ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ
СОФИЯ

Том Volume 53 2020 Брой Issue 1

ANNUAL OF THE UNIVERSITY OF ARCHITECTURE, CIVIL ENGINEERING AND GEODESY
SOFIA

Получена: 20.12.2019 г.
Приета: 22.01.2020 г.

PROTECTION OF THE BRIDGE AND RIVER BED TRAINING ON THE RIVER TRIPUŠNICA IN BOSILEGRAD MUNICIPALITY IN SERBIA

D. Radivojević[1], A. Ilić[2]

Keywords: *hydraulic modelling, river bed training, stabilizing structure, erosion control*

ABSTRACT

Bridges and their piers in the river bed change the streamflow and cause local erosion. Therefore, it is necessary to design the downstream stabilizing structure that will enable bridge protection, establishing a balance between water and sediment regime.

In this paper an example of the bridge on the mountain river Tripušnica stability in Radovnica, Southeastern Serbia is shown. The bridge is endangered due to inappropriate river bed training. Downstream of the bridge cascade system was constructed but later ruined by the strong stream forces due to the lack of structures for energy dissipation. The design for reconstruction of minor and major river beds and cascade systems is adopted in order to provide the bridge and the river bed stability. By hydraulic modelling, the streamflow and river depths are optimized. Downstream of the bridge a new cascade system is designed with soothing pool for energy dissipation and putting the river stream back in the natural conditions.

1. Introduction

The Tripušnica River passes through the suburb Radovnica, Trgovište municipality in the Southeast of Serbia. From the Dukat Mountain below the summit of "Bela Water", the

---

[1] Dragan Radivojević, Assist. Prof. Dr. Eng., Dept. "Water Engineering", Faculty of Civil Engineering & Architecture, 14 A. Medvedeva St., Niš, Serbia, e-mail: dragan.radivojevic@gaf.ni.ac.rs

[2] Aleksandra Ilić, Dept. "Water Engineering", Faculty of Civil Engineering & Architecture, 14 A. Medvedeva St., Niš, Serbia, e-mail: dragan.radivojevic@gaf.ni.ac.rs

largest stream springs, which with other streams near the village of Radovnica forms the Crna River. Streaming toward the West with several of its small tributaries, just downstream of the bridge, with the tributary of the Prolesac River it forms the Tripušnica River. At the Trgovište town center the watercourse changes its name to the Pčinja River.

The main stream of the river is 10,15 km long, with the average bottom slope of 8,7%. Discharge variation during the year is significant, like on other mountain rivers.

During flood water the river bed is often damaged due to the erosion, and the main streamline varies its direction. There are some erosion dams constructed on some parts of the river to reduce stream speed, sediment transport and rived bed damage.

There is a bridge in the Radovnica suburb on the Tripušnica River, 40 m long and 10 m wide. The bridge is endangered due to inappropriate river bed training. The erosion around the pillars is observed (Fig. 1 and 2).

Figure 1. The bridge on the Tripušnica River in the village of Radovnica during summer

Figure 2. The bridge on the Tripušnica river in the village of Radovnica during winter

There is a derogated erosion control barrier downstream of the bridge pillars. The cascade structure was constructed of gabions with the concrete top layer. The barrier was constructed in three levels, but the height of the lowest level was about two meters above the river bottom, and the impact of the spilled water jet was very strong. There was no stilling pond constructed downstream of the cascade structure. During the flood waters, the river was spilling over the barrier and making the hole in the river bottom (Fig. 3).

Figure 3. Derogated spillway on the downstream side of the Radovnica Bridge

Due to the river bed erosion, the cavities were formed behind the structure. Gabions on the downstream part got destroyed, one by one. Parts of the concrete layer are still hanging. The river has itself formed some kind of unstable stilling pond.

Due the damaged barrier and potential for its further erosion stability of the bridge pillars is endangered. The river bed is also damaged on the upstream side of the bridge.

The river bed training and erosion prevention are some of the most important activities to keep the bridge stability, in the process of its rehabilitation.

2. Concept of the Design for the Tripušnica River Bed Stabilization

2.1. General Tripušnica River Data

For the design of the Tripušnica river bed training the following hydrographic data have been used:

- Water course Tripušnica, the Pčinja River right tributary, Aegean Sea catchment
- Total catchment area $F = 457$ km^2;
- The highest catchment altitude $H_{\mathrm{max}} = 1828$ mnm;
- The lowest catchment altitude $H_{\mathrm{min}} = 1828$ mnm;
- Average catchment altitude $H_{sr} = 940$ mnm;
- The center of gravity of the basin $L_c = 4{,}03$ km;
- Average stream slope $I_{sr} = 8{,}7\%$;
- Average balance stream slope $I_{ur} = 6{,}8\%$;
- Average catchment slope $I_{sl} = 43{,}07\%$.

The following hydrological data have been used:

- Flood water $Q_{0,1\%}$ = 149,87 m^3/s;
- Flood water $Q_{1\%}$ = 81,49 m^3/s;
- Flood water $Q_{2\%}$ = 67,48 m^3/s;
- Flood water $Q_{5\%}$ = 53,13 m^3/s;
- Medium water Q_{sr} = 0,35 m^3/s;
- Low water $Q_{\min}$ = 0,035 m^3/s.

The Republic Hydrometeorological Service of Serbia has issued as a design precondition flood water $Q_{2\%}$ = 67,48 m^3/s as merit, and flood water $Q_{1\%}$ = 81,49 m^3/s as control criteria for the bridge hydraulic conductivity test.

The following geodetic data have been used:

- A natural river bed of length L = 110 m in the vicinity of the bridge has been recognized on the longitudinal river bed profile;
- The river bed has been recognized on 15 transverse profiles; the relative stationary starts about 60 m on the downstream side of the bridge;
- The site plan of the respective section has been figured in the scale R = 1: 500.

2.2. The Tripušnica River Bed Training Objectives

The Tripušnica River has naturally formed its bed for low waters upstream of the Radovnica Bridge. In the bridge area the stream makes pressure to the high right bank.

A low embankment, about 70 cm high, on the left bank cannot protect uninhabited areas from fifty or a hundred years flood waters, but can make protection against smaller flood waters, of the order of 20 years and smaller. These areas do not have high value and do not deserve expensive flood protection measures and higher embankment.

The most important measure to ensure the bridge stability is proper reconstruction of the vertical stabilization barrier on the downstream side in order to prevent local erosion in the vicinity of the bridge pillars.

The objectives of the river bed training design are as follows:

- Forming the minor river bed upstream of the bridge with optimal hydraulic shape and slope, protecting the bridge pillars of the stream dynamic forces and erosion;
- Forming major river bed upstream of the bridge for flood waters;
- Design with the appropriate material to prevent erosion in the river bed resistance;
- Reshape of the damaged erosion control barrier downstream of the bridge;
- River specific energy dissipation;
- Energy stilling structure design.

2.3. The Tripušnica River Bed Training Concept

The following actions are designed to achieve the river bed stability:

a) Earthworks on shaping the natural river bed, downstream and upstream of the bridge, forming minor bed with the designed route; designed minor bed should be at a distance of at least 1 m away of the middle pillar raw (in order pillars to keep maximal stability and be exposed to minimal hydrodynamic forces).
b) Cascade system should be reconstructed on the downstream side of the bridge; gabions filled with the large stone should be used, while the cascade surface should be paved with the 20 cm thick reinforced concrete layer.
c) Stilling pond 4 – 5 m long should be constructed with the large crushed stone pieces 40 – 50 cm.

d) River bed paving in the bridge area with crushed stone 25 – 30 cm in mortar, forming minor bed with trapezoidal cross section, 2,5 m wide in bottom, 0,5 m high, with the sides slope 1:1,5.

e) Forming consolidation thresholds on the upstream and downstream sides.

f) Grass planting on the high part of the slope on the right bank, above the river bed stone lining.

2.4. Water Surface Profile Calculation – Hydraulic Analysis

Regarding the adopted river bed training concept, water surface profiles are computed for the merit flood waters. Computation process is conducted using HEC RAS („HEC-RAS" – River Analysis System – Steady Flow Water Profiles, US Army Corps of Engineers – Hydrologic Engineering Center).

Water surface profiles from one cross section to the next by solving the energy equation with a "standard step method" iterative procedure. The Energy equation is written as follows [1, 2, 3, 5]:

$$Z_1 + Y_1 + \frac{a_1 v_1^2}{2g} = Z_2 + Y_2 + \frac{a_2 v_2^2}{2g} + h_e , \tag{1}$$

where Z_1, Z_2 are elevation of the main channel inverts;

Y_1, Y_2 – depth of water at cross sections;

a_1, a_2 – velocity weighting coefficients;

g – gravitational acceleration;

h_e – energy head loss.

The energy head loss (he) between two cross sections is comprised of friction losses and contraction or expansion losses. The equation for the energy head loss is as follows [5]:

$$h_e = L\bar{S}_f + C\left|\frac{a_2 v_2^2}{2g} - \frac{a_1 v_1^2}{2g}\right| , \tag{2}$$

where L is discharge weighted reach length;

$\bar{S}_f$ – representative friction slope between two sections;

C – expansion or contraction loss coefficient;

g – gravitational acceleration;

h_e – energy head loss.

The designed river bed area is divided into three sections:

- Upstream section, with the bottom slope 1,76%;
- Cascade spillway and stilling pond section;
- Downstream section, with the bottom slope 1,87%.

Due to the bottom slope, it is obvious that there is supercritical flow regime on the upstream and downstream sections. For all discharge values upstream normal depth on the cross section profile PP15 is used as boundary condition. Water depth on the cross section PP15 with functional relationship with the discharge value is presented on the Fig. 4 [4].

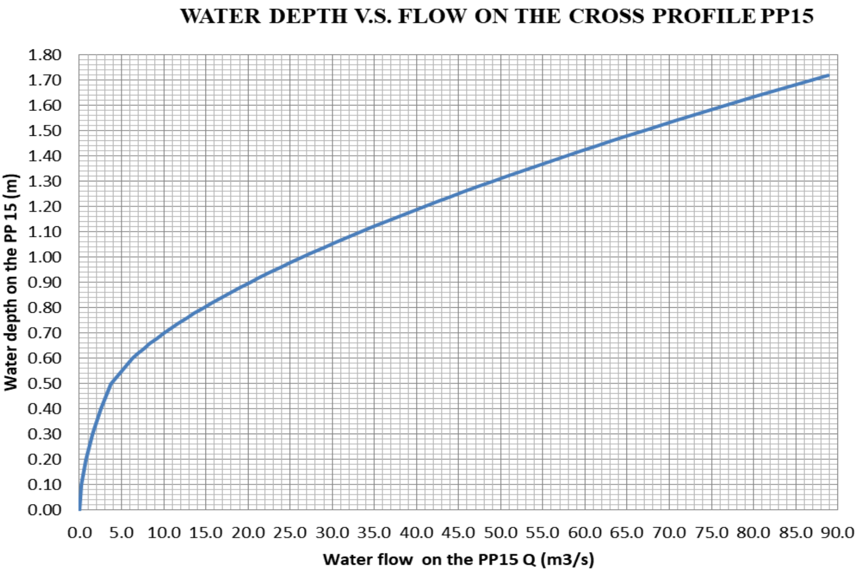

Figure 4. Water depth v.s. discharge value on the section upstream end, profile PP15

Water surface profile is computed from the upstream end of section (transversal cross section PP15) toward downstream section for steady gradually varied flow.

The river bed is divided into the three conveyance areas: *k* = 1 (minor bed), *k* = 2 (left inundation), *k* = 3 (right inundation). Manning's friction coefficients are assumed empirically for the site conditions as follows:

- For the minor river bed ($k = 1$), for unpaved riverbed, redesigned only by earthworks, $n = 0{,}030$, and for inundations ($k = 2$ and $k = 3$) $n = 0{,}060$.
- For the area paved with the crushed stone in mortar $n = 0{,}025$, and for inundations ($k = 2$ and $k = 3$) $n = 0{,}035$.

Maximal hydraulic conductivity on the PP15 is 3,75 m^3/s. For the merit flood waters, water levels on the PP15 are computed as follows:

- $Q_{1\%} = 81{,}49\ m^3/s$, water surface level is $Z = 938{,}37$ m, water depth is 1,62 m in the minor river bed and 1,12 in inundations.
- $Q_{2\%} = 67{,}48\ m^3/s$, water surface level is $Z = 938{,}23$ m, water depth is 1,48 m in the minor river bed and 0,98 m in inundations.
- $Q_{5\%} = 53{,}13\ m^3/s$, water surface level is $Z = 938{,}07$ m, water depth is 1,32 m in the minor river bed and 0,82 m in inundations.

Calculated water surface profile for the merit water flows is shown in the Tab. 1 and the graphical presentation in the area of the bridge is shown in the Fig. 5.

Merit water surface level under the Rastovnica bridge (the lowest level on the bridge structure is 939,00 m) are as follows:

- $Q_{1\%} = 81{,}49\ m^3/s$, water surface level is $Z = 936{,}73$ m, $H = 1{,}27$ m under the bridge.
- $Q_{2\%} = 67{,}48\ m^3/s$, water surface level is $Z = 936{,}73$ m, $H = 1{,}39$ m under the bridge.
- $Q_{5\%} = 53{,}13\ m^3/s$, water surface level is $Z = 936{,}54$ m, $H = 1{,}44$ m under the bridge.

Due to the computed water surface profile, for the designed river bed shape it is proven that the bridge has proper hydraulic conductivity [4].

Table 1. Computed water surface level for the merit flows

Profile	Stacionary		Q total	Qminor	Q(L,I)	Q(R,I)	Bottom	Surface	Depth	Velocity	Area	Width	Fraudd
			(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m)	(m)	(m)	(m/s)	(m^2)	(m)	No
Profile 15	110,44	Q_{sr}	0,35	0,35			936,40	936,46	0,06	2,43	0,14	2,67	3,35
Profile 15	110,44	$Q_{5\%}$	50,5	20,02	16,52	13,97	936,40	937,75	1,35	3,99	25,05	29,33	1,14
Profile 15	110,44	$Q_{2\%}$	64,5	24,27	21,75	18,48	936,40	937,89	1,49	4,34	29,34	29,92	1,17
Profile 15	110,44	$Q_{1\%}$	78,4	28,41	26,97	23,02	936,40	938,02	1,62	4,65	33,22	30,44	1,20
Profile 14	99,98	Q_{sr}	0,35	0,35			936,22	936,34	0,12	1,07	0,33	2,87	1,01
Profile 14	99,98	$Q_{5\%}$	50,5	20,66	14,89	14,95	936,22	937,39	1,17	4,78	21,21	30,01	1,47
Profile 14	99,98	$Q_{2\%}$	64,5	24,86	19,78	19,85	936,22	937,51	1,29	5,18	24,83	30,35	1,51
Profile 14	99,98	$Q_{1\%}$	78,4	28,91	24,71	24,79	936,22	937,63	1,41	5,51	28,21	30,67	1,54
Profile 13	90,70	Q_{sr}	0,35	0,35			936,05	936,17	0,12	1,12	0,31	2,85	1,07
Profile 13	90,70	$Q_{5\%}$	50,5	21,25	18,19	11,06	936,05	937,46	1,41	4,04	23,99	25,97	1,12
Profile 13	90,70	$Q_{2\%}$	64,5	25,95	23,96	14,59	936,05	937,61	1,56	4,44	27,85	26,41	1,17
Profile 13	90,70	$Q_{1\%}$	78,4	30,43	29,79	18,17	936,05	937,75	1,70	4,73	31,73	26,85	1,19
Profile 12	79,27	Q_{sr}	0,35	0,35			935,85	935,97	0,12	1,1	0,32	2,86	1,05
Profile 12	79,27	$Q_{5\%}$	50,5	18,09	21,57	10,84	935,85	936,86	1,01	4,93	13,27	23,54	1,64
Profile 12	79,27	$Q_{2\%}$	64,5	21,25	28,77	14,48	935,85	936,96	1,11	5,22	15,66	23,84	1,65
Profile 12	79,27	$Q_{1\%}$	78,4	24,27	35,99	18,14	935,85	937,06	1,21	5,46	17,90	24,12	1,65
Profile 11	69,27	Q_{sr}	0,35	0,35			935,68	935,79	0,11	1,2	0,29	2,83	1,20
Profile 11	69,27	$Q_{5\%}$	50,5	17,91	21,69	10,90	935,68	936,70	1,02	4,82	13,53	23,57	1,6
Profile 11	69,27	$Q_{2\%}$	64,5	21,15	28,84	14,51	935,68	936,80	1,12	5,16	15,82	23,86	1,63
Profile 11	69,27	$Q_{1\%}$	78,4	24,18	36,05	18,17	935,68	936,89	1,21	5,41	18,05	24,13	1,63
Profile 10	64,27	Q_{sr}	0,35	0,35			935,59	935,71	0,12	1,13	0,31	2,85	1,09
Profile 10	64,27	$Q_{5\%}$	50,5	17,91	21,69	10,90	935,59	936,61	1,02	4,82	13,53	23,57	1,60
Profile 10	64,27	$Q_{2\%}$	64,5	21,15	28,84	14,51	935,59	936,71	1,12	5,16	15,82	23,86	1,63
Profile 10	64,27	$Q_{1\%}$	78,4	24,19	36,04	18,17	935,59	936,80	1,21	5,41	18,03	24,13	1,63

The Radovnica bridge 59,27 PP9

Profile 8	53,25	Q_{sr}	0,35	0,35			935,41	935,52	0,11	1,15	0,3	2,84	1,12
Profile 8	53,25	$Q_{5\%}$	50,5	17,68	21,84	10,98	935,41	936,45	1,04	4,68	13,88	23,61	1,54
Profile 8	53,25	$Q_{2\%}$	64,5	20,84	29,04	14,62	935,41	936,55	1,14	4,98	16,32	23,92	1,55
Profile 8	53,25	$Q_{1\%}$	78,4	23,84	36,27	18,29	935,41	936,65	1,24	5,21	18,64	24,21	1,56
Profile 7-1	52,71	Q_{sr}	0,35	0,35			935,40	935,47	0,07	1,46	0,24	3,65	1,81
Profile 7-1	52,71	$Q_{5\%}$	50,5	17,58	21,16	11,76	935,40	936,44	1,04	4,63	13,84	24,16	1,45
Profile 7-1	52,71	$Q_{2\%}$	64,5	20,53	28,36	15,61	935,40	936,54	1,14	4,95	16,22	24,83	1,48
Profile 7-1	52,71	$Q_{1\%}$	78,4	23,28	35,66	19,46	935,40	936,63	1,23	5,2	18,48	25,45	1,50
Profile 7	52,70	Q_{sr}	0,35	0,35			934,40	934,42	0,02	4,55	0,08	3,65	10,02
Profile 7	52,70	$Q_{5\%}$	50,5	22,69	17,79	10,02	934,40	935,24	0,84	7,38	9,2	22,69	2,57
Profile 7	52,70	$Q_{2\%}$	64,5	25,72	24,89	13,9	934,40	935,32	0,92	7,63	11,07	23,24	2,53
Profile 7	52,70	$Q_{1\%}$	78,4	28,49	32,12	17,79	934,40	935,40	1,00	7,8	12,87	23,75	2,49
Profile 6	49,71	Q_{sr}	0,35	0,35			934,40	934,46	0,06	1,59	0,22	3,65	2,08
Profile 6	49,71	$Q_{5\%}$	50,5	21,95	20	8,55	934,40	935,30	0,90	6,7	9,9	21,69	2,26
Profile 6	49,71	$Q_{2\%}$	64,5	25,08	27,68	11,75	934,40	935,39	0,99	6,95	11,9	22,32	2,23
Profile 6	49,71	$Q_{1\%}$	78,4	27,99	35,47	14,94	934,40	935,47	1,07	7,15	13,81	22,91	2,20
Profile 5c-1	49,27	Q_{sr}	0,35	0,35			933,40	933,42	0,02	4,59	0,08	3,65	10,13
Profile 5c-1	49,27	$Q_{5\%}$	50,5	25,25	17,67	7,58	933,40	934,21	0,81	8,57	7,95	20,98	3,05
Profile 5c-1	49,27	$Q_{2\%}$	64,5	28,56	25,21	10,73	933,40	934,29	0,89	8,84	9,61	21,51	3,00
Profile 5c-1	49,27	$Q_{1\%}$	78,4	31,59	32,92	13,9	933,40	934,36	0,96	9,02	11,21	22,01	2,94
Profile 5c	46,71	Q_{sr}	0,35	0,35			933,40	933,46	0,06	1,6	0,22	3,65	2,09
Profile 5c	46,71	$Q_{5\%}$	50,5	24,4	19,51	6,59	933,40	934,25	0,85	7,87	8,5	20,33	2,73
Profile 5c	46,71	$Q_{2\%}$	64,5	27,78	27,5	9,22	933,40	934,33	0,93	8,15	10,25	20,91	2,69
Profile 5c	46,71	$Q_{1\%}$	78,4	30,92	35,61	11,87	933,40	934,41	1,01	8,36	11,92	21,46	2,65
Profile 5b	46,70	Q_{sr}	0,35	0,35			932,40	932,42	0,02	4,59	0,08	3,65	10,13
Profile 5b	46,70	$Q_{5\%}$	50,5	27,04	17,54	5,92	932,40	933,19	0,79	9,42	7,23	19,84	3,39
Profile 5b	46,70	$Q_{2\%}$	64,5	30,6	25,39	8,51	932,40	933,26	0,86	9,72	8,75	20,35	3,34
Profile 5b	46,70	$Q_{1\%}$	78,4	33,85	33,43	11,12	932,40	933,33	0,93	9,94	10,21	20,82	3,28

Profile 5a-1	43,71	Q_{sr}	0,35	0,35			932,40	932,46	0,06	1,6	0,22	3,65	2,09
Profile 5a-1	43,71	$Q_{5\%}$	50,5	26,48	20,79	3,23	932,40	933,24	0,84	8,6	7,69	18,3	2,99
Profile 5a-1	43,71	$Q_{2\%}$	64,5	30,22	29,67	4,61	932,40	933,33	0,93	8,9	9,31	18,91	2,95
Profile 5a-1	43,71	$Q_{1\%}$	78,4	33,7	38,68	6,02	932,40	933,41	1,01	9,13	10,86	19,48	2,90
Profile 5a	41,10	Q_{sr}	0,35	0,35			932,20	932,28	0,08	1,69	0,21	2,67	1,93
Profile 5a	41,10	$Q_{5\%}$	50,5	30,35	18,23	1,93	932,20	933,30	1,10	7,93	8,35	16,53	2,58
Profile 5a	41,10	$Q_{2\%}$	64,5	35,12	26,52	2,86	932,20	933,40	1,20	8,28	10,11	17,13	2,56
Profile 5a	41,10	$Q_{1\%}$	78,4	39,55	35,01	3,84	932,20	933,50	1,30	8,55	11,79	17,68	2,53
Profile 5	39,28	Q_{sr}	0,35	0,35			931,81	931,86	0,05	2,59	0,14	2,59	3,62
Profile 5	39,28	$Q_{5\%}$	50,5	38,66	10,4	1,44	931,81	933,27	1,46	7,47	10,5	14,72	2,10
Profile 5	39,28	$Q_{2\%}$	64,5	46,09	16,03	2,38	931,81	933,47	1,66	7,76	13,42	15,83	2,03
Profile 5	39,28	$Q_{1\%}$	78,4	53,14	21,84	3,42	931,81	933,64	1,83	7,99	16,36	17,14	1,98
Profile 4	29,28	Q_{sr}	0,35	0,35			931,63	931,75	0,12	1,06	0,33	2,87	1,00
Profile 4	29,28	$Q_{5\%}$	50,5	32,73	16,52	1,25	931,63	932,75	1,12	7,96	10,6	15,8	2,51
Profile 4	29,28	$Q_{2\%}$	64,5	39,52	23,09	1,89	931,63	932,91	1,28	8,35	13,11	16,47	2,45
Profile 4	29,28	$Q_{1\%}$	78,4	46,02	29,78	2,61	931,63	933,05	1,42	8,66	15,56	17,1	2,40
Profile 3	19,96	Q_{sr}	0,35	0,35			931,45	931,57	0,12	1,08	0,32	2,83	1,02
Profile 3	19,96	$Q_{5\%}$	50,5	36,58	10,97	2,95	931,45	933,13	1,68	5,81	14,24	15,22	1,48
Profile 3	19,96	$Q_{2\%}$	64,5	44,07	16,1	4,33	931,45	933,39	1,94	6,01	18,46	17,24	1,41
Profile 3	19,96	$Q_{1\%}$	78,4	50,93	21,62	5,85	931,45	933,63	2,18	6,15	22,78	19,09	1,36
Profile 2	9,94	Q_{sr}	0,35	0,35			931,26	931,38	0,12	1,06	0,33	2,9	1,00
Profile 2	9,94	$Q_{5\%}$	50,5	40,24	10,08	0,17	931,26	932,90	1,64	5,6	12,64	13,62	1,53
Profile 2	9,94	$Q_{2\%}$	64,5	49,48	14,38	0,63	931,26	933,16	1,90	5,81	16,37	15,61	1,45
Profile 2	9,94	$Q_{1\%}$	78,4	58,06	18,97	1,36	931,26	933,39	2,13	5,96	20,22	17,43	1,40
Profile 1	0,00	Q_{sr}	0,35	0,35			931,10	931,19	0,09	0,94	0,37	4,49	1,04
Profile 1	0,00	$Q_{5\%}$	50,5	50,45	0,05		931,10	932,33	1,23	5,6	9,08	10,74	1,89
Profile 1	0,00	$Q_{2\%}$	64,5	64,25	0,25		931,10	932,52	1,42	5,85	11,23	11,73	1,83
Profile 1	0,00	$Q_{1\%}$	78,4	77,79	0,61		931,10	932,70	1,60	6,03	13,41	12,65	1,77

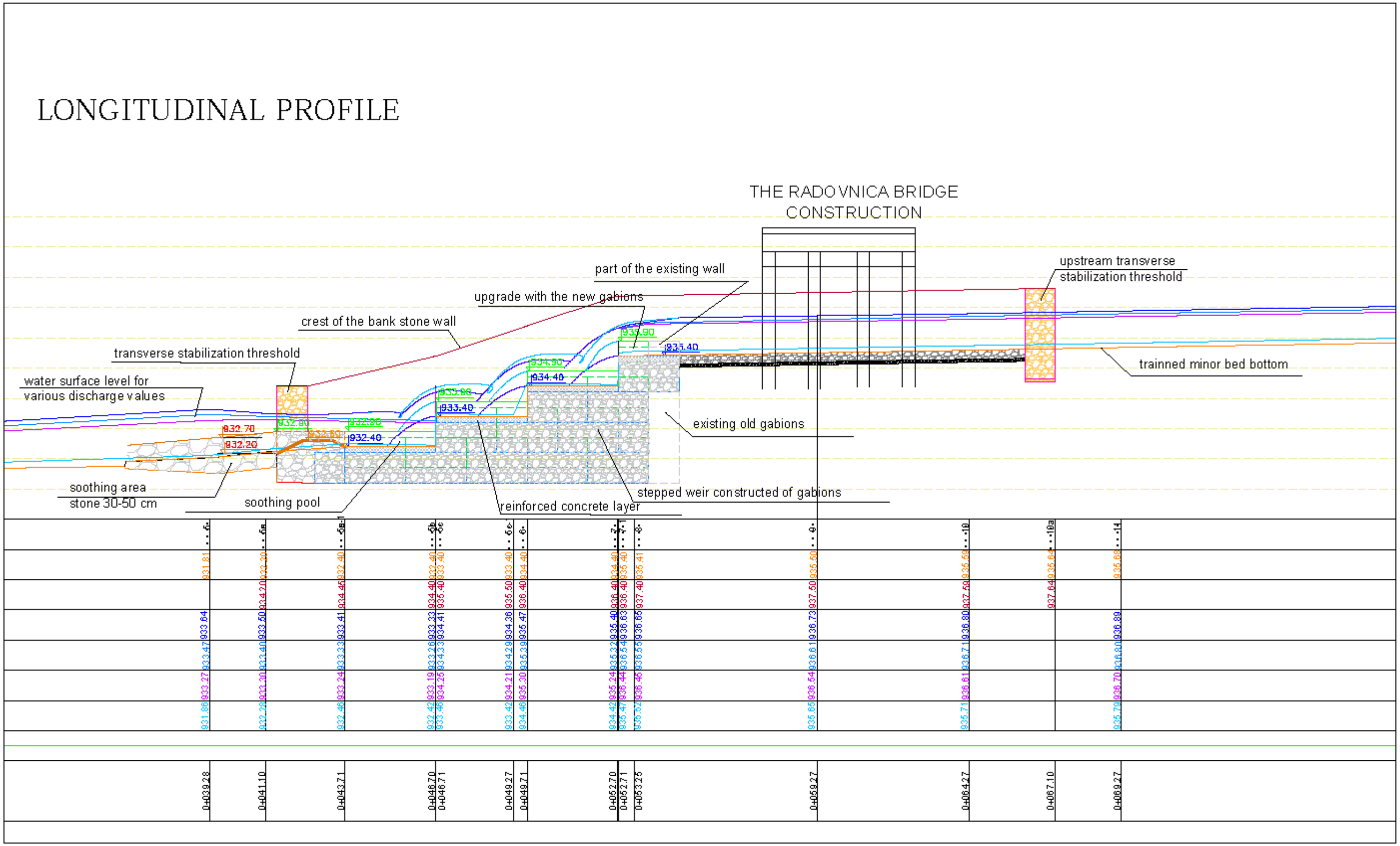

Figure 5. Water surface profile – longitudinal cross section of the designed river bed training in the area of the Rastovnica bridge

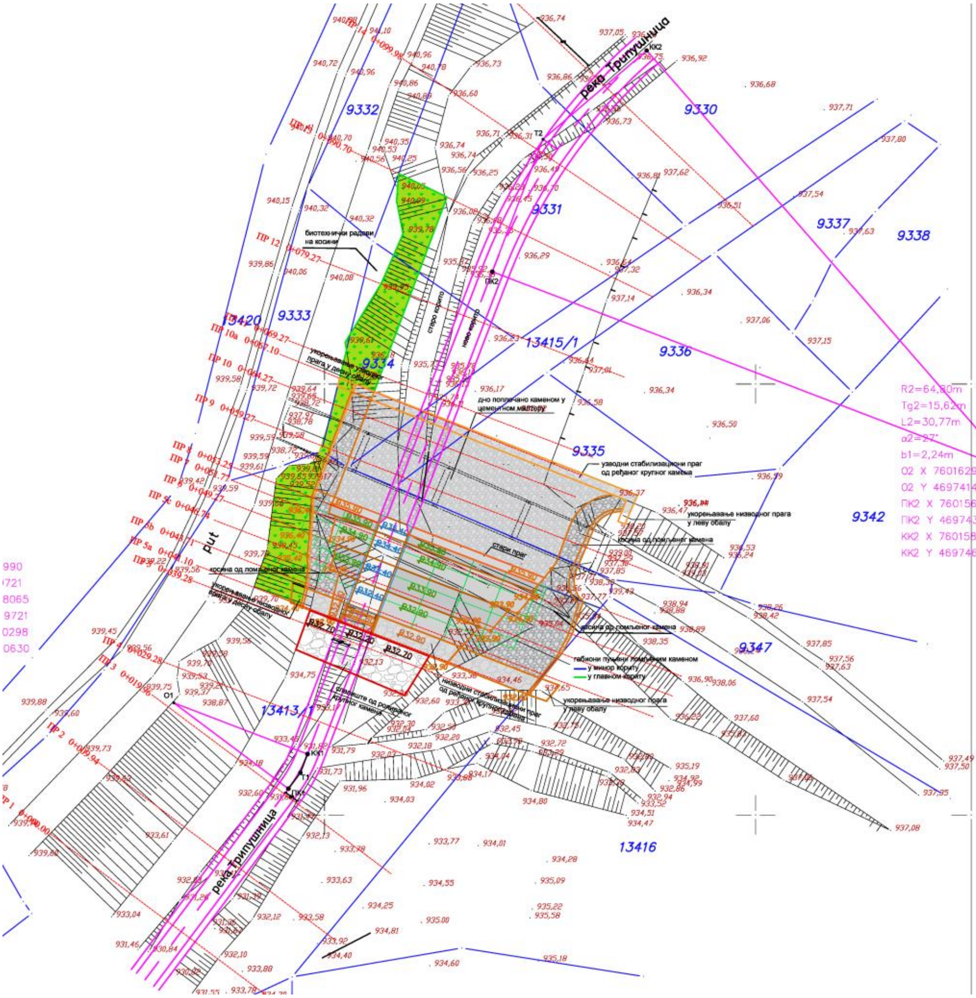

Figure 6. Site plan with designed river bed training in the area of the Rastovnica Bridge

3. Concluding Remarks

The bridge stability in the village of Radovnica in Bosilegrad Municipality is endangered and should be reconstructed. It is necessary to train river bed of the Tripušnica River in order to cut and prevent erosion process in the vicinity of the bridge pillars.

The Tripušnica river bed is designed in the tree subsections: upstream, cascade spillway, and downstream with the energy stilling pond. Water surface profile is computed by HEC RAS 5.0.3 hydraulic model and hydraulic conductivity of the designed river bed and structures tested.

As the Tripušnica River is mountain river with high discharge variation during a year, it is very important to form stable minor for low water flow, and stable major bed, with erosion preservation design.

The designed measures are combination of the earthworks, stone works with gabions on the spillway, paving works with stone in mortar, large crushed stone stabilizing thresholds and vegetation planting works.

The technical design described in this paper presents technical solution for keeping the bridge and the river bed stability. This technical solution has its positive and adverse effects.

Positive effects:

- The river bed redesign should prevent erosion in the area of the bridge and keep its stability.
- The bridge structure has sufficient hydraulic conductivity for flood water.
- The river bed and regional road should remain stable after reconstruction works get done.

Adverse impact:

- These kinds of barriers unfortunately are obstacles for fish migrations.

The Tripušnica River is divided into sections with the barriers and small hydroelectric power plant dams. Unfortunately, none of them has any kind of fish pathway. This bad practice has significant adverse impact on biodiversity and water spices.

REFERENCES

1. Babić-Mladenović, M. Uredjenje vodotoka, Institute for Water Resources Jaroslav Černi, Belgrade, 2018, ISBN: 978-86-82565-51-2.

2. *Jovanović, M*. Regulacija reka - Rečna hidraulika i morfologija, Civil Engineering Faculty Belgrade, 2008, ISBN: 978-86-7518-084-5.

3. *Muškatirović, D.* Regulacija reka, Civil Engineering Faculty Belgrade, 1991, ISBN: 86-395-0345-1.

4. *Radivojević, D., Ilić, A.* Detailed Technical Design for The Radovnica Bridge Rehabilitation with the Tripušnica River bed stabilization, 2018, KSB Inženjering Vranje.

5. US Army Corps of Engineers, Hydrologic Engineering Center, 2014, HEC-RAS5.0.3.