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FLOOD RISK FROM DANGEROUS DAMS IN BULGARIA

Abstract: This study aims to evaluate the condition of small dams in Bulgaria and analyse the challenges in managing small dam flood risk . After the bursting of two small dams caused devastating deadly floods in the town of Tsar Kaloyan in 2007 and in village of Biser in 2012, public sensitivity to the safety of such facilities greatly increased. A number of administrative measures have been taken to improve the management of small dams and increase their security, but many of the problems remain unresolved. A methodical approach to managing flood risk from small dams requires concerted action between activities aimed at enhancing the safety of the dams themselves, managing river basin flood risk, and managing flood risk in riparian settlements. In this study, we analyse the factors that increase the threat of and vulnerability to such disasters, using the floods in Tsar Kaloyan and v. Biser as case studies. The results demonstrate a need to link more closely flood risk management plans in river basins to those in settlements, and to ensure they factor in the geographical characteristics of the territory and the impacts of climate change. The study has found a lack of effective control both of the condition and safety of small dams and of the implementation of planned risk mitigation activities. The dialogue between citizens and institutions on the risk of such disasters does not deliver the desired results.

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Introduction

Floods in recent years have highlighted the positive role of protective dikes and dams, as well as the concealed hazards if dams are poorly operated and maintained. The maintenance and safety of the 50 big (complex and significant) dams in the country, which are public state property, are under strict control and in accordance with the Water Act (AM. SG No 98/2018). Small dams provide water for irrigation and regulate river flow to protect from floods. Most of them were built in the 1950s and 1960s. During big floods, many small dams overflow through the crest of the wall and suffer considerable damages. Between 2005-2016 there were 63 such incidents [1]. Small dams in Bulgaria are managed by municipalities, industrial plants, and irrigation and forest authorities or concessionaires. The catchment management is the responsibility of the River Basin Directorates and local governments. After the devastating flood disasters in Tsar Kaloyan, district Razgrad in North-East Bulgaria (August 2007) and in village Biser, district Haskovo in South-East Bulgaria (February 2012), caused by the bursting of the „Ezerche"1and "Ezerche" 2 and the "Ivanovo" dams respectively, a lot of questions arose about the number, state, management and ownership of these dams and the institutional responsibilities for small dam safety in Bulgaria.

In this study, we explore the complex factors which increase of the flood hazard related to the safety of small dam walls. We analyze the role of particular geographical factors that increase flood risk in river catchments with adjacent small dams, based on the experience from last two disasters caused by the bursting of “Ezerche” 1 and “Ezerche” 2 and “Ivanovo” Dams. The results would be of interest for the local authorities and managers who are engaged professionally with this problem.

Methods and data

Of primary importance for this study is to define “small dams” and “hazardous dams”. There are different definitions in different countries. Current dam classification in Bulgaria is based on dam dimensions. According to the Water Act, *large dams* are those with walls higher than 15 m or walls between 5 and 15 m and reservoir of more than 3 000 000 m^3; *small dams* are all that do not meet these thresholds [2].

According to Ordinance No13 from 29.01.2004 (annulled in 2016), dams in Bulgaria are classified as small if they have a wall height less than 15 meters and volume less than 1 million. cu. m. Art 46 of the same ordinance lists the criteria for classification of the potential danger of dams.

Pursuant to Art. 46 of Ordinance No 13 of 29.01.2004 on the terms and conditions for carrying out technical operation of the dams and their facilities, the technical condition of the dam are categorized like this: 1 – good working order; 2a – malfunctioning, partially operable (when at least one of the technological safety indicators is violated); 2b – malfunctioning, partially operable (when at least one of the structural safety indicators is violated); 3 – malfunctioning, inoperable (when both technological and structural safety indicators are violated and require operating load reduction and repairs); 4 – pre-failure state (when their further exploitation is inadmissible due to an unacceptable risk to people, property, or the environment).

The data for hazardous dams in Bulgaria analyzed in this study are collected from [5] and [6] and classified according to the standards in Ordinance No 13 [3].

The physico-geographical characteristics (geology, geomorphological and hydrological characteristics of the terrain, climate, soil and vegetation cover and land use) of the catchment in which the dam is located determine the speed and volume of surface flow formed in conditions of extreme rainfall, the resulting flood zones and the potentially endangered settlements and people. The technical parameters of the dams take into account normal physicogeographical and geological conditions of the catchment. Climate change and changes of land use and land cover in the catchments can significantly increase the risk of large water quantities flowing over a short time period into the reservoir cup, which can cause overflow or even destroy dam walls. This is particularly dangerous for embankment (earth or rock) dams, which comprise almost all small dams in Bulgaria. How dams respond in such situations depends on proper management of flood risk for the site. This encompasses the legal framework for their management, monitoring, and control, and the appropriate maintenance of the structural, technological and functional safety of dam walls, exhaust facilities, spillways, etc.

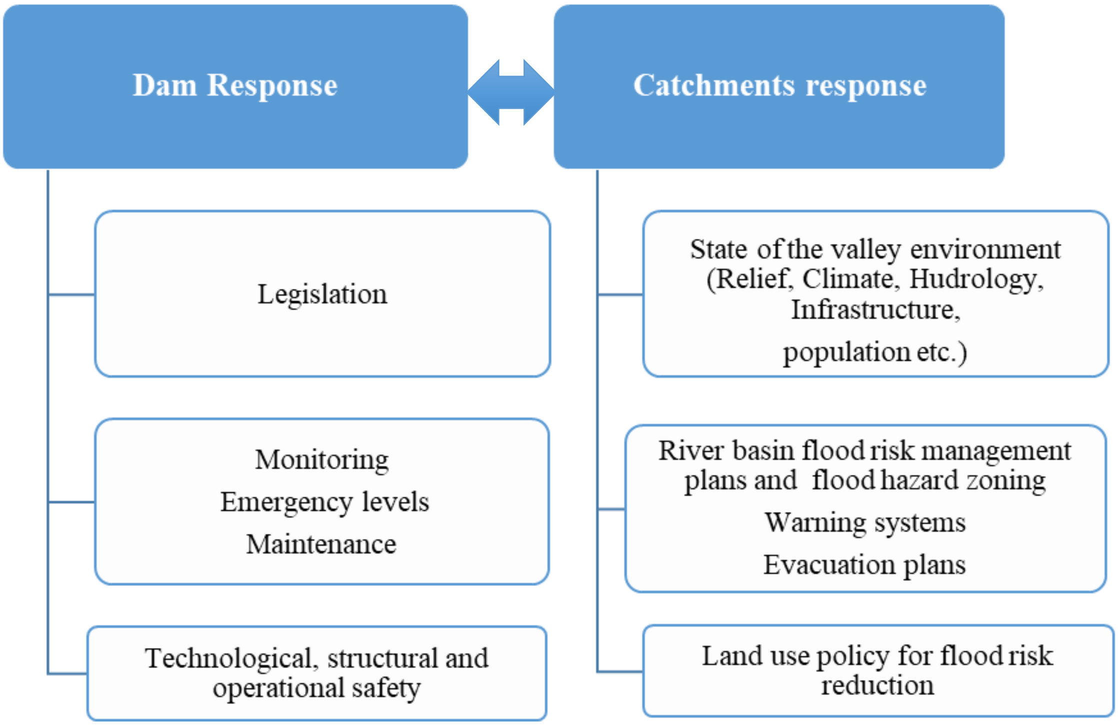


Fig.1. Dam-catchments flood hazard response indicators – after [4]

Dam hazard management and risk reduction are analyzed in the context of existing legal and operational safety regulations and management at the time of the disaster events. The catchment disaster response is analyzed on the basis of the geographical characterization of the affected catchments and settlements from two particular devastating flood events caused by small dams breaking. The dam response depends mainly on technological and structural operational safety, their monitoring and maintenance according to the level of emergency. The catchment response may accelerate or reduce the flood risk hazard. That is why it is important to implement an integrated flood management approach for both the catchments and the adjacent small dams (Fig. 1).

The sources of data used in the study include a preliminary database for hazardous dams in Bulgaria in 2015 and 2016 [5], [6], meteorological and hydrological data from Bulletins of the National Institute of Meteorology and Hydrology, scientific publications, materials from the press and others. Statistical, geomorphological and GIS based cartographic methods were implemented in the research.

Dam Response

Over the last decades, there has been an increase of the daily maximum precipitation and related flood events in Bulgaria. Very often such events put small dams and hydro-technical facilities under great stress and in some cases even cause dams to burst with disastrous consequences for the affected areas. Very illustrative examples for disasters related to such events are the floods in town of Tsar Kaloyan, district Razgrad in North-East Bulgaria on August 6-7, 2007, and in village Biser, district Haskovo in South-East Bulgaria on February 6, 2012. After the bursting of the small dams “Ezerche” 1 & 2 and “Ivanovo”, the government initiated a series of measures, including amendments and supplements to the Water Act. The Ordinance No13 on the modalities for carrying out the technical operation of the dams and their facilities [3] was annulled in 2016 [7] and replaced by a new Ordinance on the conditions and procedures for implementation of the technical and safety operation of dams and facilities, as well as control on their technical conditions [7]. A Water Coordination Council at the Council of Ministers was established in 2012 to ensure coordination of the activities related to the development of river basin management plans and flood risk management [8].

The aim of the proposed changes was to introduce clear rules for the ownership of water infrastructure and to ensure the technical safety of dams. The control of the technical condition and safety of all dams and their facilities on the territory of Bulgaria, regardless of the ownership, was assigned to the newly established State Agency for Metrological and Technical Supervision (SAMTS) and specifically to the Directorate General "Supervision of dams and related facilities" (DG) at the Ministry of Economy in 2016. In 2014-2016 check of all small dams were carried out and a single register of small dams was created and is periodically updated. As of July 2019, 6 844 bodies of water have been identified, but 1 273 of them were classified as "not dams" and still others were registered with different names, without defined locations, with unclear ownership, or lacking any documentation [9]. So, we may conclude that presently in Bulgaria there are about 5 571 dams. Of those, 556 dams are classified as "significant" and "big" dams, and the rest do not meet the requirements for these categories [1]. As the process of the categorization of all dams in Bulgaria is not finalized, our analysis is not precise in terms of number of small dams. However, data collected up to now provide quite good notion about the scale of the problem with their management.

All dams in Bulgaria are classified according to three degrees of potential danger, depending on the worst possible consequences of the release of the waters stored in the dam due to the destruction or improper operation of the dam: 1. high degree of potential danger; 2. significant degree of potential danger; 3. low degree of potential danger [2]. The criteria for classifying the degree of potential danger are determined in the Annex No 1 to Art. 10, para. 2 of the Ordinance on the terms and conditions for implementation of the technical and safe operation of the dam walls and their facilities and for carrying out control of their technical condition [10]. The classification of dams by degree of potential hazard makes it possible to determine a different periodicity of inspections by the control body – SAMTS. Annual controls are envisaged to ensure the safe operation of dams at a "first, high" and "second, significant" degree of potential danger. These dams, in the event of an emergency, would endanger people's lives and health, critical infrastructure, roads from the Republican road network, industrial enterprises, etc. [11].

Another problem, which the legislative changes are expected to solve, concerns the ownership of small dams. From the 5 178 dams inspected, 4 198 are municipal property, 328 are state-owned, 186 are private and 29 are property of the irrigation association. There are 176 dams without clear owners and 252 dams without documents for ownership [9]. According to the law, the owners are responsible for the technical condition and safe operation of the dams. However, in many cases the owners are municipalities that are not financially able to carry out these activities. The changes from July 2018 in the Water Act allow all municipalities that have no financial resources for the maintenance and safe operation of dams to transfer ownership of the dams to the state for free. The mayors of municipalities declared their intention to transfer the ownership of 2 717 dams free of charge to the state at the end of 2018. As at 20 November 2020 the ownership of 336 dams has been changed from municipal to state-owned [11].

As local authorities play a crucial role in flood risk management, we analyzed the geographic distribution of potentially dangerous small dams within each municipality, using data for 625 confirmed potentially hazardous dams [6]. The classification used in this assessment is based on the subsequently amended Ordinance 13/ 29.01.2004 on the terms and conditions for carrying out technical operation of the dams and their facilities. Pursuant to Art.46 of Ordinance No 13, the technical condition of the dam may be classified as: 1 – good working order; 2a – malfunctioning - partially operable when at least one of the technological security indicators is violated; 2b - malfunctioning - partially operable when at least one of the structural security indicators is violated; 3 - malfunctioning - inoperable, when technological security and structural security indicators are violated; 4 – pre-failure state- when their further exploitation is inadmissible due to an unacceptable risk to people, property and the environment. In 2015 and 2016, respectively 804 and 625 small dams were inspected [6]. The analysis of the results shows that the number of hazardous dams in categories

2a, 2b, 3 and 4 in 2015 was 482 (59,95% of all inspected dams), and in 2016 it was 340 (54,4%). Fig.2 (a and b) illustrate the distribution of the relative share of each category for the years 2015 and 2016. The results show that dangerous dams of categories 2, 3 and 4 predominate, with 64% of all dams examined in 2015 and 54% in 2016. The distribution of hazardous dams of all categories (2a, 2b, 3and 4) by districts shows that the problem with dam safety is biggest in districts of Pleven, Plovdiv, Stara Zagora, Pazardzhik and Burgas, which have more small dams due to their flat relief with intensive agriculture and need for irrigation (Fig. 3). The data show that in 2015, there were 91 small dams in pre-emergency state in 54 municipalities in the country (Fig. 4).

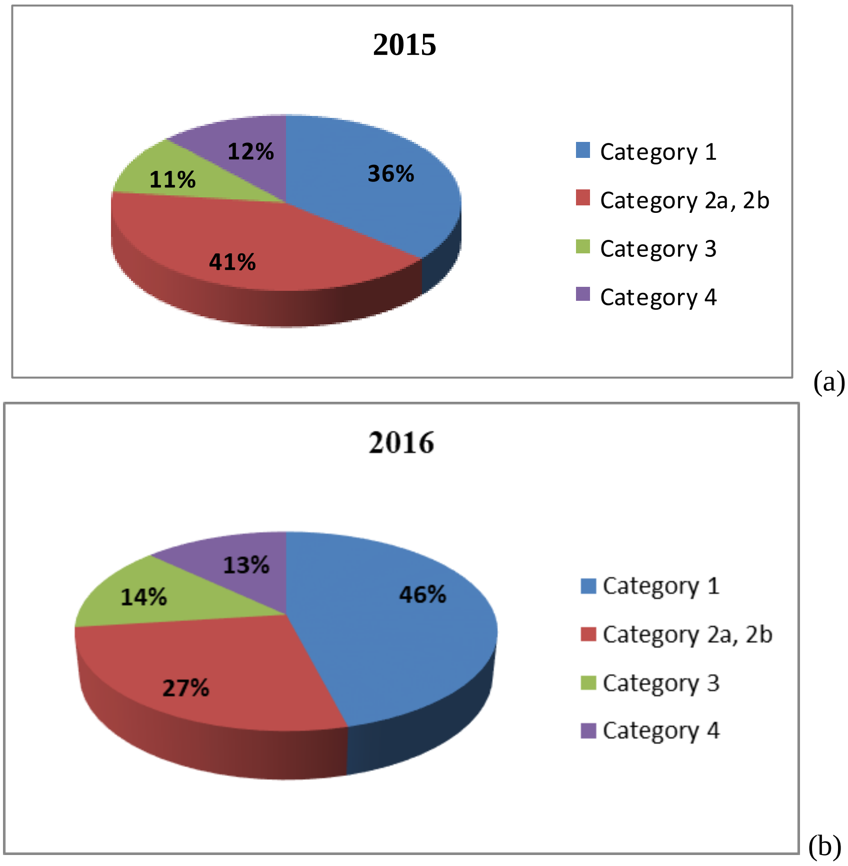


Fig. 2. Relative share of each hazard category for inspected dams in 2015 (a) and 2016 (b)

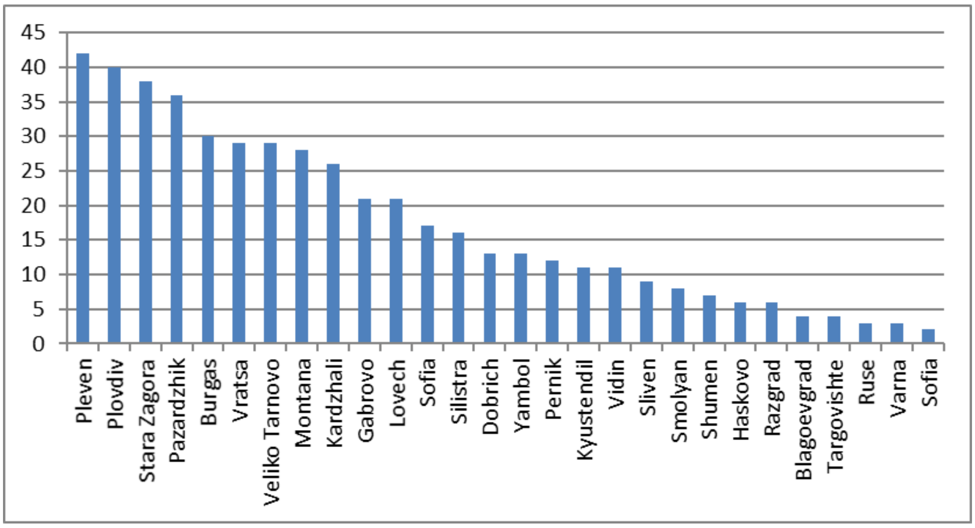


Fig.3. Distribution of hazardous dams of 2a, 2b, 3and 4 category by districts in 2015

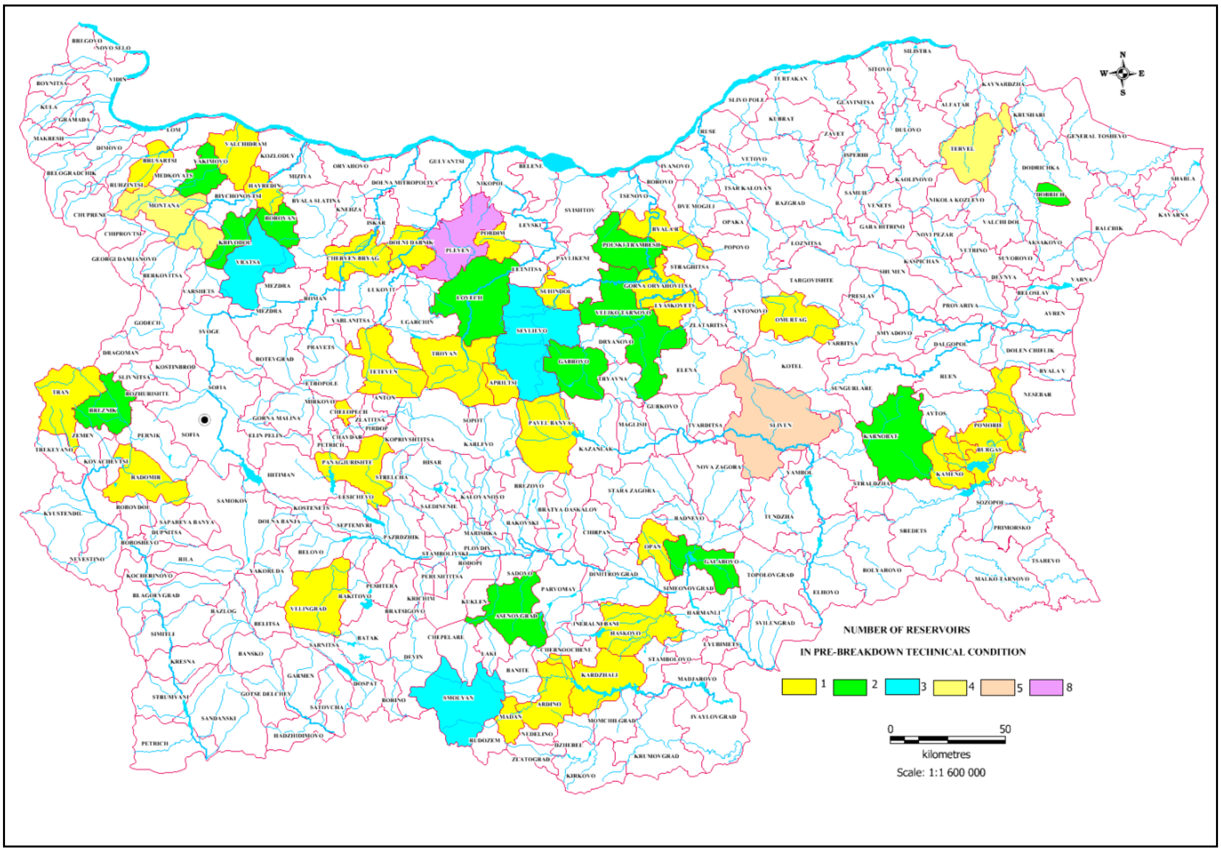


Fig. 4. Municipalities with small dams in pre-emergency state (2015)

After the amendment in Water Act in 2018 and the entry into force of the new Ordinance on the terms and conditions for implementation of the technical and safe operation of the dam walls and their facilities and for carrying out control of their technical condition [10], the process of classification of dams according to the new criteria for degree of potential danger pursuant to Art. 141b of the Water Act has been fully completed in 13 of 28 districts in Bulgaria as of the end of 2020. All dams in the following districts have been inspected: Sofia-grad, Sofia, Pernik, Vratsa, Montana, Lovech, Razgrad, Veliko Tarnovo, Gabrovo, Ruse, Silistra, Dobrich and Shumen. The classification currently covers 1665 dams, 540 of which fall into the first, high degree of potential danger. In the second, significant degree of potential danger, there are 167 dams and in the third, low degree of potential danger - 425 dams. For about 533 of the inspected small dams, there is evidence that they are in good working order and will be excluded from SAMTS supervision [11].

Catchments response

In this section, we will examine the main drivers which lead to increase of losses from flood events using an analysis of the data for two flood disasters caused by small dams that burst after extreme hydro-climatic conditions. The two disasters, in the town of Tsar Kaloyan and in village Biser, occurred in areas with different geographical characteristics, but exhibit similar causes and consequences.

The town of Tsar Kaloyan (3 693 inhabitants) is situated in the Northeastern part of the Danube Plane in the Hlebarovska (Torlak Lom or Tsarkaloyanska) River Basin. Tsar Kaloyan municipality has 6 371 inhabitants [12] and three settlements: Tsar Kaloyan, Ezerche and Kostandenets. The local economy is primarily agriculture driven, mainly via farming cooperatives. There are 7 cooperatives in the settlements Tsar Kaloyan, Ezerche and Kostandenets: one dairy farm in the town of Tsar Kaloyan and two dairies and four small enterprises for the production of shoes in village Ezerche.

The disaster on 06-07 August, 2007 in the town of Tsar Kaloyan was caused by the bursting of the dam wall of "Ezerche" 1 and the overflow of the dam "Ezerche" 2. Both dams are located above the town of Tsar Kaloyan. All small dams in the area were managed by different concessionaires.

"Ezerche" 1 Dam was built in the early 90s at the site of the demolished inoperable small dam "Kayadzhik" . A local entrepreneur obtained a 25-year concession agreement for the dam site. He restored the dam's earth embankment wall with bulldozers to create a fish farm. Neither the wall, nor the water management features were built according to good engineering practice. Instead of spill- or sluiceways, the developer installed a drain pipe through the tamped-down dirt wall . Inspection after the flood discovered a huge gaping hole at that place in the wall [13]. On 6.08.2007, starting at 13:00 h, the area experienced heavy rainfall with a probability of less than 1 % (90 mm/m2 for about 100 minutes). The dam filled quickly and overflowed through the crest of the wall, which causes the dam to burst. The total volume of the tidal wave was about 450,000 m3 released over 3 hours. The wave height was 3 m [14].

The "Ezerche" 2 dam was also managed as a fish farm [13]. For this reason, both dams were full and lacked capacity to regulate the excess water flow of the intense rainfall that caused the disaster.

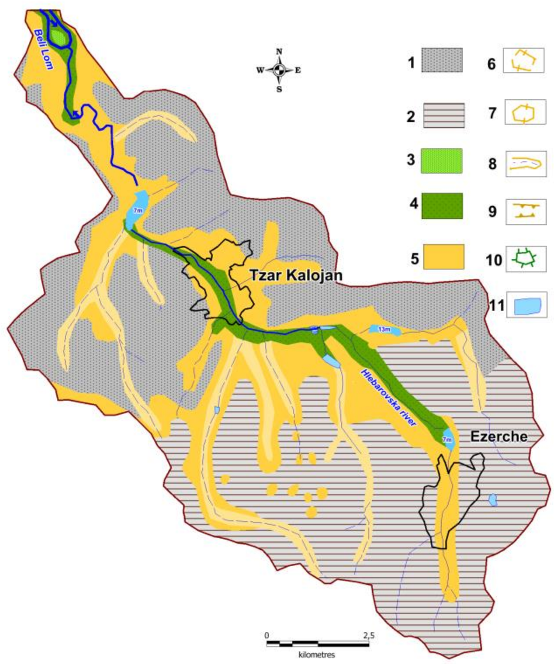
"Ezerche" 2 dam was located in the gully of a tributary of the Beli Lom river. It had volume of 52 000 m3. Like the "Ezerche" 1 Dam, it was also publicly owned by the Tsar Kaloyan municipality. Its wall initially withstood the pressure, but failed later as a result of the water overflow. After seeing that the water will spill over the wall, the concessionaire opened the tap completely, but it was too late. The area flooded area by the dam overflow was 64,98 ha. The dam wall of "Ezerche 2" was partially destroyed [15]. Because of the damage to the wall there was a risk of subsequent flooding of the city and the dam was emptied over the following days.

The sudden increase in the water flow through the town of Tsar Kaloyan at around 16:30h took eight lives. The damage amounted to over BGN 2 000 000 (EUR 1,000,000). The flooding destroyed 70% of the transport infrastructure and 1,100 families were affected to varying degrees [16].

In addition to the anthropogenic factors, the specific natural conditions in the catchment of the Hlebarovska River also contributed to the severity of the disaster. It was triggered by an extreme amount of rain falling within the watershed in a very short time. The climate in this part of the country is Temperate-Continental, with a spring-summer precipitation maximum. In Tsar Kaloyan the average January temperature fluctuates from 1.8° to -2°C and the annual rainfall amount is 611 mm. From 5th to 7th August in 2007, a cyclone passed over the Balkans, creating conditions for heavy rainfall across the country. There was heavy rainfall throughout northern Bulgaria. In Tsar Kaloyan, the total rainfall over the three days was 426mm, with 291mm recorded in a period less than 24 hours between 6th and 7th August [17].

The maximum 24-hour precipitation measured previously for the area had been 104.3 mm in 1949 [18]. When such extreme amounts of precipitation fall in relatively small river basins, the morphography, lithology, soils and the land cover type of the basin are key determinants for the speed and quantity of the surface runoff.

The source of Hlebarovska River is near the village of Ezerche. The river passes through town of Tsar Kaloyan and then flows into the right bank of Beli Lom River east of the village of Pisanec. The total length of Hlebarovska River is 22.9 km. The Hlebarovska River Basin is located in the hilly relief of Ludogorie region at an altitude of 100 to 400 m and spans an area of 98.3 km^2. The basin is much wider in the upper and middle reaches of the river (90% of its area). After the town Tsar Kaloyan, the basin narrows sharply. The terrain is intersected by a dense network of dry valleys with meridian and submeridian direction, separated by low hills. The rock base consists of sedimentary rocks, primarilylimestone from the lower Cretaceous. Open karst and buried paleokarst, as well as Plio-pleistocene sediments of clay and typical loess (Fig. 5) are ubiquitous. The hill slopes predominantly have small declination (from 1 to 5°) and valleys typically have wide bottoms with trough-like profile. Dry canyon-like valleys with slopes steeper than 15° have formed in the lower Cretacious limestone rocks (in particular in the area south of v. Ezerche). The largest downcutting by the river is 169 m, located at the confluence in the Beli Lom River in the northwest part of the basin.. The structural-lithological characteristics of the area play a major role in the formation of the morphography of drywalls. The density of the talveg network of dry valleys ranges from 200 to 4 000 m/km2. Broad floodplain terraces have formed in the valley of Tsar Kaloyan township, with the valley bed spanning 1 km at the widest point [19]. The Tsarkaloyanov karst region is constrained between the villages of Dryanovets, Ezerche, Downeyak and Nisovo [20]. It exhibits typical karst forms, dominated by pot-holes (sink-holes), with a distribution density of 4-5/ km2. By burying the paleokarst, the loess preserved the kaolin weathering crust, which affects the infiltration of rainfall and the distribution of groundwater.



Фиг. 5. Geomorphologic map of Hlebarovska River Catchment

Legend: 1. Loess accumulation surface; 2. Loess erosion-accumulation surface; 3. River terrace – T4; 4. Floodplain terrace; 5. Karst slopes; 6. Relict pot-holes; 7. Active pot-holes; 8. Dry valley with periodic runoff; 9. Canyon valley; 10. Bypass hill; 11. Reservoir

The disaster in village Biser was caused by the failure of the "Ivanovo" Dam. Although precipitated by heavy rain and snow melt, it illustrates the lack of disaster prevention responsibility and preparedness by the local authority. „Ivanovo" is a large dam - the 151th largest in the country (out of nearly 3000), with a 19m-high dam wall and volume of 3 million cubic meters [21]. Village Biser is located in Harmanli municipality, district Haskovo, Southeast Bulgaria. There are about 500 houses and 752 inhabitants in the village. Main economic activities are agriculture and dairy farms. Municipality Harmanli has an area of 411,4 km^2 and 25 settlements with a total population of 24 947 inhabitants. A dispute about who in the municipality of Harmanli was responsible for the management of the "Ivanovo" Dam had been ongoing since 2003 [22]. The nearby military shooting range was relying on the dam to supplement its firefighting water reservoirs. The wall of the dam "Ivanovo" started cracking in 2006, but no measures were taken because of disputes about the ownership of the dam and the shifting of responsibility between the Ministry of Defence, Harmanli municipality and district administration in Haskovo. People from v. Biser wrote warning letters to the local authorities several times. In 2009, the Executive Agency for Fisheries and Aquaculture notified the Regional Administration in Haskovo of strong leakage from the wall of the "Ivanovo" Dam. After ten years of inaction by the authorities, the dam wall broke and water submerged the village of Biser at 08:30h on February 6, 2012.

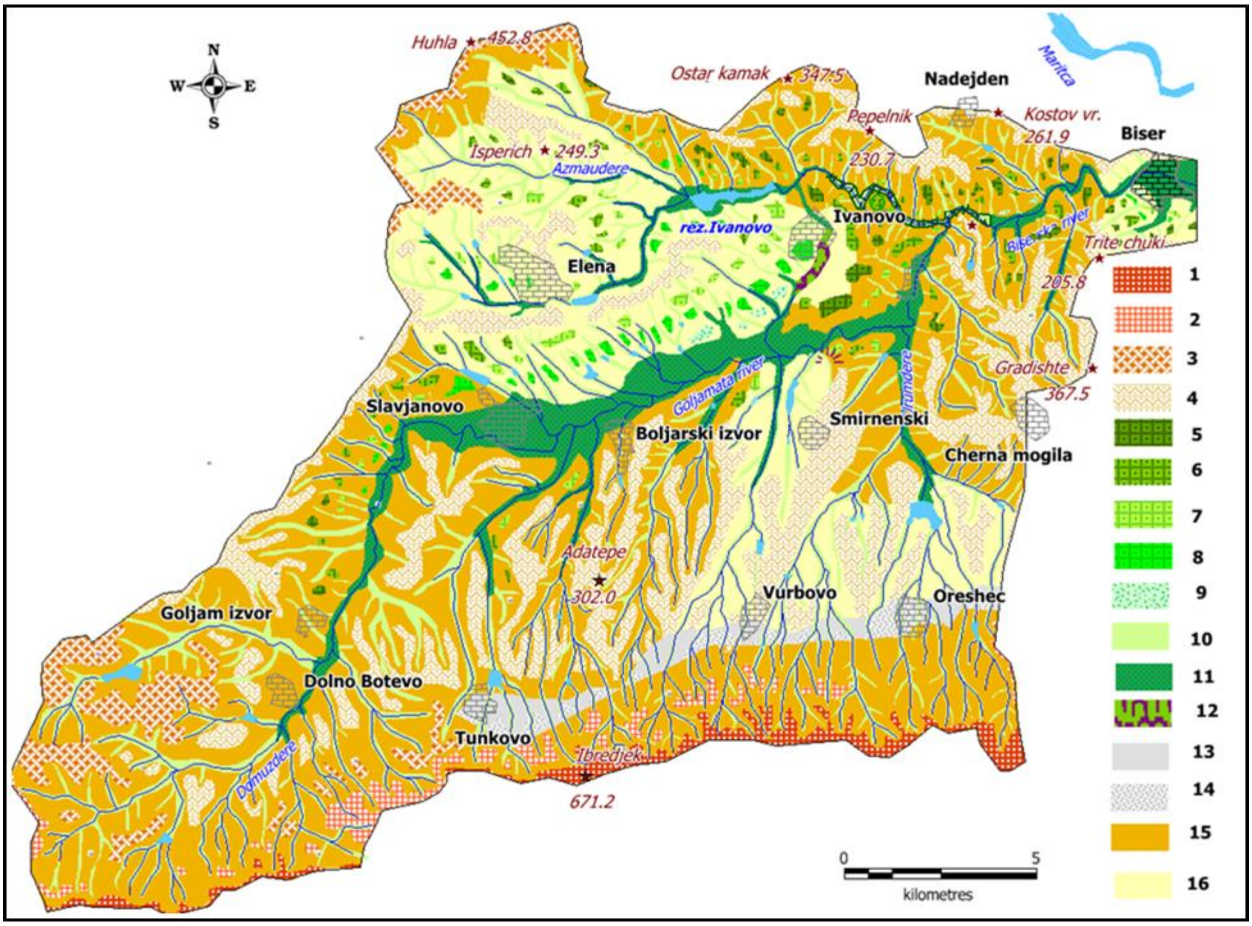
The area is characterized by Continental-Mediterranean climate with precipitation maximum in autumn and winter. Heavy rainfall fell in the Eastern Rhodopes on 5th and 6th February 2012, which caused intense snow melting and flooding in the regions of Haskovo and Harmanli. In Southern Bulgaria, as well as elsewhere in the country, the amount of precipitation during this period exceeded the monthly norms and reached 142 l/m2 in Haskovo [23]. As a result, the upper soil layers were highly saturated. Under pressure from the incoming waters of the Amzaka River and the chunks of ice that had formed in the dam cup, the “Ivanovo” Dam wall burst at 07:30h.

Of the 146 meters span of the dam wall, 50 m were washed away. A tidal wave with 3-5 meters height reached the village Biser one hour later. The one-storey houses were completely flooded. Ten people died and there was significant property damage [23]. In the two villages, Biser and Hazel, 55 houses were completely destroyed, and another 36 houses became uninhabitable. The costs were estimated at over BGN 7 million (EUR 3.5 million), of which BGN 4 million (EUR 2 million) was the cost to restore the railway infrastructure between Haskovo and Svilengrad [23].

The catchment of the Bieserska River is located in south-eastern Bulgaria, in the hilly relief of the Eastern Rhodopes. The area of the catchment area is 387.5 km2. The river length is 46.2 km and its average annual discharge is 0.41 m3/s [24].

The large dam „Ivanovo” is located at 144 m above sea level (a.s.l.), and v. Biser is situated 10 km downstream at 75 m a.s.l. River Biserska collects the waters of the River Azmakdere, on which “Ivanovo” Dam is located, and of the Golyama River, and then flows into the Maritsa River.

Before the villlage of Biser, the river cuts the root rocks, forming a narrow asymmetrically developed flood terrace with local swamps. The river basin exhibits right-hand asymmetry. The valley slopes are steep to sheer, rocky, cut by numerous narrow canyon-shaped valleys. In some sections of the valley, the right valley slope is almost sheer, made of gliss and amphibolites. The total length of the valleys (dry and constant flow) is 749 km. Downcutting ranges between 3-30m. The flood terrace of the Biserka river valley is developed along the left slope on Paleogene sediments of gravel up to 3 m thick. At v. Biser, the terrace is formed on Plio-Pleistocene sediments and has accumulative genesis. The total area of flood plain is 27.8 km^2, and v. Biser occupies 3.04 km^2 of it. A first terrace above the flood plain (T1) has relatively larger spread on the left valley slopes in the valleys of the Golyama River and Karamande River. The second terrace above the flood plain (T2) has very limited distribution. On the geomorphological map it is combined with the first one (Fig. 6).



Фиг. 6. Geomorphologic map of the Biserska River Basin

Legend: 1. Preneogene surface; 2. Neogene surface; 3.Upper Neogene surface; 4. Pliocene-Pleistocene surface; 5. River terrace – T5; 6. River terrace – T4; 7. River terrace – T3; 8. River terrace – T2; 9. River terrace – T1; 10. Valleys; 11. Floodplain river terrace; 12. Old river bed; 13. Proluvial sediments; 14. Proluvial cones; 15. Steep slopes; 16. Slightly inclined slopes

Discussion

The Tsar Kaloyan disaster of 06-07 August, 2007 was caused by the bursting of the dam wall of "Ezerche"1 and by the overflow of the dam "Ezerche" 2 in the Hlebarovsa River Basin. Key contributing factors were inappropriate maintenance, bad management and lack of control by the municipality as owner and by the concessionaires as operators. Despite the extreme precipitation, if the spillway of "Ezerche"1 had functioned properly, it could have delayed the overflow until after the peak of the wave, when the volume of water was thinner and slower. This was the case at the "Ezerche"-2 dam, where the spillway was functioning and the wall overflowed much later [14]. Both "Ezerche"-1 and "Ezerche"-2 dams should have been drained in advance to free capacity for excess rainwater, as was their design purpose. This was not done because of their exploitation as fish farms, so instead of regulating the runoff they amplified it when the dams failed. At the same time, the geographical features of the catchment area of the Hlebarovska River played an important role in magnifying the scale of the disaster. The vast area of the basin in the upper and middle reaches of the river, combined with the extreme 24-hour rainfall, caused powerful surface run-off that collected in the local erosion bases of the main river valley and spilled into the floodplain around the city. The easily soluble loess materials, which cover the heavily deforested slopes, quickly filled the river and raised the water level. The buried karst is filled with kaolin and other deposits that prevented water from being infiltrated quickly into the surface rock massif. Wide deforested and dry canyon-shaped valleys very quickly took the water to the riverbed. The sharp narrowing of the river in its lower reaches, between the town of Tsar Kaloyan and its confluence into the Beli Lom River, maintained the height of the wave and the retained it in the valley. The high wave effect further intensified because two large Hlebarovska River tributaries, Kurubunar River and the Manastiritsa River, flow into the river downstream from the town [19].

During the 2012 disaster in the village of Biser, the rainfall was less extreme than that in the town of Tsar Kaloyan in 2007. However, the apathy of the institutions that systematically neglected the warnings about the cracks and leaks in the dam proved fatal on the day of the disaster. The problem of the “unclear” ownership of the dam comes to the fore, even though the dam is listed as public-municipal in all documents. The fact that a substantial part of the village was built on the floodplain terrace of the Bieserska River contributed to the significant property damage. The hydromorphographic characteristics also played a role in the disaster: before reaching the village of Biser, the river drains a large area with a dense network of dry valleys with steep eroded and, in some places, deforested slopes. The catchment characteristics, the intensity and quantity of the rainfall, and the rupture of the dam made the disaster inevitable and greatly limited the time for emergency rescue response – only 60 minutes. Had an early warning system been in place, the loss of life may have been avoided.

The number of deaths in both disasters is unacceptably high. The analysis of the post-disaster inspection reports in both cases reveals that risk management and disaster management plans were in place, both on the part of the municipalities and on the part of the dam concessionaires. However, in both cases there was a serious problem with communication and a lack of even basic systems for any kind of early warning. The inhabitants of Tsar Kaloyan and Biser were not aware of the plans for action and evacuation in the event of a disaster. Despite the severe repercussions of these and other floods, riverbeds are still not cleaned systematically. Inhabitants in flood-prone areas continue not to insure their property: of the 55 destroyed houses in the village of Biser, only one was insured.

It is also worth noting that although the people in both Tsar Kaloyan and v. Biser have been partially compensated for the property damage, the activities of improving safety and flood prevention are progressing at a very slow pace. The consequences of the 2007 disaster did not lead to increased focus on floor risk from dangerous dams, nor to the implementation of measures to reduce the risk of other similar disasters. They did not lead to the strengthening of the “Ivanovo” Dam wall, despite multiple warning signals since 2003, before it burst in 2012. The measures taken by the government after the disaster in v. Biser to create an inventory and categorize dams gave initial results only in 2015-2016, but only in the form of legislative changes and preliminary assessments of some of the dams. As of the end of 2020, this process is not yet complete. The inventory and categorization of dams in 15 more districts of the country and the strengthening of hundreds of dangerous dams are still pending.

It is of paramount importance to train additional staff for the evaluation and monitoring of hydro-technical facilities and to increase public awareness and engagement with the problem of flooding from dangerous dams. For this purpose, it is necessary to open databases with the condition of dams and hydro-technical facilities to public access, deploy trained specialists for the maintenance of these facilities, and provide free access to reliable meteorological and hydrological information.

Conclusions

The analysis of these two disasters is necessary to draw the attention of institutions and dam owners to the critical factors for dam safety. The number of small and medium-sized dams classified as dangerous in Bulgaria is significant and most of them (about 56%) are located in populated areas with flat-hilly or low-mountain relief in the hypsometric belt from 200 to 1000 m. The examples demonstrate that flood risk management in river basins with adjacent small dams must take into account not only the safety of the dam structures, but also the possible effects of the river basin geographical characteristics in the event of a disaster. Most of the small dams in the country were primarily intended for irrigation and regulation of the runoff when they were built. Later, their main purpose became fish farming. Because they need to keep the dams fuller for the fish, operators often do not reduce water volume after the irrigation season to ensure the dam has sufficient capacity for runoff regulation. According to the regional scenarios for climate change in the Balkan region, the incidence of both intense rainfalls and prolonged dry periods will become more frequent. As a result, the importance of small dams will increase and their technical condition must meet the standards for their operational security. It is also essential that territory management and land use are tailored to the potential risk of flooding in the adjacent river basin. Special attention should be paid to flood risk management plans for catchments with adjoining small dams. Hydrological models can simulate the behaviour of the river basins in conditions of extreme rainfall with different intensity, given different afforestation, land use, etc. parameters. These plans and simulations must also be aligned with the municipal plans for climate change adaptation. Local authorities must focus on active preventive measures to mitigate flood risk and on preparing the local population for disaster response.

Despite the serious safety problems of the small dams in Bulgaria, there is a positive trend for their solution. Specific legislative actions have been taken to clarify and settle the ownership of small dams. Progress has been made to categorize dams by degree of danger. Early warning systems are established in large river basins, such as those of the Arda, Tundzha and Maritsa rivers. New approaches have been developed for dam management by aligning flow forecast and early warning systems. A classification system of dams in Bulgaria in GIS was established in the NIMH [1].

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