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EXPLORING THE POTENTIALS OF SMALL URBAN STREAMS IN CREATING BLUE-GREEN INFRASTRUCTURE IN THE CITY OF NIŠ, SERBIA

Abstract:

"Blue-Green Infrastructure" (BGI) is a simple and cost-effective natural resource that enhances the appeal, resilience and sustainability of urban areas. Small urban streams are an important BGI component that is often underused, especially regarding stormwater management. The aim of this research is to explore small urban streams and their integration into BGI in the urban area of Niš, and to point out the benefits that their restoration would bring in functional, social and environmental terms. Results of this study show that Niš urban area has significant "Blue" natural capital in small streams, and that standing planning documents support the creation of BGI to some extent. These are good grounds for the implementation of BGI in urban planning practice.

Keywords: stormwater management, stream restoration, urban area resilience, planning measures

ИСПИТИВАЊЕ ПОТЕНЦИЈАЛА МАЛИХ УРБАНИХ ВОДОТОКОВА У КРЕИРАЊУ ПЛАВО-ЗЕЛЕНЕ ИНФРАСТРУКТУРЕ У ГРАДУ НИШУ, СРБИЈА

Сажетак:

„Плаво-зелена инфраструктура" (ПЗИ) је једноставан и ефикасан природни ресурс који повећава привлачност, отпорност и одрживост урбаних подручја. Мали градски водотокови су важна ПЗИ компонента која је често недовољно искоришћена, посебно у погледу управљања атмосферским отицајем. Циљ овог рада је да истражи мале урбане водотокове и њихову интеграцију у ПЗИ у урбаном подручју Ниша, и да укаже на користи које би њихова обнова донела у функционалном, социјалном и околишном смислу. Резултати ове студије показују да урбано подручје Ниша има значајан „Плави" природни капитал у малим потоцима и да важећи плански документи у одређеној мери подржавају стварање ПЗИ-ја. Ово су добри темељи за имплементацију ПЗИ у урбанистичку праксу.

Кључне ријечи: управање атмосферским отицајем, обнова потока, отпорност, планске мере

1. INTRODUCTION

Increasing urbanization and especially urban densification have resulted in the increase of paved surfaces in urban areas, which are usually impervious [1]. Impervious land cover alters both the quantity and quality of surface runoff water. In terms of the hydrologic cycle, less water is infiltrated and more runs off at the surface. Also, most of the water runoff nowadays contains pollutants caused by human activities (hard metals from roads, roofs and paved surfaces, lawn chemicals from fertilization). This runoff is conventionally conveyed into pipe-based drainage systems (so-called "grey infrastructure"[1]) and then transported further, directly into waterways, instead of being filtered through soil. Therefore, it can be stated that impervious surface affects the physical structure of streams and rivers, as well as biodiversity and abundance of wildlife. In urbanized areas, large volumes of excess stormwater runoff in a short amount of time can cause flash flooding, water pollution and destroyed habitat. All of these points significantly contribute to the importance of adequate stormwater management.

It is becoming more and more evident that the traditional "gray" approach to infrastructure, which discharges stormwater into pipes, is unable to respond to the challenges of intense urbanization and stresses associated with climate change. New strategies and approaches have been developed in the last couple of decades to mitigate the impact of stormwater runoff and pollutant loading. The role of "Blue-Green Infrastructure" (BGI) in stormwater management in highly urbanized areas is becoming increasingly important as an alternative to conventional pipe-based stormwater management in cities [2]. BGI offers a feasible and valuable solution for urban areas facing the challenges of climate change, by complementing or even replacing the need for grey infrastructure [3].

Blue-Green Infrastructure grid is created by interconnecting various natural open spaces in urban areas, with green or blue linear pathways for walking, cycling, kayaking, rowing and other recreation. Blue-green infrastructure connects: (1) the *blue component*, which refers to urban hydrological functions, such as watercourses (rivers, streams) and still waters (lakes, ponds), and (2) the *green component*, which entails vegetated areas in urban environment, such as urban forests and meadows, parks and protective greenery. As many urban areas already possess some natural capital (blue and green), implementing the BGI grid is not a technologically demanding or expensive task. Various authors [4][5][6][7] state that BGI has multiple benefits:

- Mitigation of the "heat island" effect[2],
- Improved stormwater management and reduced flooding and erosion in urban areas,
- Improved adaptation of urban areas to climate change,
- Establishment of new recreational areas and sport fields,
- Preservation of biodiversity and restoration of the ecosystem,
- Improved water quality,
- Improved health of urban residents,
- Creation of high quality urban areas with added aesthetic value,
- Socio-economic benefits.

Small urban streams are a very important BGI element. Often, small urban streams seem to be neglected, devastated and forgotten, and their potential stays hidden. It is only with a flood event that they return to the focus of people's attention [8]. Restoration of small urban streams and creeks and re-profiling existing urban water edges can help build capacity for stormwater through retention and detention [6]. Many cities around the world are exploring the possibilities to use small urban streams as a BGI element to reduce the city's risk of flooding from intense rainfall and strengthen the ecosystem, and thus improve the resilience of urban areas. Cities such as Graz (The Streams of Graz program, 2006) and Oslo (Oslo Reopening Waterways Project, 2002) are already implementing programs for restoration of small watercourse in order to help address the climate change challenges (Figure 1).

[1] "Grey infrastructure" is called that way because of the massive amounts of concrete and metal typically involved [9].

[2] "Heat island" is a phenomenon that occurs in urban environments with temperatures that are much higher than in natural environment, due to intensive urbanization and the increase of paved surfaces.

a

(a) Flood protection and renaturation of the Gabriachbaches River, Graz. Ecological upgrading of the river by removing the former concrete half-shells and creating a meandering low-water channel with wooden pilots.

Source: http://www.wasserwirtschaft.steiermark.at/cms/beitrag/10006871/4579632/

b

(b) Reopening of approximately 650 m of the Hovinbekken stream, Oslo, with a natural filtration system to create a clean habitat to native species and a popular recreation zone. Until the 1980's, the stream was considered problematic and it was put in underground pipes and culverts.

Source: https://www.klimatilpasning.no/eksempler/blagronne-losninger/hovin-bekken/

Figure 1. *Restoration of small urban streams in Graz and Oslo.*

Aside from the watercourse itself (blue component), green areas in the riverfront zone that are designed to retain, filter and absorb stormwater can significantly reduce flooding in urban areas. Riverfront projects that are planned and developed as natural cleaning systems, with sedimentation basins, water rapids and shallow waters with dense vegetation, also help to control pollution and improve water quality for the urban citizens and wildlife. From the aspect of sustainability, it is of crucial importance to filter pollutants before they enter the drinking water system. Vegetation slows the runoff water, filters it and then allows it to infiltrate into the ground or into a storm drain, thereby improving water quality.

There are additional benefits of vegetated areas next to the watercourses. Green space accessibility is associated with increased physical activity [10][11]. By implementing greenery in the flood plain of river or stream, new public open spaces are created and accessibility of sport-recreational amenities is improved. In this manner, healthier lifestyle for the denizens is promoted, and the overall improvement of population health may be expected.

Floodable public open spaces are an excellent opportunity for modern stormwater management within urban areas because they can have large retention capacity. They are particularly convenient and easy to use in watercourse-adjacent areas, where they can be implemented as floodable parks and recreation spaces or floodable public space, such as wet plazas and squares [6]. Floodable parks and recreation areas throughout the watershed receive stormwater outflow and can also provide retention, cleansing and infiltration of stormwater by using technical elements such as bioswales, rain gardens, bioretentions, infiltration trenches etc. Floodable public spaces are typically hardscapes with some potential vegetation [6]. In addition to using formerly mentioned technical elements in vegetated areas, they can implement porous pavement in order to absorb more quickly large amounts of stormwater and therefore reduce flooding. Additionally, floodable open spaces can convey stormwater to drainage systems or rainwater tanks, in order to allow the spaces to return to normal use quickly and to reuse stormwater runoff.

Finally, by reviving small urban watercourses, socio-economic benefits are achieved. The overall design can restore not only the ecosystem, but also create new neighborhood character and spaces for social interaction. Even though the investment might initially be higher than standard waterfront design, in the long run it will be cheaper than total costs associated with repair of erosion and flood damages.

This research explores the impact of small urban streams within the concept of Blue-Green Infrastructure, and considers their potential use in shaping the post-socialist urban landscape in the City of Niš, Serbia. With a population of approximately 260.000 inhabitants (2011 Census), Niš is the third largest city in Serbia and a typical post-socialist city of medium-size. Post-socialist

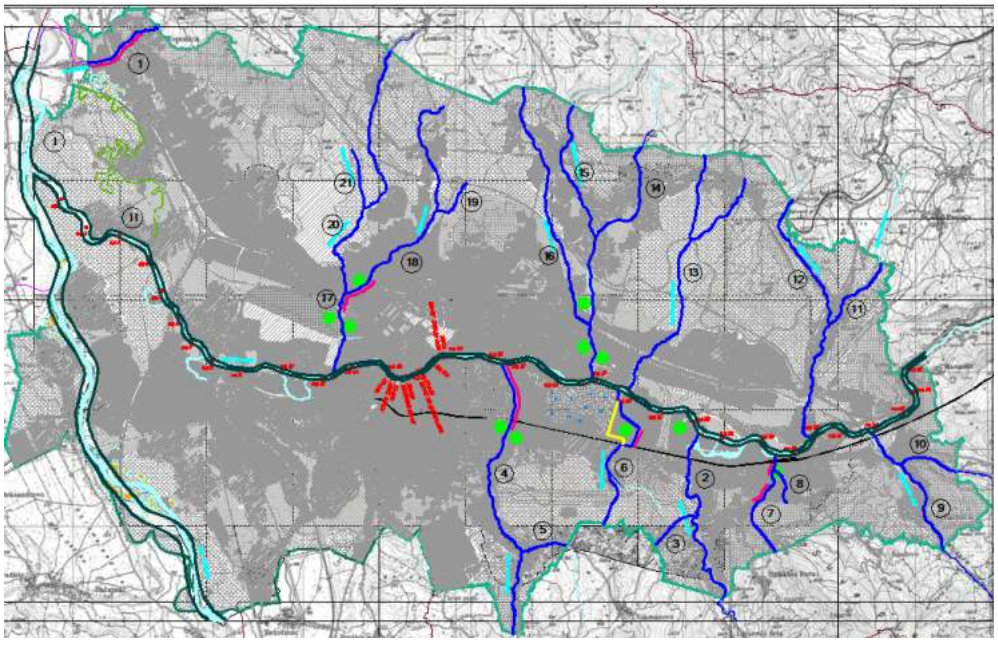
development period had significant implications upon the urban landscape of Niš, with urban densification and loss of public open space/green areas being the most remarkable features of transition [12]. The increase of paved surfaces had significant environmental impacts. Traditional stormwater system is often unable to absorb and process all of the excess water runoff, resulting in flooding of various parts of urban area. In Niš territory there is a multitude of small watercourses, which have torrential character and are completely underused from the BGI perspective. Unfortunately, the BGI approach has not been yet been considered in urban planning policy and culture.

It is the standpoint of this research that the creation of the Blue-Green Infrastructure grid, that would involve small urban streams as the blue component, could significantly improve not only stormwater management in Niš, but also provide new recreational spaces, restore the ecosystem and improve the overall quality of life of urban residents. Therefore, this paper investigates small watercourses in Niš territory, evaluates their current state, explores proposed planning solutions and examines the possibilities of their integration into the Blue-Green grid in the City of Niš.

2. MATERIALS AND METHODS

There are twenty-three significant watercourses in the territory of the City of Niš, which is the area covered by the Master Plan (MP) of Niš 2010-2025 (Figure 2). Four of them are waters of the first order and the rest are waters of the second order[3]. Two major watercourses of the first order in the analyzed area are rivers Nišava and Južna Morava. All remaining watercourses are smaller and can be classified as urban streams.

This research explores the potential of small watercourses of the City of Niš in creating a BGI grid, by using a review of relevant literature, analysis of standing planning documents and field observation. Small urban streams represent the focus of this research, with their impact on urban and suburban area of the City of Niš. The effect of these watercourses on rural settlements, beyond urban border, is not evaluated in this study. A total of 21 small streams located within the administrative area of the City of Niš are analyzed, and their main characteristics are presented in Table 1. In the defined urban area, these watercourses have a total length of about 90 kilometers.



Border of MP of Niš 2010-2025 area
Localities endangered by flood waters
Large watercourses
Small urban streams
Regulated stream
Newly planned stream route

[3] According to the Water Law [13], in line with their importance for water management, surface waters in Serbian territory are divided into waters of the first and second order.

I Južna Morava, II Nišava, 1. Toponička River, 2. Kutinska River, 3. Vukmanovski Creek, 4. Gabrovačka River, 5. Vukmanovska River, 6. Suvodolski Creek, 7. Kovanlučki Creek, 8. Suvobanjski Creek, 9. Jelašnička River, 10. Kunovička River, 11. Malčanska River, 12. Crveni Creek, 13. Knezselski Creek, 14. Matejevačka River, 15. Kamenička River, 16. Brenička River, 17. Rujnička River, 18. Humski Creek, 19. Brenički Creek, 20. Rujnički Creek, 21. Grkovački Creek. Source: Authors' drawings on the MP of Niš 2010-2025: Infrastructure – Plan of regulation of watercourses

Figure 2. *Watercourses in the urban area of the City of Niš.*

Table 1. *Watercourses in the City of Niš territory*

No.	Name	Category	Tributary of	Floods (year of critical event)	Riverbed regulation	Length in MP area
1.	Toponička River	I	Južna Morava	Yes (2012, 2018.)	Partly regulated	2,1 km
2.	Kutinska River	I	Nišava	Yes (2004, 2012, 2014, 2018.)	Partly regulated	8,0 km
3.	Vukmanovski Creek	II	Kutinska River	No	Unregulated	1,3 km
4.	Gabrovačka River	II	Nišava	Yes (1926, 1948.)	Partly regulated	5,5 km
5.	Vukmanovska River	II	Gabrovačka River	No	Unregulated	1,1 km
6.	Suvodolski Creek	II	Nišava	Yes (2014.)	Mostly unregulated	4,5 km
7.	Kovanlučki Creek	II	Nišava	Yes	Partly regulated, insufficient existing regulation	3,0 km
8.	Suvobanjski Creek	II	Kovanlučki Creek	Yes	Unregulated	1,0 km
9.	Jelašnička River (Studena)	II	Nišava	Yes (2014.)	Partly regulated	2,7 km
10.	Kunovička River	II	Jelašnička River	Yes (2014.)	Unregulated	1,5 km
11.	Malčanska River	II	Nišava	Yes	Unregulated	5,2 km
12.	Crveni Creek	II	Malčanska River	No	Unregulated	3,7 km
13.	Knezselski (Suvodolski) Creek	II	Nišava	Yes	Unregulated	9,0 km
14.	Matejevačka River	II	Nišava	Yes	Unregulated	7,0 km
15.	Kamenička River	II	Matejevačka River	No	Unregulated	7,5 km
16.	Brenička River	II	Matejevačka River	Yes	Unregulated	7,0 km
17.	Rujnička River	II	Nišava	Yes	Partly regulated, insufficient existing regulation	2,2 km
18.	Humski Creek	II	Rujnička River	Yes	Partly regulated	8,2 km
19.	Brenički Creek	II	Humski Creek	No	Unregulated	1,2 km

20.	Rujnički Creek	II	Rujnička River	Yes	Unregulated	7,0 km
21.	Grkovački Creek	II	Rujnički Creek	No	Unregulated	1,6 km
Sources of data: MP of Niš 2010-2025; Operational plan for flood defense in the City of Niš territory for watercourses of the II order for 2018; Own research						

The planning database involves 16 standing documents: the MP of Niš 2010-2025 and 15 Plans of General Regulation (PGRs) [14-30], which cover entire municipalities or parts of municipalities of the City of Niš:

- Crveni Krst (CK) - Phases I, II, III, IV west (IVw), IV south (IVs),
- Pantelej (PN) - Phases II, III east (IIIe), IV north (IVn), IV northeast (IVne), IV northwest (IVnw),
- Niška Banja (NB) - Phases I, II, III,
- Palilula (PL) - Phase II,
- Medijana (ME).

Planning documents that are considering each of the watercourses are given in Table 2.
Current characteristics of small urban streams, their regulation, arrangement and related flooding issues, as well as traditional habits in using the space in waterfront zones, are determined on the basis of field investigations, the use of various legislation, satellite photo images and available data from internet sources. Review of standing planning documents involves the analysis of planned land uses adjacent to the watercourses in order to determine their potential for BGI. The results of this research should help to provide a better insight into the "blue" natural capital of the city of Niš regarding its current state and proposed planning solutions, and to establish a quality database for the creation of BGI grid in Niš urban area.

3. WATERFCOURSES IN THE CITY OF NIŠ

Erosion processes and torrential floods are some of the most significant natural hazards in Niš area. Small urban streams in Niš city territory all have torrential character. After heavy rains or snow melting, their flow volume increases and a large amount of debris is carried with the flow. In summer months there is very little water flow, so sometimes the streams dry out. Current state regarding riverbed regulation and main issues for each of the analyzed small urban stream is discussed in more detail in this chapter. Regarding flood protection from the outflows of small streams in the territory of the City of Niš, some planning measures are provided in the MP of Niš and in PGRs of various city municipalities, and these are also further discussed here.

The role of urban planning in protecting buildings from flooding is extremely important, in terms of determining the permitted use of each zone according to flood risk [31]. Therefore, this research investigates land uses that are planned by current planning documents along the analyzed watercourses, and the results are presented in Table 2.

Toponička River. Toponička River is the right tributary of Južna Morava, and it's only tributary in Niš territory. Part of its riverbed, located in the area covered by the MP, is regulated on the course downstream of the bridge in the settlement Gornja Toponica. Riverbed is not regulated upstream of the bridge. Therefore, in the section with natural riverbed, the course is variable and does not have sufficient throughput. After heavy rainfall, stormwater is retained at the parterre level due to rising levels of groundwater, which poses a threat for residential structures and agricultural facilities in this part of the settlement.

Planning documents suggest regulating the unregulated part of the riverbed in order to ensure better transport of suspended sediment and debris, consolidation of riverbeds and shores, protection of settlements against flooding, and receiving stormwaters from catchment areas along the watercourse. Protective green belt along Toponička River is also envisioned.

Kutinska River. Kutinska River is the fourth largest tributary of Nišava River, and flows into it near the settlement Nikola Tesla. It is about 40 kilometers long in total, has a large and indented river basin with a large number of small tributaries, the majority of which are outside the MP. Kutinska River has a considerable longitudinal fall in the upper section and part of the midstream, while the remaining part of the midstream, as well as lower watercourse have a small longitudinal fall. The middle and upper parts of the river have almost linear riverbeds, while numerous meanders are formed in the lower section of the watercourse (which is in the scope of this research). The large

amount of sediment downstream of Prva Kutina settlement is an indicator of torrential character of Kutinska River. Torrential floods in this basin are frequent and directly affect the hydrological regime of Nišava River, as well as flooding of suburban settlements.

Kutinska River is largely unregulated. Regulation works on Kutinska River were carried out in the length of 300 m from the confluence with Nišava River towards the railway bridge. The section upstream of the railway bridge is unregulated with a low flow profile, so that arrival of large waters leads to overflow and flooding of adjacent surfaces, especially residential and industrial buildings in the settlement of Nikola Tesla. In the analyzed section of Kutinska River, along the right bank, there are single family houses with gardens, which often infiltrate into the designated waterfront area. Riverbed is neglected, filled with waste and dense weeds. The issue of unresolved land rights is a major impediment for the regulation of this watercourse. Along the left bank of Kutinska River there is also a large stretch of agricultural land.

Planning documents suggest further regulation of Kutinska River in order to protect against flood waters by widening and deepening the riverbed. Regulatory work would primarily prevent the overflow of water from the riverbed in cases of large waters. The width of the planned area intended for regulation of Kutinska River is 32 m. A trapezoidal profile is recommended but not binding. Further construction on the watercourse route is prohibited and it is mandatory to clean and maintain the riverbed regularly.

Vukmanovski Creek. This small urban steam with unregulated riverbed is a left tributary of Kutinska River, and it flows through agricultural land only.

Gabrovačka River. Regulation of the riverbed is only partly completed. Complete regulation is performed in the section from the confluence with Nišava River to the railway line in the length of 1660 m. Riverbed is designed as a two-level trapezoidal profile. Bottom width of the riverbed is 4.0 m. Minor trough is sized according to fifty years of large water, and major trough according to 100 years of large water, with an elevation of 20cm. Unregulated riverbed is located in the segment upstream from the railway line. The 1400 m section from the railroad to the road bridge in the south is partially profiled and cleared of debris. The rest of the riverbed is 5.500 m long and totally unregulated. Due to low throughput of the profile, when reaching high waters, flooding of adjacent areas occurs in the section of unregulated riverbed.

Proposed planning actions involve increasing the throughput capacity under the railway bridge by opening new culverts, and implementing a two-level profile riverbed in the 1400 m unregulated segment from the railway to the southern road bridge.

Vukmanovska River. As its largest right tributary, Vukmanovska River flows into Gabrovačka River in the center of Gabrovac village. It does not have a regulated riverbed.

Suvodolski Creek. Natural riverbed of Suvodolski Creek does not have a clearly defined profile on certain sections of its course. Regulatory works were done only in the segment length of 400 m, from the center of Brzi Brod settlement upstream to the railway. Problems are particularly manifested in the lower part of the stream, throughout the settlement of Brzi Brod. After every heavy rain or melting snow, water overflows from the shallow natural trough and floods the surrounding residential buildings. Tubular culvert at the Niš-Niška Banja road, which is located in the upper zone of the river profile, represents a barrier even for small and medium waters. Therefore, increased sediment deposition and a decrease in watercourse profile occur in the upstream section.

The need to regulate this torrential watercourse is evident. Therefore, a completely new route for the regulation of Suvodolski Creek is planned, displacing a part of the stream's natural course. For this purpose, the urban project was made, but it has not been implemented yet. Regulation works are also planned in the urbanized area, in the settlement Suvi Do. In the segment of the watercourse that passes through agricultural land, the MP suggests an expansion of the natural riverbed according to the principle of field regulation.

Kovanlučki Creek. This urban stream has prominent torrential characteristics. Kovanlučki Creek is regulated throughout Niška Banja settlement to the Niš–Jelašnica road, and in one more segment further downstream until the railway. Existing riverbed regulation through the settlement of Niška Banja was built partly with open canals and partly with closed canals. Trough is lined with stone in cement mortar and it is partly filled with sediment and deposits. Therefore, due to the decrease of flow profile, after emergence of large waters, flooding of surrounding fields occurs.

Planning measures suggest thorough cleaning of the Kovanlučki Creek riverbed from debris, deposits and other material.

Suvobanjski Creek. Suvobanjski Creek flows as a right tributary into the regulated bed of Kovanlučki Creek just before the confluence with Nišava River. Suvobanjski Creek has a low flow profile and upon reaching large waters an outflow occurs as well as flooding of surrounding area.

Planning documents propose the regulation of this stream. Regulation should ensure that the settlement is protected from floods, and improve the elements of natural riverbed, in order to achieve more favorable conditions of water flow and sediment as well as the safety of existing facilities. A trapezoidal profile is recommended but not binding. Along the watercourse, a 3 m wide area is planned on one side for maintenance, and on the other a 1,2 m wide footpath.

Jelašnička River (also called Studena River). This urban stream is made up of two major constituents who merge in the village Donja Studena. Jelašnička River is of torrential character with a considerable longitudinal fall, and consequently has a large amount of drawn sediment. Parts of the watercourse of Jelašnička River were regulated, mainly in the areas passing through settlements. However, in certain sections in the villages of Jelašnica and Čukljenik, the riverbed is narrowed, partly covered with sediment and debris, and overgrown with trees, thus increasing the risk of torrential flooding. Deposits are particularly evident through the village Jelašnica itself, where the longitudinal fall is smaller. In 2015, regulatory work began on Jelašnička River in the area of planned development, on watercourse section that intersects with the highway. Regulation of the riverbeds should prevent water outflow from the troughs at the occurrence of high waters, and thus secure endangered objects and adjacent surfaces.

It is planned to regulate Jelašnička River from Kunovačka River to Nišava River. The upstream section of Jelašnička River, through the densely populated village of Jelašnica, is proposed for further consideration in Plan of Detailed Regulation (PDR). In the area defined for PDR, in addition to Jelašnička River, an integrative tourist zone is also planned, and some basic guidelines for the arrangement of this zone are proposed by the PGR. The following uses are suggested along the upstream route of Jelašnička River: (1) landscaped protective greenery and (2) smaller residential areas adjacent to the river, that are endangered by the river outflow. Parts of protective greenery along the river should be designed with the following characteristics: (1) park features, especially in residential areas, (2) landscaping as a buffer area towards the intact nature of the southern part of the stream, (3) water wells with multiple structures of former water mills should retain their function of draining excess water, while reconstructing water mills, and (4) forming bicycle and pedestrian paths along the river and connecting them to the immediate environment.

Kunovička River. Kunovička River is the largest tributary that flows into Jelašnička River just before the confluence into Nišava. Its riverbed is not regulated. When reaching high waters, the most endangered area is the one upstream and downstream of the bridge on the road Niš-Jelašnica-Studena, especially when bridge opening gets blocked by trees, deposits and debris.

Regulation of Kunovička River on watercourse section that intersects with the highway also began in 2015. Planning documents suggest regulating Kunovička River along the entire route covered by the PGR.

For both Jelašnička and Kunovička Rivers the PGR prescribes leaving a minimum of 3 m corridor of open area along regulated watercourses, and a minimum of 5 m of open area along unregulated watercourses, for the case of flood protection. It is also mandatory to prohibit further construction on the watercourse route as well as to regularly clean and maintain the riverbeds.

Malčanska River. The riverbed of Malčanska River is not regulated. This river is of torrential character, with a large longitudinal fall and, consequently, a large amount of drawn sediment, whose deposits are particularly evident zones of bridges. In the village of Malča itself, the river flow profile is deep, so that there is no flooding of adjacent surfaces. Flooding occurs in the zone near the highway bridge (road to Svrljig) and directly downstream. When the level of Mačanska River reaches large waters, tubular culvert on the highway bridge gets blocked by debris and waste materials, and causes flooding of the bypass road as well as of the agricultural fields. Downstream of the culvert, riverbed profile is partially covered and overgrown with trees. Therefore, the river endangers the banks, bridge and areas downstream of bridge on the left bank.

As Malčanska River flows downstream through uninhabited area, and according to the planned land uses, following planning actions are proposed by the MP: (1) expansion of the natural riverbed according to the principle of field regulation on the segment of the watercourse through agricultural land, and (2) regulation and arrangement of the flow profile with a two-level trough on the watercourse segment throughout building area. However, there is no project documentation for the regulation of Malčanska River. Further urban consideration through the Plan of Detailed Regulation is suggested by the PGRs in order to regulate the riverbed. For the watercourse segment downstream

of the highway, the PGR prescribes a mandatory corridor of open area for flood protection - minimum of 3 m along regulated watercourses and 5 m along unregulated watercourses. It is also mandatory to prohibit further construction on the watercourse route as well as to regularly clean and maintain the riverbeds. Creation of a protective green belt is also suggested.

Crveni Creek. This small stream is the right tributary of Malčanska River and flows into it in the area of Malča settlement.

Further urban consideration through the Plan of Detailed Regulation is suggested by the PGR in order to regulate part of the riverbed. General planning guidelines suggest a creation of the protective green belt.

Knezselski Creek. Riverbed of Knezselski Creek is not regulated and is mostly overgrown with weeds and bushes. From the settlement Knez Selo to the confluence, this stream flows through the uninhabited area in the length of 6 km. Therefore, the outflow of the watercourse causes damage to agricultural land. The biggest issue concerns the bridge on the Niš-Svrljig highway, which gets clogged in times of large waters due to deposits, trees and debris. This causes flooding of the upstream section of about 300 m, and also endangers the downstream section of about 300 m whose riverbed profile is overgrown with trees and covered with deposit.

Therefore, two sets of planning measures are proposed in line with future land use: (1) expansion of the natural riverbed according to the principle of field regulation in the zone of agricultural land, and (2) regulation and arrangement of the flow profile with a two-level trough in the building area. Further urban consideration through the Plan of Detailed Regulation is suggested by the PGRs in order to properly regulate the riverbed. It is also mandatory to prohibit further construction on the watercourse route as well as to regularly clean and maintain the riverbeds. Formation of a protective green belt is suggested.

Matejevačka River. The basin of Matejevačka River is elongated and surface erosion is present throughout most of the basin. In the middle and lower parts of the basin, the stream carries large amounts of torrential sediment and has a variable and unstable trough. Matejevačka River receives Kamenička River just downstream from the village of Donji Matejevac, and Brenička River in the zone of the highway. No regulatory works were carried out on Matejevačka River. Main issues concern flow profiles on almost all bridges, which are partially enclosed by deposits, debris, shrubs and trees. In terms of flood protection, the greatest problem is the section of Matejevačka River downstream from the confluence with Brenička River to the confluence with Nišava, where the flow of large waters is increased by approximately 75%. Thus, the unregulated and narrowed flow profile of Matejevačka River through the village of Donja Vrežina cannot convey such large waters. The situation in Donja Vrežina is further exacerbated by illegal residential development along the shoreline of the minor (lower) trough.

In order to control fooling, the following planning actions are suggested by the MP: (1) the priority is implementation of flood protection regulatory works through Donja Vrežina settlement, (2) regulation of Matejevačka River till the conjuction with Brenička River with a two-level riverbed profile, (3) deepening of the riverbed downstream from the highway bridge, (4) deepening of the existing trough in the zones of bridges, and (5) realization of retarding embankments to the confluence with Nišava River. The PGR suggests a more detailed elaboration of Matejevačka River in the settlement Gornji Matejevac by designing a Plan of Detailed Regulation. For this purpose, a corridor of total width of 30 m is reserved. Until PDR is completed, the PGR provides some general guidelines for land use along the watercourse in Gornji Matejevac. PGR also suggests performing watercourse regulation with a “natural” design, using natural materials such as earth and stone, as well as the formation of a protective green belt.

Kamenička River. Regulatory works in the riverbed of the Kamenička River were not performed, only works on the anti-erosion control of its basin. Narrowing trough at intersections of watercourse and roads represent an issue in the settlements.

For the area of Donji Matejevac settlement, PGR suggest watercourse regulation by using “natural” design, with natural materials such as earth and stone, and the creation of a protective green belt. Through the area of Kamenica settlement, PGR prescribes the elaborationof the Plan of Detailed Regulation for river regulation.

Brenička River. This urban stream was a right tributary of Nišava River that flowed into Nišava downstream of the settlement Donja Vrežina. With the construction of Niš-Pirot highway, the natural riverbed of Brenička River was interrupted and partially displaced, and the waters of this watercourse were conveyed into the flow of Matejevačka River. There is insufficient throughput of

this newly formed riverbed section of Brenička River. Regulation of this section is necessary so that the flow profile could fit the required one. In Brenica village, the culvert under the road is partially filled, and the trough downstream of this culvert is narrowed, covered with sediment and occasionally overgrown with trees. The section in the area of Kamenica bridge is also overgrown with shrubs and trees, and the profile is partially filled with deposits.

PGRs prescribe the elaboration of a Plan of Detailed Regulation for the regulation of Brenička River. Formation of a protective green belt is also suggested.

Rujnička River. It is formed by two tributaries: Rujnički and Humski Creek, which merge in the settlement Ratko Jović in the urban area of Niš. The basin of Rujnička River has a lenticular shape, while the tributary basins have an elongated shape. Due to high level of groundwater in the settlement Šljaka, large waters often appear as an issue in the settlement. Regulation works on Rujnička River have not yet been completed. Works were performed in stages and in the following sections: (1) from the composition of Rujnički and Humski Creek, near the boulevard road, the regulated section of the trough starts with a cascade, and is lined with stone in cement mortar up until the industrial railway track, (2) from the industrial railway track to the bridge on the Belgrade-Niš railway line, works were performed according to the projected profile of the trough. Regulated section of Rujnička River downstream of the boulevard road does not have sufficient throughput capacity.

The MP envisages to innovate hydrological bases and calculations and to harmonize project documentation with them, and to perform regulation works until the confluence with Nišava River. PGRs suggest the elaboration of a Plan of Detailed Regulation for the section of Rujnička River from the railway to the confluence with Nišava River. Defined river corridor width for the PDR is 40m. Further construction on the watercourse route is strictly prohibited, while cleaning and maintaining the riverbed is mandatory.

Humski Creek. Humski Creek is a stream of torrential character. From the joining with Rujnički Creek, this urban stream is regulated upstream only 900 m. The unregulated section passes through settlements Donji and Gornji Komren in the length of 2.2 km. Here the route of the natural riverbed is variable and lacks sufficient throughput. The regulated section through Ratko Jović settlement upstream of the joining with Rujnički Creek also has insufficient throughput. After heavy rainfall or snow melting, water flows out of the shallow natural bed and floods the surrounding residential buildings. Unresolved land ownership issues represent a major challenge for the regulation, landscaping and arrangement of Humski Creek.

MP suggests thorough cleaning of the riverbed of Humski Creek from sediment and other material, both along the regulated and the unregulated section of the watercourse in the settlement. Regulation and arrangement of the entire watercourse is also planned, in order to protect this area from flooding. Creation of park areas and protective green belt upstream of the highway are suggested by the PGR. In the section of Humski Creek in the zone of the center of Donji-Gornji Komren, on the right bank, a 1 km long promenade is planned. Further construction on the watercourse route is prohibited and regular cleaning and maintaining the riverbed are mandatory. The section of Humski Creek from the composition with Brenički Creek up to the village of Hum is intended for further urban consideration by Plan of Detailed Regulation.

Brenički Creek. This small urban stream is a left tributary of Humski Creek.

PGR prescribes the elaboration of the Plan of Detailed Regulation for the regulation of the section of Brenički Creek covered by the Plan. Formation of a protective green belt is also suggested.

Rujnički Creek. This urban stream is of torrential character and no regulation works have been carried out on it. Watercourse section from the joining with Humski Creek to the highway (length of 1 km) has a narrow flow profile, which represents a major problem in overcoming flood waters. Riverbed section adjacent to the primary school is particularly problematic, because the concrete culvert profile is insufficient for large waters. The section upstream of the highway is filled with sediment and overgrown with vegetation.

PGRs suggest absolute priority of regulation works on this natural and unregulated riverbed. Trapezoidal riverbed profile is recommended but not obligatory. The section of the stream that starts 400 m upstream of the highway is intended for further urban consideration through the Plan of Detailed Regulation. Regulatory work will prevent the outflow from the trough when the level reaches high waters, ensure unobstructed and safe flow of small and large waters, protect settlements from flooding and enable reception of stormwaters from areas adjacent to the stream. Smaller

landscaped areas are planned next to the regulated part of Rujnički Creek in Donji Komren. Formation of a protective green belt is also suggested along the watercourse.

Grkovački Creek. This small unregulated stream flows through agricultural land into Rujnički Creek as its right tributary.

Table 2. *Planned land uses along smal urban strams in the City of Niš territory*

No	Name	Standing planning documents	Adjacent land use												
			E	K	H	S	CI	T	OG	SP	R	B	CT	C	F	A
1.	Toponička River	MP of Niš PGR CK III PGR CK IVw	b						a		b	a b				
2.	Kutinska River	MP of Niš PGR NB II					a		a		b c e	a b c				
3.	Vukmanovski Creek	MP of Niš PGR NB II														
4.	Gabrovačka River	MP of Niš PGR PL II PGR ME	a b		a				b c		a b c d e	a				
5.	Vukmanovska River	MP of Niš									b					
6.	Suvodolski Creek	MP of Niš PGR PL II PGR ME	a						a b		b	a b				
7.	Kovanlučki Creek	MP of Niš PGR NB I			c				b		b	a				
8.	Suvobanjski Creek	MP of Niš PGR NB I									b					
9.	Jelašnička River	MP of Niš PGR NB III							a b		b e	a				
10.	Kunovička River	MP of Niš PGR NB III							a		a b	a				
11.	Malčanska River	MP of Niš PGR PN IIIe PGR PN IVne							a c		b	a b				
12.	Crveni Creek	MP of Niš PGR PN IVne							a b		a b	a				
13.	Knezselski (Suvodolski) Creek	MP of Niš PGR PN II PGR PN IVne							a		a b	a b				
14.	Matejevačka River	MP of Niš PGR PN II PGR PN IVn							a c		a b	a b				
15.	Kamenička River	MP of Niš PGR PN IVn PGR PN IVnw							a c		a b	a				
16.	Brenička River	MP of Niš PGR PN II PGR PN IVnw							a c		a b	a b				
17.	Rujnička River	MP of Niš PGR CK I PGR CK IVj					b		a b		b e	a b				
18.	Humski Creek	MP of Niš PGR CK I PGR CK II	a		a		b		a b d		a b e	a b				
19.	Brenički Creek	MP of Niš PGR CK II					b		a							

20.	Rujnički Creek	MP of Niš PGR CK I PGR CK II	a						a b c		b e	a b				
21.	Grkovački Creek	MP of Niš														

Legend

	Land use present
	Land use not present

Within building area. E_Education: a-Primary, b-Higher; K_ Kindergarten; H_Healthcare: a-Primary, b-Specialized center, c-Health-Spa complex; S_Sport; CI_Communal Infrastructure: a-Market place, b-Cemetery; T_Traffic areas; OG_Public Open/Green spaces: a-Protective greenery, b-Park/Landscape greenery, c-Recreation, d-Public square; SP_ Special purpose; R_Residential: a-Low density-suburban, b-Moderate density-urban/suburban, c-Medium density, d-High density, e-Business-residential; B_Business zones: a-Business and Shopping, b-Business-Production-Trading, c-Industry; CT_ Catering/Tourism; C_ Church.

Outside of building area. F_ Forest; A_ Agriculture.

4. REVIEW OF EXISTING CONDITION AND PLANNING MEASURES, AND POTENTIAL FOR IMPLEMENTING BGI

Nowadays, riverbeds of small urban streams in Niš territory are a mix of: (1) natural unregulated sections and (2) regulated sections that are either lined with stone in cement mortar or designed as concrete channels. One stream is even partly concealed in pipes (Kovanlučki Creek). This research has identified that in their current state, small streams in the city of Niš territory:

- Are often neglected because of illegal waste disposal and poor maintenance,
- Are often polluted and have an endangered ecological capacity,
- Represent a flooding hazard in all unregulated and in some of the regulated watercourses,
- Do not offer any recreational areas, or offer a very limited extent of recreation,
- Have a reduced aesthetic value,
- Have some landscaping and designing constraints due to illegal developments.

When it comes to the outflow of small streams, pollution and large amounts of sediment and debris are major risks. A very important issue concerns the low level of social and environmental awareness of the residents of nearby areas, since small urban streams often represent a site for illegal waste disposal, thus contributing to flooding and erosion of adjacent land. Pollution and poor maintenance of greenery is a big concern not only for stream outflows from their regular course, but also for habitat and the ecosystem in waterfront areas. Spontaneous and unplanned development represents an additional challenge. Namely, as the city grew in time, illegal development approached the banks of streams and creeks, thus increasing the risk of flooding. Retaining floodwater in the adjacent areas is therefore made difficult or impossible, which is a case with Kutinska River, Matejevačka River and Humski Creek. It can be concluded that small urban streams in Niš are quite underused and that a series of actions need to be performed in order to fulfill their potential and integrate them into a Blue-Green Infrastructure grid.

When reviewing future development of small urban streams in Niš, certain positive guidelines can be observed in standing planning legislation regarding flood protection. The most important planning action for all small watercourses is the suggested riverbed regulation as a flood protection measure for the endangered zones, both in building areas and in agricultural land. Plans also suggest widening and deepening the riverbeds in order to prevent flooding, where land rights enable such actions. For a multitude of urban streams, the problems of both poor maintenance and adjacent illegal development are addressed in planning documents. Prohibiting further construction on the watercourse route and performing regular cleaning and maintaining of the riverbeds is suggested for Kutinska River, Jelašnička River, Kunovička River, Malčanska River, Knezselski Creek, Rujnička River and Humski Creek. All of these actions favor the creation of the BGI grid.

Even though the plans themselves do not recognize the term “Blue-Green Infrastructure”, some of the issues are well addressed in planning regulations. Protective greenery along the watercourse is

envisioned in the majority of planning documents, for 15 small streams. In the case of settlement Pantelej, even some networking of green and blue areas can be observed, which makes a great potential for the BGI - linear protective green belts along Knezselski Creek, Brenička River and Matejevačka River represents a segment of the green system which is connected to the river bank of Nišava. Together with other suggested types of green open spaces, protective greenery provides a good land reserve for retaining floodwaters in areas adjacent to the stream, as well as the opportunity for interconnecting the green components by blue pathways.

Newly planned paths along some of the streams (pedestrian path along Humski Creek, Suvobanjski Creek and Jelašnička River, and bicycle path along Jelašnička River) enable recreational areas for the population, but could also represent a significant linkage potential of the BGI grid. Plans prescribe the provision of open space in the flood plain of watercourses for Jelašnička River, Kunovička River and Malčanska River (3 m along regulated watercourses, and 5 m along unregulated watercourses). Sport fields and sport areas are envisioned adjacent to ten small watercourses, thus enhancing the potential for the green component of BGI. Public open spaces (squares) adjacent to Humski Creek in centers of villages Hum and Donji-Gornji Komren are an additional potential for the implementation of modern stormwater management techniques. Some plans indirectly favor the restoration of the stream's ecosystem by recommending watercourse regulation with a "natural" design, by using earth and stone as natural materials, i.e. for Matejevačka River and Kamenička River.

It is important to point out that the Plan of General Regulation of Niška Banja - phase III suits modern stormwater management approaches and BGI creation to a considerable extent. In addition to providing a bicycle path and various open spaces along Jelašnička River, a particular quality of this Plan is that it prescribes open green areas with park features in residential plots that are endangered by the river outflow. Also, the Plan recognizes the potential of water wells of former water mills on Jelašnička River for stormwater management and suggests maintaining their original function of draining excess water for flood protection. The suggested landscaped buffer zone towards the southern part of the stream, with the purpose of preserving natural environment along the stream, is also a planned characteristic that favors BGI.

As welcomed as these planning actions are in particular sites, they seem to be insufficient for general planning of urban watercourses in the whole of Niš area when it comes to new planning paradigms and techniques. In light of the proclaimed tendencies of "living with water" rather than defending from it, creating Blue-Green Infrastructure is advised in the entire Niš territory, as well as using the vast potential of small urban streams as a significant "Blue" element. Aside from planning measures, a wider social action and a shift in paradigm are necessary, in order to revive small urban streams and utilize their full potential within sustainable development practices. Therefore, a series of following actions is proposed with the goal of implementing the BGI concept in the city of Niš:

- *Restore ecological quality of the streams*, by: (1) firmly preventing pollution through stricter institutional and field control and increased penalties for pollutants, and (2) raising awareness of local population and city administrations on the significance of nature preservation, through educating, training, local municipality campaigns, workshops and bottom-up approach in urban planning,
- *Restore biodiversity of the streams*, by promoting "natural" design with rocks and earth, as well as planting trees and shrubs in the waterfront zone, thus creating new habitats for fish, insects and birds. Re-opening the closed canals of riverbed regulation is mandatory in the case of Kovanlučki Creek,
- *Implement floodable parks and sport-recreation areas*, by applying modern stormwater management techniques in open green spaces adjacent to the streams, for retaining and cleansing the outflow (bioswales, rain gardens, infiltration trenches, bioretentions). This can be achieved by providing additional open green spaces, children's playgrounds, sport fields and recreation spaces (i.e. in the spaces where stream's bed has been widened), but also by using water-sensitive design for the already planned open green areas or for redesigning existing ones,
- *Implement floodable public open spaces – squares and plazas,* by using porous pavement in defined public open spaces adjacent to watercourses, and other technical elements of modern stormwater management in vegetated zones of the square/plaza. This is possible by implementing water-sensitive design for two newly envisioned public squares adjacent to Humski Creek, but also by prescribing such design for all those public and commercial

facilities adjacent to watercourses that involve vast paved areas (schools, market places, business and shopping zones, catering and tourism zones, etc.),

- *Implement flood retention tanks* for possible rainwater reuse, in order to quickly drain open spaces and enable their normal use, but also to provide water reserve for irrigation of greenery in arid summer months,
- *Resolve land rights* in a manner that would also enable BGI implementation, since two crucial issues for the regulation of watercourses (land rights and illegal developments) are addressed in plans and legislation but still remain a big concern in actual situation in the field,
- *Improve building codes for developments in flood plains with wet and dry flood proofing techniques and insurance premiums*. For new developments that are at risk of flooding, it is necessary to elevate the groundfloor level to a safe pre-defined height, as well as elevate all electrical components and inventory, and thus enable water to enter the basement premises. For objects that are already built in flood plains (mostly residential and mostly illegal developments), it is suggested to elevate all electrical components and inventory to the upper floors, to provide additional dry flood proofing (embankments, etc.), and to require mandatory premiums for the insurance of such structures against flood damage. It is also necessary to prescribe the minimum coverage of open green areas with stormwater management elements, both in existing and newly planned plots.

Suggested improvements regarding small urban streams that are necessary for the creation of BGI in Niš city territory, can be implemented through Plans of Detailed Regulation or Urban Projects (UP). Most of the analyzed PGRs suggest a more detailed elaboration of small watercourses in PDRs, which makes a good baseline for the BGI vision in Niš. Plans of Detailed Regulation are envisioned for Jelašnička River, Malčanska River, Crveni Creek, Knezselski Creek, Matejevačka River, Kamenička River, Brenička River, Rujnička River, Humski Creek, Brenički Creek and Rujnički Creek. For Suvodolski Creek, Urban Project was envisioned, because of the displacement of a significant part of its natural route. For remaining small urban streams, the procedure for developing a PDR or a UP may be initiated at any time.

5. CONCLUSION

It can be concluded that Blue-Green Infrastructure is a very topical issue in contemporary planning theory and practice. A multitude of examples at the global level confirm that the implementation of BGI can significantly improve the resilience of urban areas to challenges of climate change and contribute to their sustainability. BGI is also a highly valuable and cost-effective resource to make urban areas more appealing.

Small urban streams are a crucial element of the “Blue component”. This paper made an attempt to point out the unused potential of small urban streams in urban landscape of the city of Niš and to guide future development in waterfront areas. Urban area of Niš is quite rich in water, which makes a good starting point for implementing BGI grid. Aside from flood protection, restoring small urban streams would bring additional benefits. In highly urbanized areas of the city, a restored watercourse would have a great effect in improving the microclimate. Parks and landscaped areas along the streams would provide rest and recreation areas for local population. This is a particularly important point in unplanned suburban settlements, that lack organized public open spaces and green areas. Such landscaped zones could become an important focus of social life for local residents. Small urban streams as elements of the BGI can significantly help in improving stormwater treatment, as well as in upgrading the design of various urban spaces.

Current planning documents support the creation of the BGI to some extent, which is another favorable pre-condition for the implementation in Niš. However, it is the conclusion of this research that small urban streams require more attention in both planning documents and in planning practice of the City of Niš. Given the fact that a majority of small watercourses still await regulation works, as well as more detailed plans or project documentation, it can be concluded that a window of opportunity exists for the implementation of BGI. A more detailed examination is necessary to determine the exact sites along watercourses that have potential for retaining the stream outflow, and to explore their size, use and design. Further studies should also explore the “Green component” urban baseline and its potential for the creation of BGI grid.

Finally, since the city of Niš area already possesses significant “Blue” natural capital, it seems that implementing the proposed measures would be quite simple and cost-effective - it is rather a matter of shifting our planning policies and design perspectives. By restoring urban watercourses and

interconnecting them with vegetation systems within an attractive urban landscape, the city would achieve long-term viability for its residents and the entire urban ecosystem.

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