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Prospects for Mitigating the Effects of the Catastrophic Flood on the Vere River through a Temporary Reservoir

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ABSTRACT

The river Vere is a typical mountain river with its gorge of more than 40 km length, range of heights up to 1500 m. This river is considered to be one of the most dangerous rivers in the east Georgia due to its frequent catastrophic overflows. One of the aims of this paper was to estimate the approximate volume of the temporary water reservoir, formed between the Tamarashvili Highway and Gabashvili Street during the catastrophic flood in the Vere River Valley on June 15, 2015. The paper estimates that the temporary water reservoir has a strategic load to manage the catastrophic flood and its consequences, considering the maximum water consumption of the tunnel leading from Svanidze Street and the maximum water permeability of the second tunnel and also taking into account the water flowing from the slopes of temporary water reservoir.

***Key word**: flooding, water reservoir, water flow rate*

Introduction

The catastrophic flood on 13 July, 2015 in the gorge of the river Vere caused many victims and significant material damage. There is an assumption that the catastrophe was the result of torrential rain. However, we suppose that besides abundant precipitations, whose intensity, according to atmospheric radar data, was 70-80 mm, for about 3 hours [1. Banetashvili at all, 2016; 2. Amiranashvili at all, 2018], the flood was caused by the peculiarities of the artificial closed bed of the river Vere, which manifested itself in a critical increase in its hydraulic resistance [3. Kereselidze at all,2018; 4.Kereselidze, Chvedelidze,2018]. Exploitation of the river-bed began in 2010 due to construction of a highway in the last part of the gorge, which in the recent years has been under considerable urban load. The river Vere flows along ≈ 40 km long gorge and joins the main river Mtkvari. The last section of the river gorge (≈5 km) is located in the center of Tbilisi city. The river Vere is characterized with low average yearly water flow rate $Q \approx 1m^3s^{-1}$, though it is considered as one of the most potentially hazardous rivers in Georgia. Quite often, during heavy floods the water flow rate increases by two or more orders. Continuous hydrological observations on the river Vere began from 1962. However, there are quite reliable data on the catastrophic floods, which occurred in the period between 1890-1960 years. So far, the flood, which occurred on 04.07.1960, was considered as the heaviest, when during two and a half of an hour $h \approx 120$ mm precipitation was recorded. During this time, by rough estimates, the water flow rate in the river-bed in the areas of Tbilisi reached enormous value: $Q \approx$ 320 $m^3 s^{-1}$. However, it was later considered that the maximum water flow in Vere did not exceed 260 m^3s^{-1} [5.Kereselidze D. at all, 2011]

Thus, according to the experience obtained after the 13.06.2015 disaster it is obvious that the problem of a devastating flood, which was a great threat to Tbilisi in the past, will be actual in the future as well. Therefore, it is necessary to create a forecasting model of negative phenomena in emergency situations.

Fig.1. The entrance of the tunnel1 from Svanidze Street

Fig 2. The exit of the tunnel1

Constructive feature. In the 30s of the 20-th century in the areas of Tbilisi two tunnels (underground bridge) were built on the river Vere. The first tunnel was ≈ 108 m (Fig1). The old second tunnel (the old second tunnel is now the third tunnel because a new tunnel was built between the first and the old second tunnel and which (new tunnel) in our paper is referred to as the tunnel2) with the length of ≈700 m replaced the last section of the natural river-bed at the area before the confluence of the river Mtkvari. The highways passed over the tunnels. In 2010 after finishing the highway building some part (≈45%) of the natural river-bed between the inlet of the first tunnel and the river Mtkvari appeared covered due to construction of the new artificial (covered) river-bed. As a result it was a construction, a new artificial covered river-bed, consisting of seven tunnels linked to one another with open segments and had the total length of ≈ 2100 m. After the modernization the earlier constructed first tunnel became ≈ 360 m long and the old second tunnel – ≈1200 m. After completion of the construction all the tunnels were semiarch type, had flat concrete basements, compound structure made of reinforced concrete and corrugated steel leaves. It is clear that such an artificial change radically changed the geometry of the river Vere natural bed and, consequently, the hydrological parameters of the valley.

It is well known that any project of potentially vulnerable civil object should include complete assessment of negative consequences of probable disasters. It is natural that such forecasting should have been made also regarding the closed river-bed. However, as the 13.06.2015 disaster showed, seemingly, analysis of the operating mode of the closed river-bed in heavy load conditions had not been done. Supposedly, probability of significant increase of hydraulic resistance in the rather long tunnels with the corrugated inner surfaces was not considered [6. Schlichting,1974; 7.Landau, Lipschitz,1988; 8. Kereselidze

,Shergilashvil, 2016]. After the disaster the river-bed was restored in its original form. Only little corrections were made, namely, walls were built before the two tunnels for guiding the water flow. The inlets of these tunnels are located at the points of maximum bending of the open section of the artificial river-bed (Fig. 3. Tunnel 2). The open section of the ≈30 m long artificial river-bed before Tunnel 2 (Fig.3) bends to that extent that the tunnel is practically located perpendicularly to the river flow. Therefore, supposedly, in the case of increase in the water level the area between the guiding walls will become the problem area of the closed river-bed (water stagnation zone).In this case the effect of the guiding walls can be transformed in hydrodynamic funnel effect and it will additionally reduce the water flow rate in the tunnel.

Fig.3. The entrance of the tunnel 2.

Added to this is the wastewater factor in the area around Kipshidze Street during the 2015 disaster, which were: $Q \approx 30\ m^3 s^{-1}$. [4.Kereselidze at all, 2018]. If we take into account that, according to our rather strict estimation, the throughput of the closed river-bed on the is significantly less than project ($Q \approx 260\ m^3 s^{-1}$ and with about 10% inaccuracy is equal to $Q \approx 200\ m^3 s^{-1}$ [4.Kereselidze, Khvedelidze,2018], this section of the Vere river-bed, between the exit of the first tunnel and the entrance of the second tunnel, is a special danger zone.

One of the aims of this paper was toestimate the approximate volume of the temporary water reservoir, formed during the flood between Tamarashvili Highway and Gabashvili Street. It should be noted that the estimated volume of the dam on Svanidze Street in the immediate after math of the disaster was clearly misrepresented. It is possible that the mistake was made by misinterpreting the effect of a power full and slide in the vicinity of Akhaldaba, according to which the Vere gorge was blocked. Consequently, a mound was formed and a large volume of mud mass was accumulated. The dam was then breached, causing the first tunnel to be closed by flood waters. According to the real picture of the catastrophe, such a thing did not happen, otherwise the scale of the destruction would have been even more grandiose. Fortunately, the landslide developed in the last stage of rainfall arrival. In other case, it is obvious that after breaking through Dam, the floodwaters could be crossed Tamarashvili Highway, which turned into a watershed. Fortunately, flooding water level could not reach just 1-1.5 meters to Tamarashvili Highway, otherwise it would have spread to a significant part of the city along with the Vere gorge.

The problem of Kipshidze street section. Thus, in terms of the future danger, we consider the problem of temporary water reservoir between Tamarashvili Highway and Gabashvili Streets to be especially topical. We built a computer model of this section of the gorge in case of its overflowing (Fig. 4). To convincingly calculate the volume of water accumulated in the gorge, we divided this part of the valley, from the exit of the first tunnel (Fig. 2) to the entrance of the second tunnel (Fig. 3), downstream into 34 parts (Fig. 4).

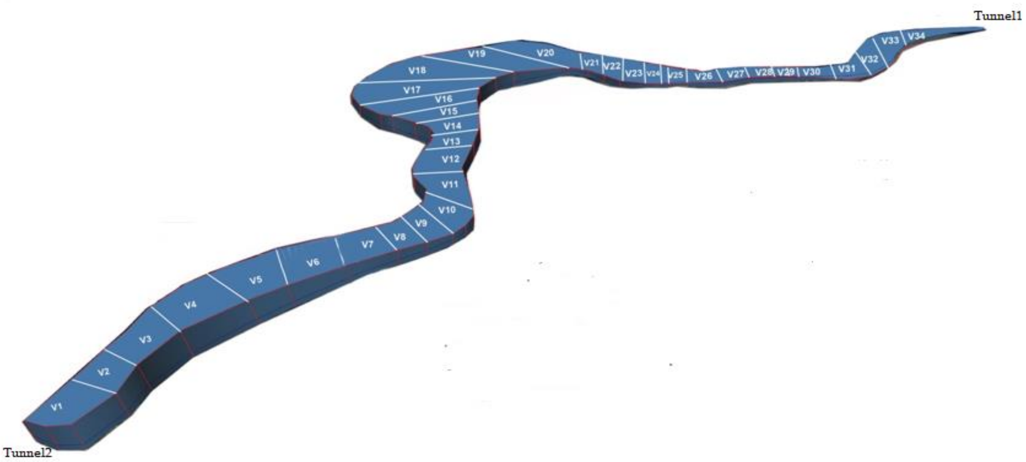

Fig.4. Temporary water reservoir model to calculate its volume

A scan be seen from Fig.4, in order to calculate the volume of the water reservoir, we need to calculate the volume of each sector and summarize them.

$$V = \sum_{i=1}^{34} V_i$$

Volume of each sector

$$V_i = S_i\, h_i,$$

Where S_i is the surface area of the i-th sector, and h_i is the height from the deepest point in the i-th sector to the water surface. The area and corresponding height of each sector are given in Table 1.

Table1

S(i) - m^2	S(i) - m^2	H(i) - m	H(i) - m
S1 = 1119	S18 = 2157	H1 = 8.0	H18 = 4.2
S2 = 959	S19 = 2994	H2 = 8.0	H19 = 4.0
S3 = 1042	S20 = 2447	H3 = 7.5	H20 = 3.7
S4 = 1733	S21 = 2648	H4 = 7.5	H21 = 3.5
S5 = 1312	S22 = 3731	H5 = 7.0	H22 = 3.3
S6 = 1645	S23 = 3930	H6 = 7.0	H23 = 3.0
S7 = 1392	S24 = 2868	H7 = 6.7	H24 = 2.8
S8 = 867	S25 = 1940	H8 = 6.5	H25 = 2.6
S9 = 1226	S26 = 2062	H9 = 6.2	H26 = 2.4
S10 = 970	S27 = 1190	H10 = 6.0	H27 = 2.1
S11 = 1240	S28 = 767	H11 = 5.8	H28 = 1.9
S12 = 1018	S29 = 955	H12 = 5.6	H29 = 1.7
S13 = 779	S30 = 1211	H13 = 5.3	H30 = 1.4
S14 = 859	S31 = 1537	H14 = 5.1	H31 = 1.2
S15 = 904	S32 = 1293	H15 = 4.9	H32 = 1.0
S16 = 1641	S33 = 801	H16 = 4.6	H33 = 0.8
S17 = 1976	S34 = 739	H17 = 4.4	H34 = 0.5

Table1 - the area of each sector (S_i) and the corresponding different between levels (H_i) of the water reservoir.

Table2

V(i) – m^3	V(i) – m^3
V1 = 8952	V18 = 9029
V2 = 7672	V19 = 11848
V3 = 7815	V20 = 9124
V4 = 12998	V21 = 9268
V5 = 9184	V22 = 12206
V6 = 11515	V23 = 11958
V7 = 9326	V24 = 8071
V8 = 5611	V25 = 5016
V9 = 7654	V26 = 4860
V10 = 5834	V27 = 2533
V11 = 7174	V28 = 1457
V12 = 5657	V29 = 1596
V13 = 4151	V30 = 1747
V14 = 4381	V31 = 1866
V15 = 4404	V32 = 1275
V16 = 7619	V33 = 606
V17 = 8723	V34 = 391

Table2 – volume of each sector (V_i)

Volume of temporary water reservoir

$$V = \sum_{i=1}^{34} V_i = 221\ 755\ m^3$$

According to our calculations, the volume of the temporary water reservoir is equal to about 225,000 m^3. In the event of a catastrophic flood, it will take approximately 75 minutes to fill the temporary water reservoir, roughly calculation. It envisages a reduction in the conductivity of the second tunnel due to the corrugated walls, a reduction in its cross-section due to a 40 cm concrete cover on the floor and, most importantly during catastrophic flood, about 50 $m^3 s^{-1}$ water flow from Kipshidze Street and from opposite slope. Catastrophic precipitation mayl ast longer, butt his time (75 min) will be sufficient for safety-related measures.

Conclusion

1. The cross-section of the second tunnel does not envisage runoff from Kipshidze Street. Also, runoff from the opposite slope should probably be considered. In our estimation, the catastrophic flooding in front of the second tunnel was significantly due to these factors. It is estimated that the runoff from Kipshidze Street was $Q_1 \approx$ (30 – 40) $m^3 s^{-1}$, which was added to the water consumption from the first tunnel.
2. According to our water reservoir model, it is likely to act as a dempher that can protect the rest of the river Vere bed from water overflow. For example, if we consider that the water flow in the first and second tunnels is $Q_2 \approx$ 225 $m^3 s^{-1}$, which is considered as a measure of the flow of June 13, 2015 (Kereselidze, Khvedelidze), in case of runoff $Q_1 \approx$ 50 $m^3 s^{-1}$from the slope, it will take T ≈ 75 min to fill the spontaneous reservoir. Even if the catastrophic rainfall continues for a longer period of time, it is likely that this time will be sufficient to implement necessary flood control measures in the lower part of the Vere Valley.
3. In our opinion, it is an urgent task to build a protective wall along the entire length of Kipshidze slope. We also note that the small, previously built wall here has already been amortized. It is therefore necessary to construct the new wall in such a way that the entire slope before the entrance to the second tunnel was protected.

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მდინარე ვერეზე კატასტროფული წყალმოვარდნის შედეგების შერბილების პერსპექტივები დროებითი საგუბარის მეშვეობით

ზ. კერესელიძე, თ. ქირია, ჯ. ქირია, ნ. ვარამაშვილი, მ. ნიკოლაიშვილი

რეზიუმე

მდინარე ვერე წარმოადგენს ტიპიურ მთის მდინარეს, რომლის ხეობის სიგრძე 40 კილომეტრზე მეტია, სიმაღლეთა სხვაობა თითქმის კილომეტრნახევარი. ხშირი კატასტროფული წყალმოვარდნების გამო ეს მდინარე ითვლება ერთ-ერთ ყველაზე სახიფათოდ აღმოსავლეთ საქართველოში. აღნიშნული ნაშრომის ერთ-ერთი მიზანი იყო 2015 წლის 15 ივნისს, მდინარე ვერეს ხეობაში განვითარებული კატასტროფული წყალმოვარდნის დროს თამარაშვილის მაგისტრალსა და გაბაშვილის ქუჩებს შორის წარმოქნილი დროებითი საგუბარის მიახლოებითი მოცულობის შეფასება. ჩვენი აზრით, სვანიძის ქუჩიდან გამომავალი გვირაბის მაქსიმალური წყლის ხარჯის და მდინარე ვერეს ე.წ. მეორე გვირაბის წყლის მაქსიმალური გამტარობის გათვალისწინებით და ასევე საგუბარის ფერდობებიდან ჩამონადენი წყლის გათვალისწინებით. დროებით საგუბარს აქვს სტრატეგიული დატვირთვა კატასტროფული წყალმოვარდნის და მისი შედეგების მართვისათვის.

Перспективы смягчения последствий катастрофического наводнения на реке Вере за счет временного водохранилища

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Резюме

Река Вере - типичная горная река с протяженностью долины более 40 километров с перепадом высот почти в полтора километра. Из-за частых катастрофических наводнений эта река считается одной из самых опасных в Восточной Грузии. Одна из целей данной статьи - оценить приблизительный объем временной плотины, образовавшейся между шоссе Тамарашвили и улицами Габашвили во время катастрофического наводнения в долине реки Вере 15 июня 2015 года. На наш взгляд, учитывая максимальную пропускную способность тоннеля, ведущего от улицы Сванидзе и также, принимая во внимание максимальную водопроницаемость так называемого второго туннеля реки Вере, и учитывая потоки воды, текущие со склонов водохранилища, временное водохранилище несет стратегическую нагрузку по управлению катастрофического наводнения и его последствий.