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Proceedings of the 2<sup>nd</sup> Regional Symposium on

# LANDSLIDES

in the Adriatic - Balkan Region  
14-16<sup>th</sup> May 2015 Belgrade - Serbia



ReSyLAB



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Landslide Leva Reka, Kraljevo, Serbia (by Biljana Abolmasov)

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Landslide Leva Reka, Kraljevo, Serbia, UAV photo (by Dragan Milovanović and Stefan Miljković)

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the terrain with the landslide. For the territory of 13 Belgrade municipalities (approximately 1700 km<sup>2</sup> of area), the total of 2341 occurrences of different state of activity were recorded and scientifically analysed through Inventory of the landslides and unstable slopes, and they were divided in 4 main categories: unstable slopes, active landslides, dormant landslides and stabilized landslides. Documentation in analogue format included 16 reports with over 220 maps – sheets of topographic maps with scale 1:5000. After 1986 and during the following years, there hadn't been any updates of the Inventory (Janjić 1981; Gojgić et al. 1995).

In the time frame of the previous 30 years a lot of area have been urbanized and significantly changed by land use and land cover. New landslides have formed, while only small number of existing landslides have been repaired (31 repaired landslides) during this time period (Đoković and Šušić 2006), and some of them became dormant. However, after heavy rainfall that affected Belgrade and most of Serbia in the spring of 2006 (similar weather condition scenario was repeated during 2014, with more severe consequences), several dozens of previously recorded landslides reactivated, and new with different magnitude became active in the City area. This pointed out a necessity for the development of newest inventory of landslides which was supported by the Belgrade Land Development Public Agency. The project was implemented by the Faculty of Mining and Geology from Belgrade during 2008-2010, together with a large number of associates – researchers from other scientific and research institutions. Apart from the analysis and reinterpretation of the existing data on landslides and additional mapping of the terrain, the following investigations were conducted during the course of the study:

- Analysis of orthophoto images,
- Development of the landslide database,
- Terrain stability mapping,
- Expert Assessing of the level of landslide hazards and risks,
- Results of the investigations were inputted in the database.

Terrains affected by the landslides of various states of activity were classified mostly based on Varnes (1978) classification into 6 categories: active (with acute moving), active with temporary suspended process, relict; stabilized, dormant, and marginally stable slopes on which landslides may develop if terrain works are performed inadequately or in case of extremely changed geomorphological-geological conditions.

The results of all field and cabinet investigation, (in analogue and in digital format) were placed on topographic sheets scale 1:5000. Project solutions regarding Information system and Database for every landslide was also given during the study, and had included spatial, lithological and engineeringgeological data, as well as data related to monitoring, degree of risk and geohazard for every recorded landslide occurrence or conditional stability of the terrain. In numbers, within the boundaries of the City Master Plan (approximately 360 km<sup>2</sup> of area), a total of 1155 landslides was recorded before 2010. There were 602 active landslides (260 with the temporary dormant process), and 248 landslides are endangering important structures in the city posing a considerable degree of risk.

### Landslides inventoring after the floods in May of 2014

Prolonged periods of heavy continuous rainfall has affected Belgrade again, among other parts of Serbia, during the May 2014. Extremely poor meteorological and hydrological conditions were, apart from the unfavourable geological structure and morphological conditions of the terrain, the main cause for the activation of existing and new landslides in the central and the peripheral territory of the city. By the Belgrade Mayor decision, City Coordination body and its expert teams for inventoring landslides on territory of Belgrade was formed. Recognition and recording of unstable slopes within the city area has been carried out only ten days after the heavy rainfall, mostly by experienced geologists – geotechnicians.

In order to implement the conclusions from the first meeting of a Coordination body, that was held at the end of May, 2014, 10 operational teams were formed in order to visit and inspect all reported landslides occurrences on

Table 1 Number of recorded landslides in Belgrade City area, May 2014

Belgrade City Municipality	N° of recorded appearance	N° of inventoried landslides	Potentially affected objects and roads	Heavily affected objects and roads
Lazarevac	6	6	0	0
Grocka	35	35	10	5
Voždovac	19	19	2	4
Rakovica	32	32	3	2
Savski Venac	2	1	0	0
Zvezdara	4	4	1	3
Palilula	1	4	0	4
Čukarica	3	3	1	2
Barajevo	6	6	0	3
Mladenovac	5	5	2	0
Sopot	26	26	3	4
Obrenovac	2	2	0	1
Zemun	11	15	11	0
<b>Sum</b>	<b>152</b>	<b>158</b>	<b>33</b>	<b>28</b>

the territories of the particular city municipality. The teams included experienced engineers – experts of geology and civil engineering with geotechnical experience. The teams included professors and associates from Belgrade University, colleagues from notable geological companies and Republic Geological Survey. Multidisciplinary teams in good cooperation with the City administration have surveyed 13 city municipalities (Tab.1), during the last week of May. Methodology of recognition and recording all landslide occurrences was specifically due to the need to conduct comprehensive field research with large number of experts in a very short period of time and also due to parameters of recorded occurrences presented as numerous attributes (textual, numeric and graphic data) had to be entered and interpreted in GIS in a short time frame that was given. The results of the field investigations conducted by expert teams were presented in a format of Inventory sheets (Fig. 2), in accordance to the format used in database of the Inventory of landslides encompassed by the general city plan developed in 2008-2010.

KATASTAR KLIZISTA PODRUČJA BEOGRADA – GO RAKOVICA	
LIST BR. 1 – OPSTI (OSNOVNI) LIST	
<b>1. Opšti podaci:</b> Topografska osnova - Beograd 41 (R 1:5000) Opština – Rakovica, Resnik Naziv - ul 13. oktobra 23 Rasprostanjenje – Neposredno iza Doma kulture i MZ Resnik Status pojave – Novo klizište, umireno Datum opservacije – 27.05.2014 Datum aktiviranja klizišta – 16.05.2014 Koordinate klizišta: X 7457114 Y 4952310	<b>2. Morfometrijski elementi klizišta:</b> Dužina klizišta – 10 m Širina u nožici – 40 m Površina - 350 m <sup>2</sup> Zapremina – 500 m <sup>3</sup> Debljina prosečna – 2,5 m Dubina klizne površine – do 2 m Oblik klizne površine – Visina čeonog ožiljaka – 1,0 m Nagib čeonog ožiljaka – 85° subvertikalno Visina bočnih ožiljaka – 0,5 m Pojava sekundarnih ožiljaka - da Pojava tenzionih pukotina – Deformisanost površine tela klizišta – ulegnuća Kategorija klizišta : umireno
<b>Izveštaj popunili:</b> Doc. Dr Zoran Radić, dipl. inž. geol. Uroš Đurić, dipl. inž. geol.	
<b>3. Kinematski status pre aktiviranja i danas (privremeno umireno, sanirano, fosilno, nepoznato)</b> Klizište ranije nije bilo evidentirano – nepoznato Na dan evidentiranja klizište je umireno	
<b>4. Mehanizam kretanja masa (lagano pomeranje, brzo kretanje, bujični tok, odron)</b> Lagano kretanje	
<b>5. Uslovi nastanka klizišta:</b> Geološka predispozicija, debljina deluvijuma, poroznost deluvijuma, nagib kosine, neplanska gradnja iznad kosine	
<b>6. Uzroci aktiviranja klizišta:</b> Infiltracija bujičnih padavina u deluvijum, povećani aktivni pritisci na potporni zid	
<b>7. Ugroženost materijalnih dobara, objekata i ljudi:</b> Oštećen je potporni zid iza Doma kulture koji se obrušio u dužini od 20 metara, zatrpan je trotoar i parking prostoriza Doma kulture. Potencijalno je ugrožena i saobraćajnica iznad kosine.	
<b>8. Prognoza ponašanja procesa i ugroženosti objekata i prostora:</b> U povoljnim klimatskim uslovima ne očekuje se reaktivacija klizišta.	
<b>9. Prethodna ocena o mogućnosti sanacije (i troškovima) terena i objekata:</b> Popravka i izrada novog armiranog potpornog zida, izrada drenažne mreže i obezbeđenje daljeg urušavanja i širenja klizišta uz padinu.	
<b>10. Napomena:</b>	
<b>11. Predlozi daljih aktivnosti:</b> Klizište bi trebalo sanirati što pre kako bi se omogućila puna funkcionalnost doma kulture i mesne zajednice	

Figure 2 Screenshot of landslide inventory sheet (on Serbian)

During the studies conducted by expert teams, special attention was given to the classification of the landslides and other occurrences of instability, according to the degree of risk caused by them and urgency of undertaking preventative and repair measures. The goal was to facilitate prioritizing prevention and repair work as well as landslide monitoring activities and make this process easier for Belgrade city administration officials. All landslides were classified in 6 categories based on a type of structure or space which are exposed to risk (Tab. 2).

The results of the field investigation were presented with description of each landslide, supplemented by

position on the orthophoto image (Fig. 3a), longitudinal cross section of the landslide (Fig. 3c) and field photographs (Fig. 3b). Investigations were completed by mid-June 2014, and they are meant to be used not only for their basic purpose of helping Belgrade city authorities to undertake urgent measures of protection of people and residential sector, as well as infrastructure facilities (Tab. 3), but also for updating the official Belgrade Landslide Inventory. Same methodology should be used for all other Belgrade municipalities that has not been investigated during 2010 - 2014 landslide inventorying to create unique and centralized landslide inventory.

Table 2. Landslide categorization by type of affected areas and objects. Categories marked with (\*), represent such degree of risk to physical property and people that require urgent measures without delay.

Landslide category		Type of affected areas and objects
I category		Forests, meadows, arable lands, wastelands
II category	II	Individual smaller buildings and objects of different purposes
	II*	
III category	III	A couple of smaller buildings and objects, parts of settlements, cottage settlements, including local utility and transportation infrastructure
	III*	
IV category	IV	Objects of collective housings, high rise buildings, including City utility, transport and energy infrastructure
	IV*	
V category	V	Industrial, mining and other production facilities, warehouses etc.
	V*	
VI category	VI	Main infrastructure objects, highways, railroads, main water supply pipes, power lines, gas lines etc.

According to the previous research, on the territory of the Belgrade Master Plan area, 1155 landslide locations were recorded (Lokin et al., 2010) and from this number, only 43 landslides were permanently repaired until 2014. While according to our information, from the total of 28 locations (2014 events) where immediate preventative or stabilization measures needed to be undertaken, repair of transport routes has been performed in the following 3 Belgrade locations: Matice Srpske Street in Mirijevo, Volgina Street in Zvezdara and Oslobođenje Street in Resnik. Work has been done before the beginning of April 2015, which is 10 months after the survey and recording of landslides in Belgrade. Municipality officials in cooperation with public utility companies had performed measures in order to clear the local transport routes for further use, without final repair, only for some of the 28 priority locations.

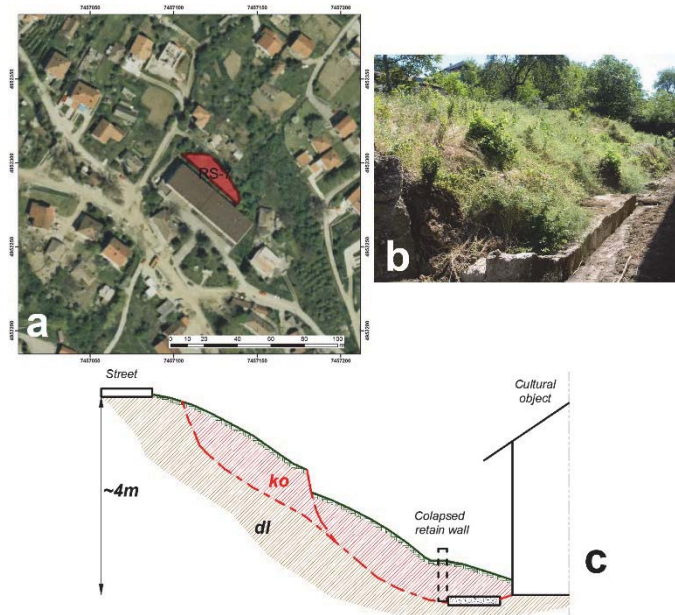


Figure 3. a) orthophoto of recorded landslide b) image of damaged retain wall c) geological cross-section (sketch)

**Conclusion**

Existing data from the Inventory of landslides in Belgrade (1986. and 2010.) had not been given proper consideration during the relatively uncontrolled urbanization process in various city municipalities (Grocka, Voždovac, Palilula, Zvezdara, Rakovica, Sopot, Obrenovac) which are known as municipalities with large number of landslides. This caused over 60 new landslide occurrence during extremely poor hydrometeorological conditions that occurred during mid-May 2014 in Belgrade and most of the Serbia.

According to our knowledge, from the total of 28 locations where immediate repair measures needed to be undertaken, complete landslide reparation had been performed on the 3 transport routes before the beginning of April 2015. For some, the most necessary interventions had been performed, while the work on preparing project documentation and securing funding is still ongoing for the complete repair of the most of other landslides.

The results of this investigation that was completed by mid-June 2014, need to be entered as an update in the existing official landslide inventory. Risk from landslides in city municipalities is being determined by developing thematic maps using multi criteria decision analysis of all available geological, geotechnical and numerous other data, as well as analysis of influences of different factors that are, as a rule, combined, leading to landslide occurrences.

Table 3. - Overview of recorded landslide occurrence on the Belgrade City territory, after heavy rainfall during May 2014.

Landslide location	Municipality	Number of occ.	Affected objects						Vulnerability		
			Objects		Road infrastr.		Utility infr.		Potential	Active	
			Residential	Outbuilding	Main	Local	Sewerage& Water	Power Supply			Pastures, forests
Lazarevac		6	3	2		1					
Grocka		35	29	15	1	12			1	10	5
Voždovac		19	10	11		5			2	2	4
Rakovica		32	5	1	1	3	4	1		3	2
S.Venac		2				2					
Zvezdara		4	10		1	3	2	3	1	1	3
Palilula		4	4						1		4
Čukarica		3			2					1	2
Barajevo		6	2	2	1	3					3
Mladen.		5	3	1					4	2	
Sopot		26	11	6	4	5	1	2	12	3	4
Obrenov.		2		1	1	1					1
Zemun		11	15	4						11	
<b>Sum</b>		<b>155</b>	<b>92</b>	<b>43</b>	<b>11</b>	<b>35</b>	<b>7</b>	<b>6</b>	<b>21</b>	<b>33</b>	<b>28</b>

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