

2014 Doboj Floods – Consequences and Hazard Elimination Activities

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Abstract: The Republic of Srpska is susceptible to natural disasters, with particular regard to floods. Floods had caused human losses and property damage to both civilian and commercial facilities, road infrastructure and other infrastructure, on several occasions, including the 2014 floods. It is not always possible to predict natural disasters but human and material losses may be reduced if institutions undertake planned prevention activities and educate the population in terms of flood protection and risk reduction. The paper addresses floods as the natural disaster to which the Republic of Srpska is susceptible due to a long network of non-regulated water streams and frequent heavy rains. A special attention is paid to the floods which heavily affected the city of Doboj in 2014 as we analyze the activities on hazard elimination and consequence mitigation. The analysis is based on the study, assessment and plans designed in order to protect the city from floods in near future. Along with that we analyzed the impact of floods on the changes in the size of traffic flow requirements on the part of the M-17 road damaged in floods.

Key words: natural disaster, floods, hazard, consequence, defense.

INTRODUCTION

Natural disasters¹ consequentially occur due to activities of forces of nature and severely affect humans, other living beings, and property. Most common natural disasters are drought, earthquakes, fires, landslides, drifts, stormy winds and frost. Climate change has had an increasing impact on the frequency of natural disaster occurrence with floods being the most common natural disaster in the Balkans [2]. Hence, scientists and general public have been paying a growing attention to the flood risk mitigation and protection [11]. Flood is an overflow of water from both natural and artificial recipients, i.e. riverbeds and water accumulations. Being a natural process and an atmospheric and hydrological phenomenon, floods may last long and disturb large areas with massive consequences for humans, environment, property, agricultural soil and road infrastructure [3].

According to the origin, there are several categories of floods – floods caused by rain and snow melting, ice jams, floods caused by high water levels, torrential floods, floods caused by landslides, and floods caused by dams or levees cracks. Other than water amount

and hydrological regime, the following parameters are crucial for flood occurrence – size and shape of the watershed, river network density, terrain slope, meander features of the riverbed, the ratio of surface water and groundwater outflow, woodiness of the terrain, and the deposit ratio [4]. Given the timeline of the flood wave formation, floods may be slow-rising floods (typical of large rivers), torrential floods (hilly areas) and sudden floods (large flood waves are formed due to crashing of hydropower or water management facilities). According to the size, floods may be minor, moderate, major and catastrophic [3].

From the hydrological point of view, the Republic of Srpska is relatively rich in surface and groundwater hydrological networks. All the major river streams are parts of the Black Sea drainage basin. The backbone of the Black Sea drainage basin is the low-lying Sava River water stream fed by the rivers of Una and Sana, Vrbas, Ukrina, Bosna and Drina. All these river streams are characterized by composite river valleys with large river slopes and distinguished hydro-energetic potentials. In addition, the Republic of Srpska has suffered climate change effects resulting from natural element activities and laws of wide air mass circulation. Summers are warm and winters are moderately cold, the mean annual air temperature being above 10°C. The distribution of precipitation has been rather uniformed and largest amounts are poured down in May and June. As a rule,

1 "Natural disasters are hydrometeorological, geological and biological phenomena caused by forces of nature: earthquakes, floods, torrentuous floods, heavy rains, atmospheric outbursts, hail, drought, drifts, landslides, avalanches, extreme air temperature, waterstream freezing, infectious disease epidemic, vermin, and other large natural phenomena which may threat the well-being of humans and cause large damage" (*Zakona o zaštiti i spasavanju, 2012*).

the amount of precipitation declines from west (1500 mm) to east (700 mm) due to air flow from the west [1].

Given the abovementioned facts, we may say that floods, including torrential floods, are the most common natural disaster in the Republic of Srpska in terms of human and material losses and that they occur in both rural and urban areas. Most rivers in the country are likely to occasionally overflow and floods are even more likely to take place in plain areas [11]. The regions most susceptible to floods are the middle and upper streams of the Sava River tributaries: Novi Grad, Prijedor (the Sana River), Banja Luka (the Vrbas and Vrbanja rivers), Čelinac (the Vrbanja River), Doboj, Šamac and Modriča (the Bosna River), Foča, Novo Goražde, Zvornik, Bijeljina (the Drina River), as well as the following settlements along the Sava River valley: Kozarska Dubica, Gradiška, Srbac, Brod, Derventa (the Ukrina River), Šamac, Brčko and Bijeljina. Speaking of karst fields, the most threatened ones are Gatačko polje, Nevesinjsko polje, Dabarsko polje, Fatničko polje, Bilečko polje, Trebinjsko (Mokro) polje, Ljubomirsko polje, Ljubinjko polje and Popovo polje [9].

Erosion and torrential floods are another threat for the watersheds in the Republic of Srpska. Torrential floods have a large impact on roads, settlements, and agricultural soil in river valleys. The estimations indicate that around 85% of the Republic of Srpska's territory is affected by erosion, which is most pronounced in the Drina River watershed (around 94% of the watershed suffers some type of erosion) and the Adriatic Sea drainage basin (around 93% is affected by erosion). The Sava River watershed is where the erosion occurs the least frequently (around 49% of the watershed). High intensity erosion (category I – excessive, II – intense, and III – moderate erosion) affects only 15% of the overall territory suffering from erosive processes, whereas most territory registers weak erosion processes which can be addressed through biological protection measures. The following river streams are well-known for erosion processes: the lower Una River, parts of the Sava River watershed (the Gomjenice River), the narrow Sava River watershed (the Vrbaška and Jablanica rivers, parts of Tinja Brka and Lukavac river stream), the lower Vrbas River (rivers of Vrbanja and Turjanica, the narrow Vrbas River watershed, the Povelich River), The Ukrina River watershed (rivers of Vijak, Mala Ukrina and Velika Ukrina, the narrow Ukrina River watershed down to the town of Derventa), The Bosna River watershed (The Usora, Glogovica, Lovnica and Zarječje river streams), the Drina River watershed (the Janja and Tarna river streams, parts of the Drinjača river stream, the Lim and Rzav, and Križevica river streams), the Sušica river stream within the Trebišnjica River watershed [6].

The Republic of Srpska witnessed major floods in 2014. It was the intensive precipitation from March to May that caused overflows in the rivers of Bosna, Sava,

Drina, Vrbas, Una, Sana and their tributaries, resulting in sudden and extreme floods in many cities and municipalities [10]. In the year of 2014, the Bosna River and its tributaries flooded the city of Doboj and the municipalities of Šamac and Modriča, causing human losses and massive property and infrastructural damages. Given the fact that the Bosna River overflow resulted in a large number of human victims and major infrastructural destruction in the city of Doboj, this paper accounts for the consequences the flood left in both city center and suburban areas. The paper also provides an analysis of activities conducted in order to eliminate the hazard and mitigate consequences as well as the city's flood defense plan. Finally, we provide certain recommendations in regard to protection improvement and rescue plan for the near future.

CONSEQUENCES OF NATURAL DISASTER – FLOODS IN THE CITY OF DOBOJ

Massive precipitation occurred in the territory of the city of Doboj in March, April and May 2014 causing catastrophic flood and landslide as the Bosna River² and its tributaries Usora and Spreča overflowed the riverbed. The immeasurable consequences were manifested in the destruction of housing, commercial and public facilities, interruption of public and telecommunication traffic, water and electricity supplies, and finally, severe devastation of agricultural soil, buildings and forests.

Doboj has witnessed three major flood threats in its recent history: on May 13, 1965 the maximum water level was registered at the Doboj gauge station at 142.79 m altitude; on June 21, 2001 the maximum water level was registered at 142.47 m altitude; and on May 15, 2014 the maximum water level was registered at 144.41 m altitude. The latest flooding water level was 1.5 meters higher than those ever registered before. The first two water levels were approximate to the so-called centennial statistical probability of high water level, and the third maximum was around 1 meter higher than so-called millennial statistical probability of high water level [5].

Causes and types of damage initiated by flood

From March to May 2014, the city of Doboj was exposed to a series of cyclones resulting in constant rainfall and occasional heavy rainfall. Massive precipitation was particularly pronounced from 14th to 18th of May (150 liters per square meter), which later led to a sudden increase of water level in riverbeds. Another crucial factor, which led to impaired hydrological circumstances at the Modrac dam and the Spreča River, was the sudden water inflow to the lake and the consequential increase of the Bosna River water level. The water inflow to the lake was 1.600 m³/s at 03:00 pm on May 16, 2014, and the water

² The Bosna River is 275 kilometers long, 35-150 meter wide, 1-7 meters deep.

outflow from the lake was 1.137 m³/s at 01:00 p.m. on May 16, 2014. Two factors acted simultaneously. Massive precipitation and abundant discharge from the Modrac Lake resulted in an alarming situation at the hydrological systems of the Bosna, Spreča and Usora rivers, finally causing major floods in the city of Dobož. The hydrological station on the Bosna River located near the pumping station in the city of Dobož registered the highest ever water level (730 cm) on May 15, 2014 [8].

Given that the soil was sodden by large amounts of water, many landslides accompanied the flood and caused damages to both private facilities and public infrastructure.

5.168 hectares of land were affected by the flood on the city of Dobož's territory. The flooding area of the Bosna and Usora rivers and inland river streams covered the surface of 4.676 hectares, and the flooding area of the Spreča River covered the surface of 492 hectares. Therefore, the flood covered the center of the city of Dobož, suburban areas and 33 other settlements. Along with the settlements located in the valleys of Bosna and Spreča rivers, the flood also affected parts of Stanari and Raškovci settlements. The total estimated losses were 172.688.971,95 BAM. 45.845.714,33 BAM was the damage on private buildings and private property, and 123.059.227,62 BAM was the damage of legal entities in terms of buildings, equipment, and indirect losses. There were 2.850 flooded housing facilities registered in the city center, suburban areas and other settlements.

The data outlined in Table 1 suggest that most of the damage was registered on private buildings and private housing facilities, which was 98.5% of total losses on private property.

Table 1. Estimated damages on buildings and citizens' property in BAM

Summary of damages on facilities and assets owned by private citizens									
Soil	Buildings	Equipment	Longterm plots of land	Livestock, fowl, fish, current assets	Household assets	Working capital	Other assets	Total	
477.707,30	25.061.269,63	31.307,00	12.153,90	107.940,00	20.079.379,50	61.159,40	14.797,60	45.845.714,33	

Taken from: (Study on estimated damages, 2014)

Consequences of the Dobož city floods did not only entail material damage but also human losses. Once the water withdrew from specific parts of the city, bodies of 11 victims were recovered from housing facilities and the

cause of deaths was either drowning or connected with the flood. According to the information provided by the Ministry of Internal Affairs of the Republic of Srpska, there were four male and seven female victims aged 41 to 91. Speaking of body injuries, the "Sveti Apostol Luka" public hospital in Dobož registered 73 patients with minor and major body injuries.

It was the public road infrastructure that also suffered damages. According to the estimations of supervising authorities, the losses suffered by road infrastructure mounted up to 3.784.030,00 BAM (categorized roads – 433.350,00 BAM; uncategorized roads – 2.250.680,00 BAM; city roads and utility infrastructure – 850.000,00 BAM; infrastructure facilities – 250.000,00 BAM).³

In addition, the flood also resulted in interruption of regular social and commercial activities in the city of Dobož. Those activities mostly referred to postponed classes in primary and secondary schools and colleges, closed kindergartens, interruption of road and telecommunication traffic, urban and suburban transport, shut-down of businesses and social activities, stoppage of electricity and water supplies, etc [5].

Table 2 provides information on damages in terms of sectors of activity, i.e. commercial and non-commercial sectors. Commercial sectors which suffered most damage were trade (67.7% of total commercial damage), hospitality industry and tourism (11.3%), and handicrafts (7.5%). Taking into account the non-commercial sectors, it was the health and social care, education, science and culture that were most affected respectively.

Table 2. Overview of damages per sectors of activity

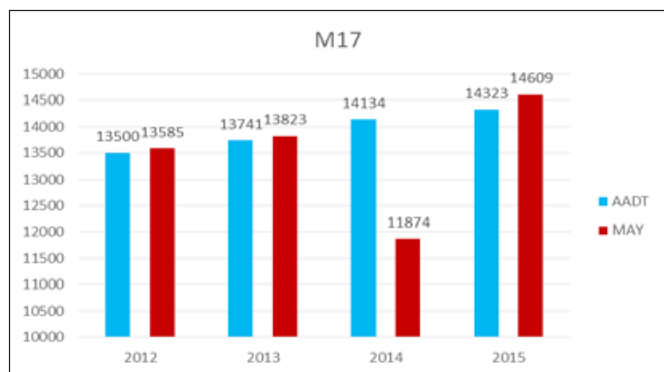
Description	No. of units	Total damage BAM
Commercial sectors	690	82.780.105,615
Industry and mining	4	910.601,91
Agriculture and fishery	6	1.734.769,72
Forestry	2	15.287,77
Water management	1	286.730,36
Civil engineering	18	4.217.708,62
Traffic and communications	7	1.799.448,14
Trade	325	56.074.710,58
Hospitality industry and tourism	130	9.361.475,72
Handicrafts	154	6.201.573,63
Utility services	27	1.092.584,96
Finances and other services	16	1.085.214,2
Non-commercial sectors	150	18.649.161,6
Education, science and culture	19	1.985.468,32
Social and health care	28	4.885.289,32
Other non-commercial activities	103	11.778.403,98

Taken from: (Study on estimated damages, 2014)

³ The amount does not include damages on regional and main roads, railways and agriculture.

The impact of floods on the size of traffic flow requirements on the part of the Doboj – Republic of Srpska border main road at location Karuše

On the part of the M17 main road, section 220 Doboj – Republic of Srpska border in the village of Karauše, an automatic traffic counter, number 000015, of the Republic of Srpska public company was placed. This part of the main road is one of the most traffic heavy parts of state roads in the Republic of Srpska and Bosnia and Herzegovina. The next graph shows the size of the traffic flow requirements from 2012 to 2015 as average daily traffic. In order to assess the impact of floods for the same analysed time period we also show the level of average daily traffic in the month of May.



Picture 1. Average daily values of traffic flow at annual level and for the month of May at the automatic counter 000015 in the village of Karuše

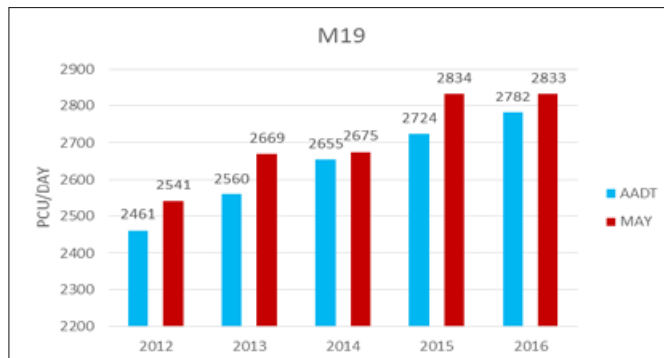
As we can see in the previous graph, characteristics of the month of May are increased requirements for traffic flow compared to AADT. However, due to damages to this part of the road, 2014 shows drastic drop in traffic flow requirements to average of 2,260 vehicles per day. That means that in May, this road was travelled by 70,060 less vehicles compared to the monthly annual average. We can objectively presume that due to floods the number of travel and transport of goods was partially decreased. However, until the section 220 of the M17 main road was repaired, a large number of vehicles was redirected to alternative roads, which increased transport labour, i.e. expenses of travel and transport of goods.

Similar characteristics of changes in traffic flow requirements were also identified at other sections of M17 main road near Doboj.

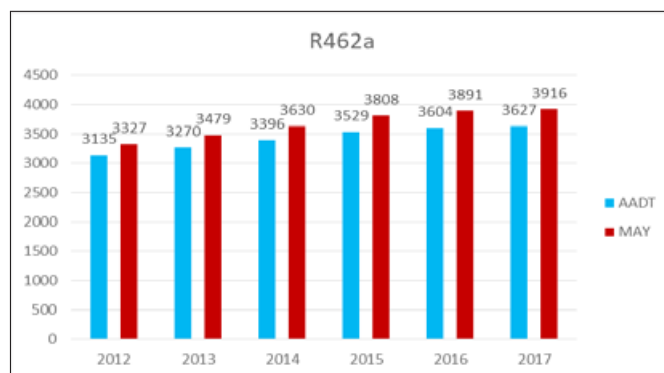
Comparative analysis of traffic flow requirements at other sections had also been damaged in the floods, a conclusion was drawn that the most damages caused by transport labour occurred at sections of the main road around Doboj.

The following graphs show changes in traffic flow requirements at Section 288 Konjević Polje Milići, M19 main road, i.e. at the automatic traffic counter 000033 at

Dušavno residential area, as well as the section Grebnice - Obudovac 1 of the R462a regional road at the automatic counter 000052 in the village of Batkuša.



Picture 2. Average daily values of traffic flow at annual level and for the month of May at the automatic counter 000033 in the village of Dušavno



Picture 3. Average daily values of traffic flow at annual level and for the month of May at the automatic counter 000052 in the village of Batkuša

As we can see at previous graphs, average daily load at analysed sections of the main and the regional road in the month of May is higher compared to AADT, i.e. does not deviate from usual trends.

Based on the conducted analysis we can conclude that the highest damages were caused by increased transport labour due to floods in the Republic of Srpska occurred on sections of M17 main road near Doboj.

ANALYSIS OF ACTIVITIES UNDERTAKEN TO ELIMINATE HAZARD AND MITIGATE CONSEQUENCES CAUSED BY FLOOD

The Republic Emergency Headquarters for the territory of the Republic of Srpska and the Doboj city emergency headquarters were formed as operational and expertize bodies to address the natural disaster caused by floods in the Republic of Srpska in April and May 2014. Also, the

Republic Emergency Headquarters appointed an expert team in order to facilitate the communication. On May 17, 2014, the Government of the Republic of Srpska adopted a Decision on emergency declaration in the Republic of Srpska due to regional flood threats. Nine days later, on May 26, 2014, the Government adopted a Decision on cessation of the Decision on emergency, with an exception of the cities of Bijeljina and Doboј and municipalities of Vukosavlje, Modriča, Šamac, Srebrenica, Donji Žabar and Šekovići. The Decision on emergency in the cities of Bijeljina and Doboј and municipalities of Vukosavlje, Modriča, Šamac, Srebrenica, Donji Žabar and Šekovići was set aside by the Decision adopted by the Government of the Republic of Srpska on June 20, 2014 [15].

Activities undertaken during and after the flood

All the activities undertaken on the city of Doboј's territory were instructed by the Republic Emergency Headquarters for the territory of the Republic of Srpska and the Doboј city emergency headquarters.

The activities undertaken during and after the floods were as follows:

- Engagement of all Civil protection resources,
- Engagement of commercial entities with resources to act during flood,
- Engagement of the Ministry of Internal Affairs of the Republic of Srpska,
- Engagement of specific resources of the B&H Armed Forces,
- Sharing information with the citizens through the media,
- Population evacuation,
- Pumping of the water from the flooded facilities,
- Conducting hygienic, epidemiological and health protection measures,
- Supplying the citizens with food, water, toiletries and other supplies,
- Reparation of infrastructure in terms of maintenance of regular water and electricity supplies.

One of top priorities was to evacuate people from the flooded housing facilities and provide them with temporary accommodation. The city Assembly allocated facilities for the temporary accommodation of people whose houses were flooded. The total of 108 people was accommodated in the facilities of "Retirement home", PE "Directorate for Construction and Development of the City" and PE "Doboј Senior Nursing Home", whereas patients were also evacuated from the "Dialysis Center". We should point out that the majority of citizens whose homes were located at lower floors were moved to higher floors in both private and joint buildings. Once the water withdrew, citizens whose houses were flooded voluntarily moved to their family, neighbors or weekend houses [5].

The Republic Emergency Headquarters for the territory of the Republic of Srpska adopted a decision to

assign a telephone number through which the citizens could report missing persons in Doboј or other threatened areas. The call center was open 24 hours a day [14].

The rescue activities were supported by the members of the Helicopter Service of the Republic of Srpska and the B&H Armed Forces who offered the Miljkovac barracks to accommodate evacuated citizens and water and food supplies. The Ministry of Internal Affairs of the Republic of Srpska and the B&H Armed Forces continuously coordinated the activities to distribute food and water through all boats and vehicles available. The available vehicles allocated to the Republic Emergency Headquarters were then at the disposal of the Doboј PSAP, who coordinated the evacuation. Food and water were transferred via boats, but once the water withdrew the water and food supplies continued via military trucks. During the first seven days, food was distributed through the heads of condominium communities for all the citizens (around 30.000 users). Afterwards, the Republic Emergency Headquarters reached a decision to distribute water, food and baby products only for those directly affected by the flood (around 10.000 users). Starting from May 25, 2014, distribution points were used to allocate humanitarian aid more easily. Hot meals were served for 1.300 public center users on a daily basis with 152 volunteers engaged in aid distribution.

Once the rainfall ceased and the water withdrew, The Republic Emergency Headquarters engaged all available resources, equipment, people and companies in order to restore the catastrophic flood damage in the city of Doboј, particularly in terms of cleaning the city and removing the bulky garbage. Many fire squads were employed in order to drain water from flooded underground facilities and provide tanks with drinking water. The assistance was offered by the cities and municipalities of Banja Luka, Trebinje, Prnjavor, Bileća, Teslić, Celje, Srbac, Rogatica, East Sarajevo, Foča, Gacko, Mrkonjić Grad, Ugljevik, Višegrad and Petrovo.

The city health centers managed to adequately distribute medicines and hygienic products to all citizens regardless of extremely difficult circumstances. Following the flood, disinfection, disinsection and deratization of the flooded areas and facilities were conducted in order to prevent possible epidemic and infection among the population [5].

The floods were followed by many activities undertaken by both the Government of the Republic of Srpska and the city of Doboј focusing on incentives for private citizens and legal entities. The Government of the Republic of Srpska initiated a Solidarity Fund as a measure to mitigate the consequences of the floods. Also, as a priority, each flooded household was allocated the single payment in the amount of 5.000 BAM as an aid to restore the flooded facilities.

FLOOD DEFENSE PLAN IN THE CITY OF DOBOJ FOR THE UPCOMING YEARS

Most floods in the city of Doboj's territory are initiated by the overflow of the Bosna River, and partly the rivers of Spreča and Usora. The most pertinent torrential points in this catchment area are located along the riverbank from Ševarlija to Kožuhe settlements on the right Bosna River bank and from the city of Doboj to the Podnovlje settlement on the left riverbank. The water levels in the riverbeds vary and are largely dependent on the season and precipitation. The water levels reach their maximum in autumn and spring, and the minimum water levels are registered in late summer and early autumn.

It is the heavy rainfall and sudden snow melting, or both, that directly trigger the floods. The height of the flood wave is mostly dependent on the amount of precipitation and large concentration of long-term rainfall. Short downpours cause local floods but long rainfall affects the entire watershed of the rivers resulting in sodden soil and increased water level along the watershed. The Doboj floods were mostly a consequence of long rainfall within the Bosna River catchment area. The city flood defense was difficult due to the large zone of the Bosna River overflow over the main road. The zone was around 850 meters long, from the Usora River mouth to the Doboj electricity substation. The Liješanj brook is the next critical point which additionally complicates the flood defense [8].

Bearing in mind all the aforementioned facts, we may infer that there are four critical points in terms of flood in the city of Doboj. The following critical points at which the city's population is most threatened are as follows:

The first critical point – location

In cases of high water levels of the Bosna River, once the water level reaches 4.80 m at the measuring bar, the backwater at the Liješanj brook may cause the flooding of the Usora local community and the entire urban area up to the "Luka" pumping station. Nevertheless, a partial regulation of the Liješanj brook stream entailed the construction of a 2.5 meter high defensive wall. Along with the regular cleaning of the Liješanj canal, the chances of flooding were significantly reduced.

The second critical point - location

The overflow over the defensive embankment takes place once the Bosna River water level reaches + 6.00 meters and the inflow surpasses the riverbed capacities. The flood wave pours over the M-17 main road covering 4.150 meter distance, from the pumping station to the Usora's mouth into the Bosna River. There is a 3.200 meter long overflow over the embankment, ranging from the point where the local road intersects the M-17 main road, over the Makljenovac local community, Elektro

Doboj substation, the turn to the "Džungla" swimming pool from the M-17 main road, all to the pumping station located at the city entrance leading to Bare local community. Then, the water spreads quickly and devastates and floods the settlements of Usora, Centar and Donji grad. Both the population and property are threatened by the flood wave.

Encouraged by the May 2014 floods, the city of Doboj constructed a protection network against water overflow from the Bosna River. The 2.400 meter long defensive embankment is set along the M-17 main road, starting from the point where the local road intersects the main road to the Makljenovac local community and Elektro Doboj substation. The embankment includes mobile concrete blocks, which greatly decrease the chances of flooding the Usora settlement and the urban area. It was in 2020 that the entire riverbed of the Liješanj brook, the left Bosna tributary, was cleaned. There was also a partial cleaning of the Lukavica riverbed which covered 1.500 meters (from the stationary to the Bešići - Ostojići bridge), which solved the issue of the Lukavica overflow in the settlement of Bušletić [7].

The third critical point - location

There is a flood threat and potential breakdown of the city sewage pumping station due to intensive rainfall and downpours. The water which pours from the local hills down to the urban area triggers the flooding of lower floors in all facilities and 180 hectares of land. We should point out that there are no backup electricity supplies at the pumping station, which is yet another threat in cases of floods.

The fourth critical point - location

The Bosna River water level above +5.30 meters would trigger the flooding of facilities located along the „Šećerane“ canal on the Usora River, and the „Luke“ and „Bosanka“ water supply lines' pumping stations because of the water retreating to the Bosna River and the lack of a pumping station at the canal. The same water level would also flood the City's thermal power plant in Prijedjel Donji (ground floors at point 0) and the facilities located in low Poljica area along the Spreča's mouth into the Bosna River.

Apart from these four critical points which threaten the urban areas, we should also mention the rural areas. Namely, once the Bosna River water level reaches +5.50 meters, the entire Doboj region is under the flood threat due to the lack of defensive embankment which might offer protection in cases of Bosna, Usora and Spreča high water levels. If the Bosna River water level reaches +6.00 meters, the following areas would certainly be flooded: the left river bank and the Maglaj - Doboj - Modriča main road, as well as the railway roads on the right river bank including the agricultural soil and infrastructure facilities in the local communities of Rječica, Paklenica Don-

ja, Trbuk, Jabučić Polje, Ševarlije, Pridjel Gornji, Pridjel Donji, Doboј Novi, Poljice, Kostajnica, Grapska, Bušletić, Osječani, Kožuhe, Bare, Bukovica Velika, Bukovica Mala, Čivčije Bukovačke, Kladari, Johovac, Kotorsko, Bukovac, Vranduk, Ritešić, Majevac and Podnovlje, covering the surface of around 3.000 hectares. Furthermore, there is a flood threat to the settlements of Poljice, Lipac, Suvo Polje, Tekučica and Boljanić covering the area of around 300 hectares along the main road to Tuzla due to potential backwater of Spreča and Bosna rivers, with minor deviations between the railway to Tuzla and the right Bosna riverbank. The lack of defensive embankment and poorly maintained water facilities could also threaten the following areas: Bukovica Velika (the area is often flooded by the Rudanka River and the water further overflows to Čivčije Bukovičke settlement due to insufficient water drainage at the M-17 main road and the dam constructed to provide water supplies to the local fish pond); settlements of Stanovi and Ljeskove Vode (poor management of the Rudanka riverbed and inadequate water drainage on the local roads, especially in the area of the Stanovi train station). Also, there is a 300-400 meter long cluttered canal on the right side of the Doboј - Banja Luka regional road and a narrow water flow section at the exit of the railway road where a car road was constructed.

Bearing in mind the fact that the large water inflow into the Modrac Lake and the water overflow caused an unfavorable hydrological situation at the Bosna, Spreča and Usora rivers back in 2014, a special attention should be paid to the hydrological system of the lake in order to conduct timely activities and mitigate all possible consequences.⁴ If the dam on the Modrac Lake collapsed, the flood wave would reach the city of Doboј (the settlement of Suvo Polje) in 230 to 240 minutes, Stanić Rijeka gorge in 260 minutes (4 hours and 20 minutes), and the mouth to the Bosna River in 4 hours and 33 minutes. The speed of the front wave is around 4.7 m/s. The Spreča River water depth in Doboј is around 5 meters in terms of the maximum average water level and it would flood 300 meters of the area outside the riverbed at the Suvo Polje point. The water level right before the Stanić Rijeka gorge would be 9.8 meters and around 8 meters in the gorge where backwater is usually formed, so it would flood the roads and the railway to Tuzla and the Doboј -Tuzla railway tunnel. The direction of the flood wave would threaten all the facilities and land within its reach. There is no threat for the city itself due to the embankment on the left Bosna riverbank ranging from the Usora river mouth to the Bare settlement. Still, the belt rang-

⁴ The Modrac dam is located in the municipality of Lukavac. The Modrac Lake accumulation is formed by the Spreča and Turija rivers and their tributaries. The accumulation surface is 16.69 km². The total capacity of the accumulation is 66.5 million m³. The overflow point is 200 meters. Water discharges from the accumulation through three outlets. In cases of high water inflow when the water cannot be discharged through the outlets, the water is further raised to the dam and the three dam spillways after which it outflows into the Spreča River.

ing from the main road to the Poljice settlement, including the settlements of Poljice, Svjetlić, Srpskih ozrenskih brigada, and Robna pijaca would be under a threat from the flood wave originating from the Bosna and Spreča rivers. It is the protection measures as integral parts of urban plans and the construction of defensive embankment that play a pertinent role in flood protection. Nevertheless, the construction of settlements failed to obey the construction terms and conditions [8].

Conducting the flood protection and rescue measures

In line with the Water Law of the Republic of Srpska, mandatory flood defense measures are applied within the regular and emergency flood defense plans.⁵

The criteria for the flood emergency announcement depend on the Bosna River water level at the water meter bar near the Bare vet station. Regular flood emergency is announced once the water level is above 3.00 meters, and the extreme flood emergency is announced once the water level reaches 4.5 meters with a tendency to grow (another reason might be the long-term high water level). The regular flood defense plan refers to the organization of the pumping station's full capacity functioning. If the water levels suggest tendency to grow, the city of Doboј's Emergency Headquarters are on standby. The emergency flood defense plan entails the activation of the Doboј's Emergency Headquarters and the following activities are conducted: all companies which own technical, material and human resources and equipment necessary for the flood defense are on alert, the public is informed about the flood threats and measures in cases of flood protection and rescue, and finally, the defense dykes and facilities are constantly monitored.

The following activities are conducted in cases when the Bosna River water level reaches 4.80 meters crucial for the emergency plan: flood defense at specific locations (the Liješanj brook and Bare settlement) and mobilization of all companies which signed the contract to engage in the activities of civil protection for the purpose of temporary defensive embankment construction. There is an emergent closure of six outlets/openings as the nine existing mobile concrete blocks are fit in in order to strengthen the defensive wall along the M-17 main road. Once the Bosna River water level reaches 5.30 meters, the flood protection measures and activities are conducted and the citizens, civil protection workers and other organizations are on alert. The water level of 5.50 meters suggests that the Doboј city emergency headquarters instruct the hydraulic structure and the canal to close (Šećerana) at the former "Bosanka" site. If there is an overflow or an uncontrolled water discharge at the M-17 main road and the water level is above 6.00 meters,

⁵ The Water Law of the Republic of Srpska arranges the integral water management in the RS territory, which entails water protection, water usage, protection from water damages, arrangement of waterstreams, institutional framework and activity funding.

the city mayor declares the state of emergency for the Doboj region. The state of emergency suggests the construction of local embankments, the evacuation of citizens and other activities in line with the planning documents and the current state of affairs.

The flood protection and rescue plan of the city of Doboj clearly defined the management and conducting of measures for protection and rescue in cases of floods. The plan defined the following sections:

- location of the emergency headquarters depending on the situation on the ground;
- roads for the evacuation of citizens;
- the city emergency headquarters' activities when on alert;
- the city emergency headquarters' activities when there is a direct threat and flood risk;
- the city emergency headquarters' activities during the floods;
- the city emergency headquarters' activities during the flood consequence removal;
- the city emergency headquarters' activities in terms of communication during the floods.

We should also mention that the plan entails prevention activities, response measures, recovery measures and reports on conducted activities [7].

CONCLUSION

Natural disasters occur more and more frequently due to climate change. Flood is the most common one in the Balkans. Over the past 60 years, Bosnia and Herzegovina has witnessed several major floods as follows: in May 1965, three floods in 1976, in June 2001, in April 2004, in December 2010, and in May 2014. Devastating floods took place in the Republic of Srpska in May 2014. Sudden heavy rainfalls caused major floods in many cities and municipalities and those most affected were Doboj, Šamac, Modriča, Čelinac, Banja Luka, Bijeljina and Prijedor.

The massive water overflow from the riverbeds of Bosna, Usora and Spreča and the Modrac Lake resulted in an alarming hydrological situation in the city of Doboj in May 2014. The floods covered 5.168 hectares and the total estimated damage was around 1.72 million BAM. According to the official information from emergency headquarters, there were 18 human victims most of which (11) were registered in the city of Doboj.

Along with damages to infrastructure, there was also significant damage due to increased transport labour. In the month of May, over 70,000 vehicles were redirected from sections of the main road around Doboj to alternative roads, which caused increased time of travel and transport of goods, as well as all other operational expenses.

Decisions adopted by emergency headquarters resulted in a whole range of measures and activities focus-

ing on providing help and assistance to the citizens – evacuation and accommodation, water pumping, health and hygiene measures, food and water supplies, and electricity supplies. Measures and activities following the floods included city cleaning, bulky garbage disposal, medicines and utility products distribution, financial assistance for the affected households and businesses, and the disinfection, disinsection and deratization in order to prevent epidemic and infections. Both during and after the floods, all available resources were engaged: civil protection services, companies, the Ministry of Internal Affairs of the Republic of Srpska, B&H Armed Forces, the Helicopter Service of the Republic of Srpska, health centers, fire squads, diving clubs, and other communities, including a large number of volunteers.

There were four critical points (locations in the city particularly threatened by flooding) identified in the city of Doboj based on the estimations and the rescue and flood prevention plans following the floods. There was a construction of a 2.5 meter high defense wall regulating a part of the Liješanj stream. Also, the riverbeds of Liješanj and Lukavica were cleaned and mobile defensive concrete blocks 2.400 m long were set in order to prevent the Bosna River overflow on the left river bank across the dyke. The authorities identified the following risks in case the city is hit by the flood again: the lack of a drain station on the water canal, the lack of a backup electricity supply source at the pumping station, the lack of defensive infrastructure along the Bosna, Usora and Spreča rivers, the lack of dykes and poorly maintained existing water stations, blocked canals along the roads, the construction of buildings and settlements without complying with the regulatory and urban spatial plans. All the identified risks suggest an urgent need for adequate measures and activities for the hazard elimination.

In order to protect the city of Doboj from future floods, we propose the following activities: the construction of upper stream accumulations and retention basins, the cleaning of all canals and riverbeds, management of watersheds, the prevention of uncontrolled waste disposal at riverbeds and canals, the prevention of unplanned gravel exploitation, the prohibition of construction in flooding zones, occasional population education via practical seminars on "Tactics of flood protection and rescue" which should include mandatory training.

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