	0.558	0.832	0.359	0.431	0.431	0.359	0.712	0.297
7	0.127	0.078	0.068	0.244	0.470	0.712	0.832	0.359	0.394	0.327	0.712	0.270
8	0.127	0.078	0.068	0.270	0.394	0.657	0.606	0.270	0.394	0.327	0.657	0.270
9	0.127	0.078	0.068	0.297	0.394	0.558	0.431	0.244	0.394	0.394	0.606	0.244
10	0.113	0.078	0.068	0.297	0.431	0.558	0.359	0.220	0.359	0.657	0.606	0.220
11	0.127	0.078	0.068	0.606	0.470	0.606	0.297	0.199	0.359	0.898	0.606	0.220
12	0.113	0.078	0.068	0.832	0.431	0.558	0.270	0.199	0.394	1.476	0.606	0.220
13	0.113	0.078	0.068	0.606	0.431	0.431	0.270	0.178	0.359	1.798	0.558	***
14	0.113	0.078	0.068	0.512	0.470	0.394	0.244	0.178	0.327	1.380	0.558	***
15	0.113	0.078	0.068	0.431	0.770	0.359	0.244	0.160	0.297	1.041	0.558	***
16	0.100	0.078	0.068	0.359	0.770	0.327	0.220	0.160	0.270	0.832	0.558	***
17	0.100	0.068	0.068	0.327	0.606	0.297	0.244	0.143	0.297	0.712	0.558	***
18	0.100	0.068	0.068	0.297	0.512	0.270	0.297	0.143	0.470	0.712	0.606	***
19	0.100	0.068	0.078	0.270	0.394	0.270	0.359	0.143	0.558	1.201	0.657	***
20	0.100	0.068	0.078	0.244	0.359	0.244	0.359	0.143	0.512	1.686	0.832	***
21	0.100	0.068	0.078	0.220	0.327	0.220	0.327	0.127	0.431	1.686	1.380	***
22	0.100	0.068	0.078	0.220	0.297	0.220	0.297	0.127	0.470	1.578	1.380	***
23	0.088	0.068	0.078	0.220	0.297	0.220	0.270	0.127	1.288	1.686	1.119	***
24	0.088	0.068	0.078	0.199	0.297	0.199	0.244	0.127	2.042	1.798	0.898	***
25	0.088	0.068	0.068	0.199	0.394	0.199	0.220	0.127	1.201	1.380	0.770	***
26	0.088	0.068	0.078	0.199	3.468	0.199	0.220	0.127	0.770	1.119	0.657	***
27	0.088	0.068	0.127	0.220	3.279	0.178	0.199	0.127	0.558	0.898	0.606	***
28	0.088	0.068	1.917	0.470	1.798	0.178	0.199	0.127	0.470	0.770	0.558	***
29	0.088	0.068	3.869	1.119	1.288	0.160	0.178	0.127	0.431	0.712	0.512	***
30	0.088	0.068	1.476	0.967	0.967	0.160	0.178	0.178	0.394	0.712	0.470	***
31	0.088	0.068		0.832		0.160	0.178		0.394		0.431	
DEC1	0.132	0.080	0.068	0.384	0.917	0.790	0.332	0.243	0.275	0.411	0.710	0.301
DEC2	0.108	0.074	0.070	0.448	0.521	0.376	0.281	0.165	0.384	1.174	0.610	0.044
DEC3	0.091	0.068	0.785	0.442	1.241	0.190	0.228	0.127	0.768	1.234	0.798	0
MIN	0.088	0.059	0.059	0.178	0.27	0.16	0.127	0.127	0.127	0.327	0.394	0.220
DAT	22	30	3	26	24	28	4	21	1	6	31	10
AVR	0.110	0.074	0.308	0.425	0.893	0.443	0.279	0.180	0.485	0.939	0.709	0.115
MAX	0.160	0.088	7.100	1.288	5.849	0.088	0.898	0.470	2.310	2.042	1.578	0.431
DAT	1	1	28	29	26	4	7	6	24	24	21	1
MIN = 0.059	AVR = 0.376			MAX = 7.1			MIN = 0.127	AVR = 0.503			MAX = 2.31	
DAT: 30.08				DAT: 28.09			DAT: 4.01				DAT: 24.03	

AVERAGE VALUE FOR 350 DAYS IS Q = 0.433 m³/s

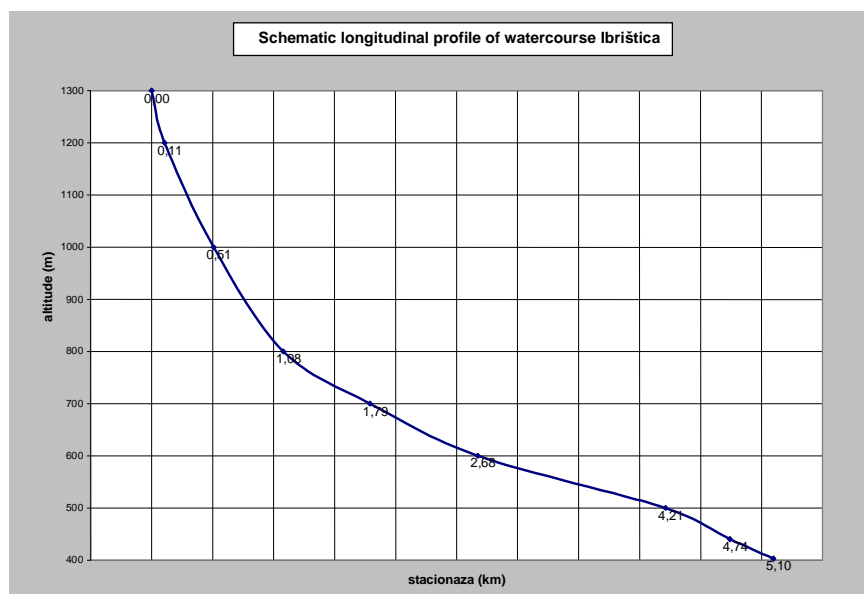
C2. WATERCOURSE: IBRIŠTICA HS: RIJEKA

Physical-geographic characteristics
of the catchment area



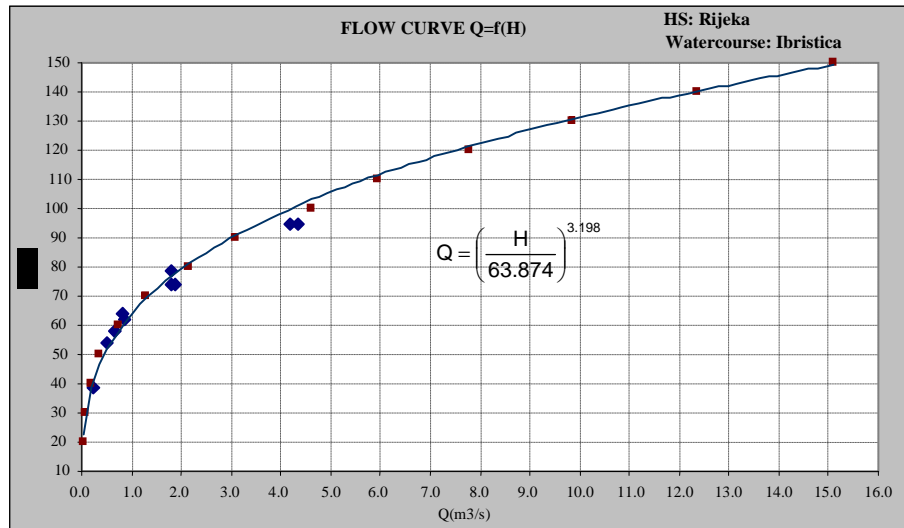
1	Catchment area F	13,6	[km ²]
2	Length of watercourse L_t	5,1	[km]
3	Perimeter of catchment area S	15,4	[km]
4	Maximum elevation of catchment area H_{max}	2030	[m.a.s.l.]
5	Minimum elevation of catchment area H_{min}	403	[m.a.s.l.]

The above table shows main parameters belonging to the watercourse and the Figure 6 below gives schematic longitudinal profile of watercourse.



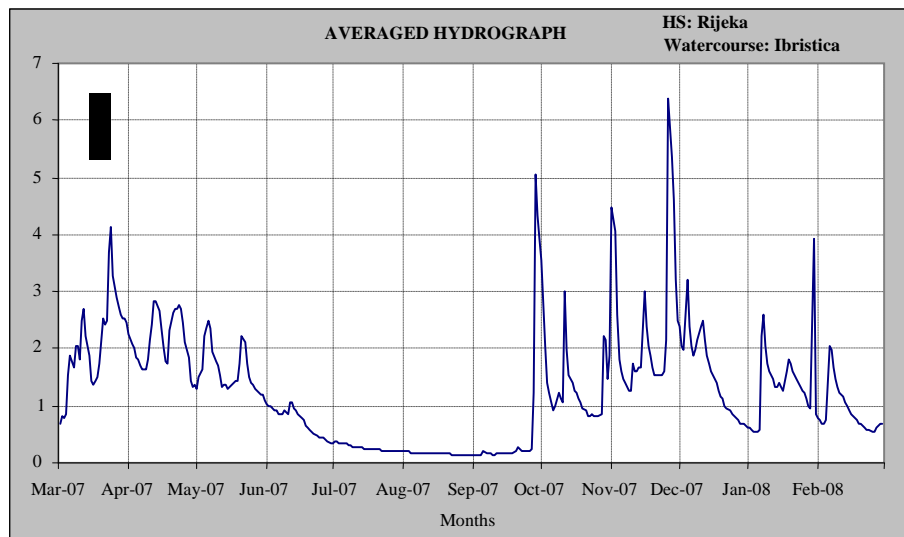
(Figure 4)

Ibrištica is right tributary of the river Gornja Morača. Preliminary analysis was performed for this watercourse long before measurements were finalised and balance is estimated at 1.0 m³/s for average waters. At the time of analysis we had 12 hypsometric measurements based on which a flow curve was designed with its extrapolation being primarily performed. Coverage of curve by water level amplitude is 63% which is on the edge of being acceptable. For extrapolated part of flow curve we have used fictive flow data corresponding to adequate water levels, in accordance with amplitude of occurrence, with 15 cm as a maximum. Maximum fictive flow is determined based on characteristics of the catchment area. Flow curve function is $Q = \left(\frac{H}{63.874}\right)^{3.198}$ based on which balance is drawn for available period of 453 days as well as a balance reduced to a period of one year. Flow curve is given on the Figure 5.



(Figure 5)

Balances made based on this curve for the whole period as well as those reduced to a period of one year may be found on the next page. Maximum recorded flow was 7.53m³/s and it was higher than average daily flow for that day by 45%. Minimum flow was 133 lit/sec as recorded in August 2007. Averaged hydrograph is given on the Figure 6. **It was estimated for this watercourse that average annual flow lasted about 49% , i.e. 188 days.**



(Figure 6)

**WATERCOURSE: IBRIŠTICA
HS: RIJEKA**

REVIEW OF FLOWS - 2007

	MART	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	***	2.4011	1.057	0.957	0.375	0.190	0.146	3.559	4.468	2.401
2	***	2.2231	1.006	0.909	0.375	0.190	0.146	2.054	4.061	2.054
3	***	2.1375	1.110	0.863	0.326	0.190	0.133	1.402	2.589	1.973
4	***	1.9733	2.223	0.819	0.326	0.174	0.133	1.222	1.818	3.212
5	***	1.9733	2.686	0.776	0.350	0.174	0.190	1.057	1.601	2.401
6	***	1.8179	3.102	0.735	0.326	0.174	0.160	0.909	1.467	2.054
7	***	1.7435	2.889	0.735	0.304	0.174	0.160	1.006	1.402	1.894
8	***	1.8179	2.138	0.776	0.304	0.174	0.160	1.222	1.280	1.973
9	***	1.8945	1.818	0.819	0.282	0.174	0.146	1.110	1.280	2.138
10	***	1.9733	1.601	0.863	0.262	0.174	0.146	1.057	1.743	2.401
11	***	2.0543	1.280	1.057	0.282	0.174	0.160	2.994	1.601	2.494
12	***	2.1375	1.110	1.057	0.282	0.174	0.174	1.973	1.601	2.138
13	***	2.1375	1.057	0.957	0.262	0.174	0.160	1.533	1.671	1.894
14	***	2.2231	1.006	0.909	0.242	0.174	0.160	1.402	1.671	1.743
15	1.110	2.3109	0.957	0.863	0.242	0.174	0.160	1.280	2.994	1.601
16	1.110	2.2231	0.957	0.776	0.242	0.160	0.160	1.222	2.401	1.467
17	1.057	1.9733	0.909	0.735	0.224	0.160	0.160	1.110	2.054	1.402
18	1.057	1.6712	0.909	0.657	0.224	0.160	0.160	1.057	1.894	1.280
19	1.110	1.7435	0.863	0.620	0.224	0.160	0.190	0.957	1.671	1.165
20	2.889	1.6009	0.819	0.584	0.224	0.160	0.282	0.909	1.533	1.110
21	2.786	1.7435	0.776	0.551	0.224	0.160	0.242	0.819	1.533	1.006
22	2.401	1.8179	0.776	0.518	0.206	0.146	0.206	0.819	1.533	0.957
23	2.138	1.8179	0.776	0.487	0.206	0.146	0.190	0.863	1.533	0.909
24	2.054	1.7435	0.776	0.457	0.206	0.146	0.190	0.819	1.601	0.863
25	2.494	1.894	0.776	0.428	0.206	0.146	0.190	0.819	2.138	0.819
26	2.686	1.743	0.735	0.428	0.206	0.146	0.224	0.819	6.376	0.776
27	2.786	1.533	0.695	0.401	0.190	0.146	1.222	0.863	5.364	0.735
28	2.686	1.222	0.735	0.375	0.190	0.146	5.052	2.223	4.609	0.695
29	2.686	1.057	0.957	0.350	0.190	0.146	4.329	2.138	3.212	0.695
30	2.686	1.057	1.165	0.350	0.190	0.133	3.931	1.467	2.494	0.657
31	2.589		1.006		0.190	0.133		1.894		0.620
DEC1	0	1.996	1.963	0.825	0.323	0.179	0.152	1.460	2.171	2.250
DEC2	0.8335	2.008	0.987	0.822	0.245	0.167	0.177	1.444	1.909	1.629
DEC3	2.545	1.563	0.834	0.435	0.201	0.145	1.578	1.231	3.039	0.794
MIN	1.0575	1.0063	0.6948	0.35	0.19	0.1331	0.7758	1.2216	0.6198	0.5506
DAT	16	30	26	28	27	29	1	21	9	31
AVR	1.17	1.855	1.247	0.694	0.254	0.163	0.635	1.374	2.373	1.533
MAX	5.052	2.494	3.212	1.165	0.401	0.190	13.459	3.931	7.715	3.559
DAT	20	1	6	10	1	1	28	1	26	4
MIN = 0.133										
DAT: 29.08										
AVR = 1.18										
MAX = 7.715										
DAT: 26.11										

**WATERCOURSE: IBRIŠTICA
HS: RIJEKA**

REVIEW OF FLOWS - 2008

	JAN	FEB	MAR	APR	MAY	JUN
1	0.620	0.735	0.695	2.138	1.533	1.110
2	0.584	0.695	0.819	1.973	1.973	1.057
3	0.551	0.695	0.776	1.894	2.138	1.110
4	0.551	0.735	0.863	1.743	2.223	1.057
5	0.584	2.054	1.533	1.671	2.054	1.057
6	2.223	1.973	1.894	1.601	1.894	1.006
7	2.589	1.671	1.671	1.533	1.818	1.006
8	2.054	1.467	2.054	1.467	1.743	0.957
9	1.743	1.340	2.054	1.743	1.743	1.006
10	1.601	1.222	1.818	2.311	1.818	***
11	1.467	1.165	2.494	2.786	1.818	***
12	1.340	1.057	2.686	3.559	1.533	***
13	1.340	1.006	2.223	3.559	1.671	***
14	1.402	0.909	1.894	3.102	1.743	***
15	1.340	0.863	1.743	2.401	1.671	***
16	1.280	0.819	1.601	1.818	1.743	***
17	1.601	0.735	1.818	1.601	1.894	***
18	1.818	0.695	1.973	1.818	1.973	***
19	1.743	0.695	2.401	2.889	1.973	***
20	1.601	0.657	2.138	3.680	2.686	***
21	1.533	0.620	2.054	3.680	3.680	***
22	1.467	0.584	2.589	3.559	3.441	***
23	1.340	0.584	5.206	3.680	2.686	***
24	1.280	0.551	6.199	3.680	2.223	***
25	1.222	0.551	4.061	2.994	2.054	***
26	1.110	0.620	3.102	2.494	1.973	***
27	1.006	0.657	2.686	2.138	1.894	***
28	0.957	0.695	2.494	1.671	1.743	***
29	3.931	0.695	2.401	1.601	1.467	***
30	0.863		2.401	1.671	1.222	***
31	0.776		2.311		1.165	***
DEC1	1.310	1.259	1.418	1.807	1.894	1.041
DEC2	1.493	0.860	2.097	2.721	1.871	0
DEC3	1.408	0.617	3.228	2.717	2.141	0
MIN	0.5506	0.5506	0.6948	1.4666	1.1104	0.9092
DAT	2	23	1	8	31	8
AVR	1.404	0.922	2.279	2.415	1.974	0.312
MAX	2.9939	2.6863	7.5127	3.9311	3.8043	1.28
DAT	6	5	24	23	20	3
MIN = 0.551						MAX=7.513
DAT: 23.02						DAT:24.03

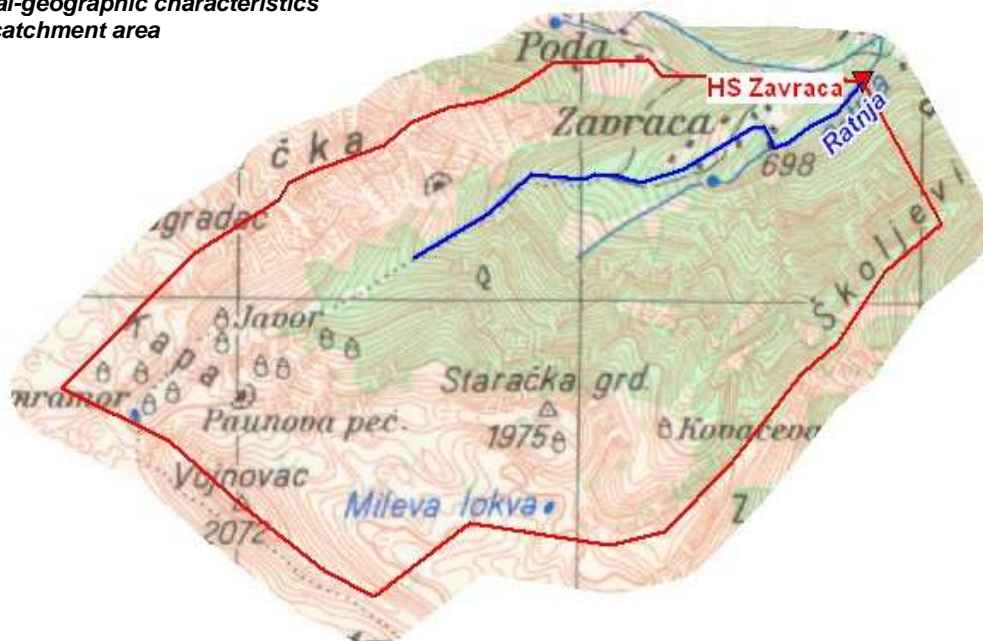
**WATERCOURSE: IBRIŠTICA
HS: RIJEKA**

REVIEW OF FLOWS

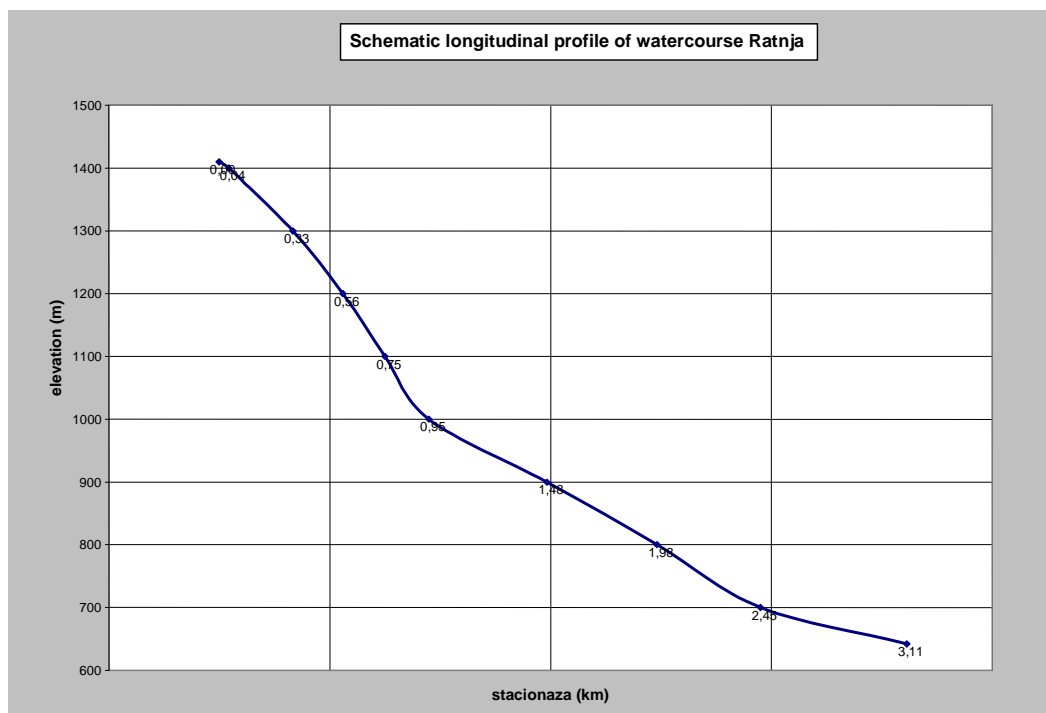
	MART	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
1	0.695	2.269	1.295	1.034	0.375	0.190	0.146	3.559	4.468	2.401	0.620	0.735
2	0.819	2.098	1.490	0.983	0.375	0.190	0.146	2.054	4.061	2.054	0.584	0.695
3	0.776	2.016	1.624	0.987	0.326	0.190	0.133	1.402	2.589	1.973	0.551	0.695
4	0.863	1.858	2.223	0.938	0.326	0.174	0.133	1.222	1.818	3.212	0.551	0.735
5	1.533	1.822	2.370	0.917	0.350	0.174	0.190	1.057	1.601	2.401	0.584	2.054
6	1.894	1.709	2.498	0.870	0.326	0.174	0.160	0.909	1.467	2.054	2.223	1.973
7	1.671	1.638	2.353	0.870	0.304	0.174	0.160	1.006	1.402	1.894	2.589	1.671
8	2.054	1.642	1.940	0.866	0.304	0.174	0.160	1.222	1.280	1.973	2.054	1.467
9	2.054	1.819	1.781	0.912	0.282	0.174	0.146	1.110	1.280	2.138	1.743	1.340
10	1.818	2.142	1.709	0.863	0.262	0.174	0.146	1.057	1.743	2.401	1.601	1.222
11	2.494	2.420	1.549	1.057	0.282	0.174	0.160	2.994	1.601	2.494	1.467	1.165
12	2.686	2.848	1.322	1.057	0.282	0.174	0.174	1.973	1.601	2.138	1.340	1.057
13	2.223	2.848	1.364	0.957	0.262	0.174	0.160	1.533	1.671	1.894	1.340	1.006
14	1.894	2.662	1.375	0.909	0.242	0.174	0.160	1.402	1.671	1.743	1.402	0.909
15	1.427	2.356	1.314	0.863	0.242	0.174	0.160	1.280	2.994	1.601	1.340	0.863
16	1.356	2.020	1.350	0.776	0.242	0.160	0.160	1.222	2.401	1.467	1.280	0.819
17	1.438	1.787	1.402	0.735	0.224	0.160	0.160	1.110	2.054	1.402	1.601	0.735
18	1.515	1.745	1.441	0.657	0.224	0.160	0.160	1.057	1.894	1.280	1.818	0.695
19	1.756	2.316	1.418	0.620	0.224	0.160	0.190	0.957	1.671	1.165	1.743	0.695
20	2.513	2.641	1.752	0.584	0.224	0.160	0.282	0.909	1.533	1.110	1.601	0.657
21	2.420	2.712	2.228	0.551	0.224	0.160	0.242	0.819	1.533	1.006	1.533	0.620
22	2.495	2.688	2.108	0.518	0.206	0.146	0.206	0.819	1.533	0.957	1.467	0.584
23	3.672	2.749	1.731	0.487	0.206	0.146	0.190	0.863	1.533	0.909	1.340	0.584
24	4.127	2.712	1.499	0.457	0.206	0.146	0.190	0.819	1.601	0.863	1.280	0.551
25	3.277	2.444	1.415	0.428	0.206	0.146	0.190	0.819	2.138	0.819	1.222	0.551
26	2.894	2.119	1.354	0.428	0.206	0.146	0.224	0.819	6.376	0.776	1.110	0.620
27	2.736	1.835	1.295	0.401	0.190	0.146	1.222	0.863	5.364	0.735	1.006	0.657
28	2.590	1.446	1.239	0.375	0.190	0.146	5.052	2.223	4.609	0.695	0.957	0.695
29	2.544	1.329	1.212	0.350	0.190	0.146	4.329	2.138	3.212	0.695	3.931	0.695
30	2.544	1.364	1.193	0.350	0.190	0.133	3.931	1.467	2.494	0.657	0.863	0.695
31	2.450		1.086		0.190	0.133		1.894		0.620	0.776	
DEC1	1.418	1.901	1.928	0.924	0.323	0.179	0.152	1.460	2.171	2.250	1.310	1.259
DEC2	1.930	2.364	1.429	0.822	0.245	0.167	0.177	1.444	1.909	1.629	1.493	0.860
DEC3	2.886	2.140	1.487	0.435	0.201	0.145	1.578	1.231	3.039	0.794	1.408	0.617
MIN	0.6948	1.0063	0.6948	0.35	0.19	0.1331	0.1331	0.7758	1.2216	0.6198	0.5506	0.5505

C3. WATERCOURSE: RATNJA RIJEKA HS: ZAVRACA

Physical-geographic characteristics of the catchment area



1	Catchment area F	9,75	[km ²]
2	Length of watercourse L _t	3,11	[km]
3	Perimeter of catchment area S	12,9	[km]
4	Maximum elevation of catchment area H _{max}	2072	[m.a.s.l.]
5	Minimum elevation of catchment area H _{min}	642	[m.a.s.l.]



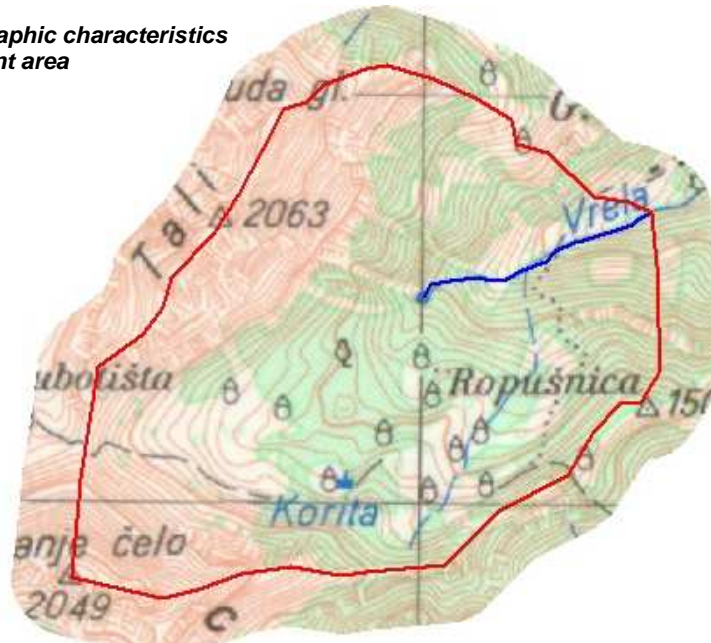
(Figure 7)

This watercourse is right tributary of the river Morača. It has a catchment area of 9.75 km² and length of watercourse is 3.11 km. Minimum altitude in the catchment area is 642 m.a.s.l. and maximum altitude is 2072 m.a.s.l. Schematic longitudinal profile of the watercourse is given on the previous page, Figure 7.

On this hydrology stations there were 12 measurements of velocity of flow, however coverage by water level amplitude is low and it is about 40% due to which it was decided not to prepare a balance for this report. In order to have a good report additional measurements would need to be performed at the time of high waters so that the whole water level amplitude would be covered and a good balance could be prepared.

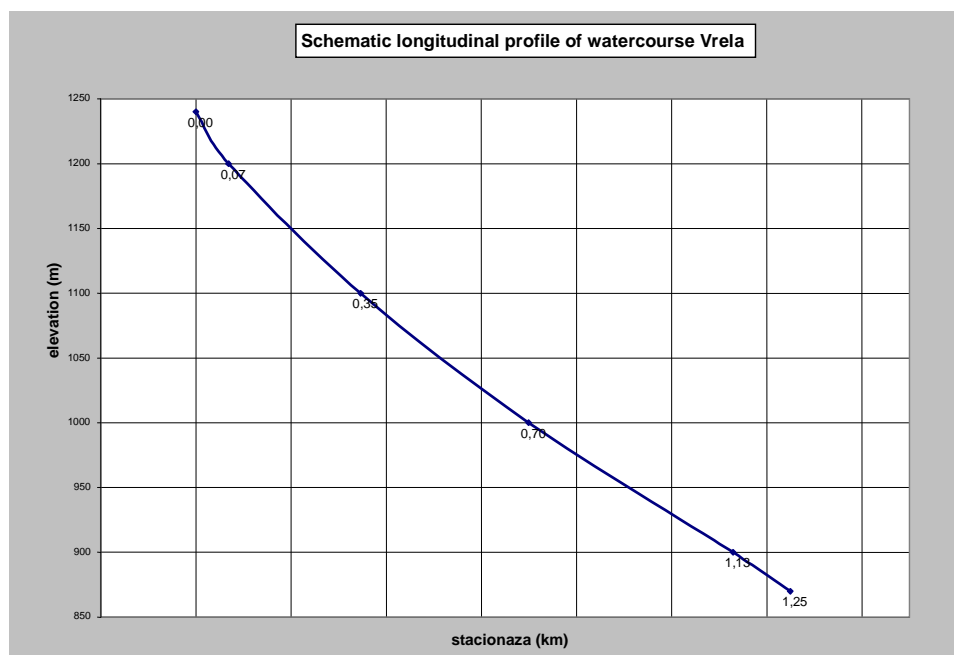
C4. WATERCOURSE: GORNJA LJUTA HS: VRELO

Physical-geographic characteristics of the catchment area



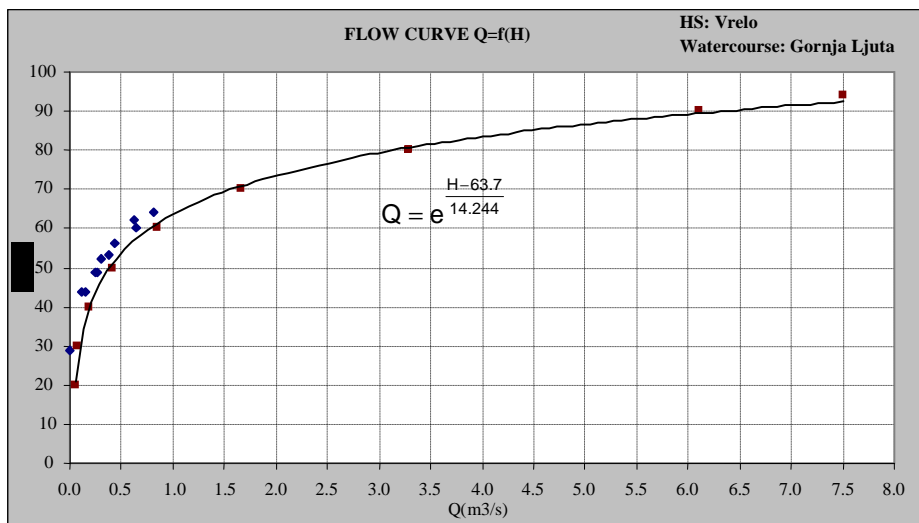
1	Catchment area F	5,08	[km ²]
2	Length of watercourse L _t	1,25	[km]
3	Perimeter of catchment area S	8,88	[km]
4	Maximum elevation of catchment area H _{max}	2063	[m.a.s.l.]
5	Minimum elevation of catchment area H _{min}	870	[m.a.s.l.]

Gornja Ljuta is right tributary of the river Morača, of the first level. It has a catchment area of 5.08 km² and length of watercourse is 1.25 km. Minimum elevation in the catchment area is 870 m.a.s.l. and maximum elevation is 2063 m.a.s.l. Longitudinal profile of watercourse is given on the Figure 8 on the next page.



(Figure 8)

There were 11 hydrometric measurements which were finalised on this watercourse. Water level amplitude is 70% covered. By applying a procedure as described in the beginning of this report a flow curve was designed, and for this watercourse it is an exponential function, $Q = e^{\frac{H-63.7}{14.244}}$, Figure 9.



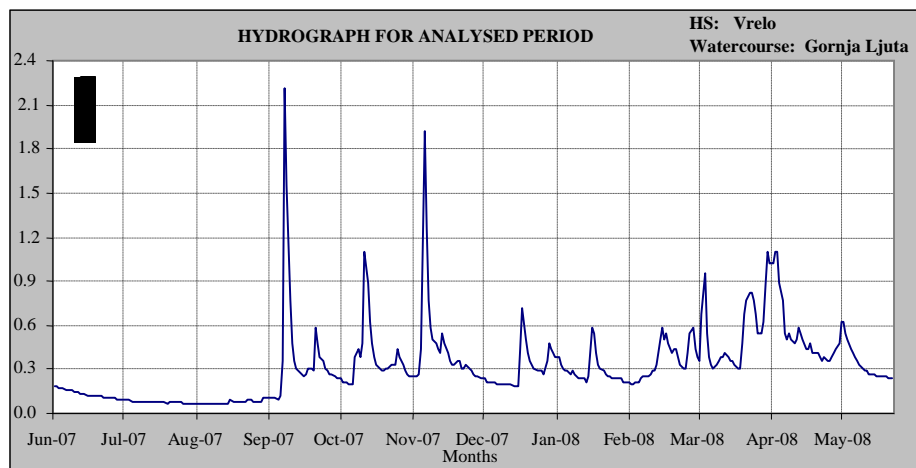
(Figure 9)

Analysed period available for this watercourse was 357 days. Balance prepared for that period, in accordance with the given flow curve is 0.324 m³/s, for average waters. Daily flows were calculated for the analysed period, as well as decade, average monthly as well as minimum and maximum monthly flows. They are given on the following page.

Maximum flow is registered in February 2008 and it amounted 1.175 m³/s and it was 50% higher than the average daily flow. Minimum flow was registered in August 2007 and it was 66 lit/sec.

Flow hydrograph for the analysed period is given on the Figure 10.

Estimated duration of average flow for the analysed period is about 24%.



(Figure 10)

WATERCOURSE: LJUTA
HS: VRELO

REVIEW OF FLOWS - 2007

	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1		0.143	0.076	0.071	0.472	1.096	0.472
2		0.143	0.076	0.071	0.356	0.887	0.440
3		0.133	0.076	0.071	0.310	0.625	0.410
4		0.133	0.076	0.071	0.289	0.472	0.543
5		0.133	0.076	0.088	0.269	0.382	0.472
6		0.124	0.076	0.082	0.251	0.332	0.410
7		0.124	0.076	0.076	0.269	0.310	0.356
8		0.116	0.076	0.076	0.310	0.289	0.332
9		0.116	0.071	0.076	0.310	0.289	0.332
10		0.116	0.082	0.076	0.289	0.310	0.356
11		0.116	0.076	0.082	0.582	0.310	0.356
12		0.116	0.076	0.094	0.472	0.332	0.310
13		0.108	0.076	0.088	0.382	0.332	0.310
14		0.108	0.076	0.088	0.356	0.332	0.332
15		0.101	0.076	0.082	0.310	0.440	0.310
16		0.101	0.071	0.082	0.289	0.382	0.289
17		0.101	0.071	0.082	0.269	0.332	0.269
18		0.101	0.071	0.082	0.269	0.289	0.251
19		0.094	0.071	0.101	0.251	0.269	0.251
20		0.094	0.071	0.108	0.234	0.251	0.234
21		0.094	0.071	0.108	0.234	0.251	0.234
22	0.189	0.088	0.066	0.101	0.234	0.251	0.234
23	0.189	0.088	0.066	0.101	0.218	0.251	0.218
24	0.177	0.088	0.066	0.101	0.218	0.269	0.218
25	0.177	0.082	0.066	0.094	0.203	0.440	0.218
26	0.177	0.082	0.066	0.116	0.203	1.921	0.218
27	0.165	0.082	0.066	0.356	0.203	1.261	0.203
28	0.165	0.076	0.066	2.211	0.382	0.771	0.203
29	0.153	0.076	0.066	1.556	0.440	0.582	0.203
30	0.153	0.076	0.066	0.771	0.382	0.506	0.203
31		0.076	0.066		0.472		0.203
DEC1	0	0.128	0.076	0.076	0.312	0.499	0.412
DEC2	0.00	0.104	0.073	0.089	0.341	0.327	0.291
DEC3	0.155	0.082	0.067	0.551	0.290	0.650	0.214
MIN	0.1534357	0.0760379	0.0660771	0.0708827	0.2031819	0.2508153	0.2031819
DAT	29	27	21	1	24	19	27
AVR	0.172	0.104	0.072	0.239	0.314	0.492	0.303
MAX	0.1894067	0.1534357	0.1006905	1.0212849	0.8273285	2.9274639	0.5824112
DAT	23	1	10	28	31	26	4
MIN = 0.066							
DAT: 21.08							
AVR = 0.249							
MAX = 1.021							
DAT: 10.08							

WATERCOURSE: LJUTA
HS: VRELO

REVIEW OF FLOWS - 2008

	JAN	FEB	MAR	APR	MAY	JUN
1	0.203	0.234	0.269	0.382	0.472	0.289
2	0.203	0.234	0.289	0.410	0.506	0.269
3	0.189	0.218	0.289	0.382	0.582	0.269
4	0.189	0.251	0.332	0.356	0.543	0.269
5	0.189	0.582	0.506	0.356	0.506	0.251
6	0.440	0.543	0.582	0.332	0.440	0.251
7	0.719	0.410	0.506	0.310	0.440	0.251
8	0.506	0.332	0.543	0.310	0.472	0.251
9	0.410	0.310	0.472	0.472	0.410	0.251
10	0.356	0.289	0.410	0.670	0.410	0.234
11	0.332	0.269	0.440	0.771	0.410	0.234
12	0.310	0.251	0.440	0.827	0.382	0.234
13	0.289	0.251	0.382	0.827	0.356	
14	0.289	0.234	0.332	0.771	0.382	
15	0.289	0.234	0.310	0.670	0.356	
16	0.269	0.234	0.310	0.543	0.356	
17	0.356	0.234	0.410	0.543	0.382	
18	0.472	0.234	0.543	0.625	0.410	
19	0.440	0.218	0.582	0.887	0.440	
20	0.410	0.218	0.440	1.096	0.472	
21	0.382	0.218	0.382	1.021	0.625	
22	0.382	0.203	0.356	1.021	0.625	
23	0.332	0.203	0.670	1.096	0.543	
24	0.310	0.218	0.952	1.096	0.506	
25	0.289	0.218	0.543	0.887	0.440	
26	0.289	0.234	0.382	0.771	0.410	
27	0.269	0.251	0.332	0.543	0.382	
28	0.289	0.251	0.310	0.506	0.356	
29	0.269	0.251	0.332	0.543	0.332	
30	0.251		0.356	0.506	0.310	
31	0.234		0.382		0.289	
DEC1	0.341	0.340	0.420	0.398	0.478	0.258
DEC2	0.345	0.238	0.419	0.756	0.395	0.047
DEC3	0.300	0.227	0.454	0.799	0.438	0
MIN	0.1894067	0.2031819	0.2690566	0.3096157	0.2886246	0.217959
DAT	2	22	1	7	31	12
AVR	0.328	0.270	0.432	0.651	0.437	0.254
MAX	0.7712378	0.7712378	1.175239	1.2607118	0.6702071	0.3321334
DAT	7	5	24	19	21	3
MIN = 0.189						
DAT: 2.01						
AVR = 0.412						
MAX = 1.175						
DAT: 5.02						

AVERAGE VALUE FOR 357 DAYS IS Q = 0.324 m³/s