MONITORING OF SELECTED GEOHAZARDS BY USING UNMANNED AERIAL SYSTEMS (UAS)

Peter Blistan, assoc. prof., Ph.D., MBA
Institute of Geodesy, Cartography and Geographical Information Systems
Faculty of Mining, Ecology, Process Control and Geotechnology
Technical University of Košice
Košice, Slovakia
e-mail: peter.blistan@tuke.sk – contact person

Department of Geotechnics, Geomatics and Waste Economy
Faculty of Environmental, Geomatic and Energy Engineering
Kielce University of Technology
Kielce, Poland
e-mail: p.blistan@tu.kielce.pl – contact person

Ľudovit Kovanič, Ph.D.
Institute of Geodesy, Cartography and Geographical Information Systems
Faculty of Mining, Ecology, Process Control and Geotechnology
Technical University of Košice
Košice, Slovakia
e-mail: ludovit.kovanic.2@tuke.sk

Matej Patera, M.Sc.
Institute of Geodesy, Cartography and Geographical Information Systems
Faculty of Mining, Ecology, Process Control and Geotechnology
Technical University of Košice
Košice, Slovakia
e-mail: matej.patera@tuke.sk

Paweł Frąckiewicz, M.Sc.
Department of Geotechnics, Geomatics and Waste Economy
Faculty of Environmental, Geomatic and Energy Engineering
Kielce University of Technology
Kielce, Poland
e-mail: pfrackiewicz0@op.pl

Marcin Gil, M.Sc.
Department of Geotechnics, Geomatics and Waste Economy
Faculty of Environmental, Geomatic and Energy Engineering
Kielce University of Technology
Kielce, Poland
e-mail: marcingil@tu.kielce.pl

Abstract

Landslides belong to the category of serious geohazard that is commonly found in different parts of the Earth. They are caused by natural as well as anthropogenic factors. Their occurrence has a significant impact on urbanisation and land use. The primary influence on landslide formation is a loss of vegetation, changes in climatic conditions and harmful human activity. In Central Europe, namely in Slovakia, there are several sites where there are localities with smaller or more massive landslides that may affect the land relief, limit the urban use of the land and cause material damage. Therefore there is necessary the systematic monitoring of these landslides. In recent years a modern trend in the geo-hazard monitoring is the use of unmanned aerial systems (UAS). Aerial photogrammetry with UAS is a new technology for monitoring of the objects on the earth surface, including landslides. One of the results of the UAS aerial photogrammetry is the point cloud. Its detail and accuracy are comparable to another modern method - terrestrial laser scanning TLS. Several scientific papers have demonstrated that a 3D model created from the point cloud obtained by processing of the UAS photogrammetry images is suitable for assessing changes in the surface of the ground. The aim of our research is long-term stage monitoring and verification of the land changes using UAS photogrammetry in selected locations in Slovakia. One of these sites is also a landslide in the cadastral area of the municipality of Nižná Myšľa, which falls into the Košice self-governing region, district Košice - okolie (Slovakia).

Key words: Unmanned aircraft systems, Photogrammetry, Mapping, Digital terrain model, Landslide

Introduction

Landslides are the most common and dangerous geodynamic phenomenon affecting urbanism on the Earth. They occur in places where there are combinations of several factors such as

- morphology of the slope,
- the inclination of the slope,
- length of the slope,
- the intensity of weathering,
- geological structure of the territory etc.

A significant influence on slope movements is also the tectonic activity and climatic conditions (GARIANO, GUZZETTI, 2016). In Europe, due to its geological and geomorphological structure, there are several sites where slope movements of smaller or larger dimensions occur. These landslides cause a change of the relief of the affected site where the use of the land is limited. Slovakia belongs to the countries with a relatively large number of landslides also. Based on the Atlas of the Slope Stability Map in Slovakia, there are 19104 registered landslides in Slovakia. These slope deformations threaten 98.8 km of motorways and roads of the first class, 571 km of roads II. and III. Class, 62 km of railways, 11 km of overhead lines, 3.5 km of oil pipelines, 101 km of gas pipelines, 291 km of waterworks and nearly 30000 buildings (WWW.1).

Landslides are generally defined as gravitational movements of rock masses from a higher position to lower. The notion of slope movements associates all the gravitational movements of rock masses in the slopes, except those where the transport media - water, snow, wind (CRUDEN, VARNES, 1996; ČABALOVÁ, BALIAK, KOPECKÝ, 1999) are carried rock material away.

Based on the geological research, it has been demonstrated that the majority of landslides in Slovakia that occurs in the inhabited areas during the last 30 years were either wholly or partly caused by man 's intervention in the sensitive stabilisation regime of old landslides. Particularly dangerous are anthropogenic influences that cause changes in groundwater regime. Landslides are mainly affecting on

- agricultural land and forests,
- urbanisation,
- communication structures,
- water management structures. (ZÁRUBA, MENCL, 1987; NEMČOK, 1982).

Material and methods

Surface object and phenomena mapping using UAS

In recent years Unmanned aerial systems - UAS is a modern technology that has been used for mapping of the surface objects including landslide hazards (NIETHAMMER et al, 2012; STUMPF et al, 2013; ARDI et al, 2018; ROSSI et al, 2018). UAS include many types of flying units. In addition to airplanes and helicopters, there are also very popular advanced multi-rotor helicopters. UAV´s are carriers for a variety of the devices, most often equipped with cameras and Lidars. UASs are now commonly equipped with navigation technologies - the Global Navigation Satellite System (GNSS), inertial measurement systems or compass that serve the positional orientation. This paper will focus on documenting and mapping of the geohazards and photogrammetric data collection using UAS. Aerial photogrammetry is a surveying method designed to collect data using photographic devices (cameras) with results in orthophotographs, topographic maps or terrain 3D models from the data thus obtained (KRŠÁK et al, 2016). These outputs can be used as underlying digital data (REMONDINO et al, 2011; NEX, REMONDINO, 2013).

The process of mapping the surface objects using UAS can be divided into two basic parts. In th e first part, we collect the data and in the second part obtained data are processed. System capabilities limit data collection. Such limitations include flight height or parameters of the digital camera used for capturing of the images. Various commercial and non-commercial software that works on the principle of automated or semi-automated output generation serves to produce requisite outputs (KYŠEĽA et al, 2013; ARCDATA, 2017; PAVELKA, 2009).

Case study – testing of the UAS v Nižná Myšľa locality

Area of interest

The area of interest is about 7 km SE from Košice in the cadastral area of the municipality of Nižná Myšľa, which belongs to Košice self-governing region, district Košice - okolie (Fig. 1). The terrain of the territory is smoothly modeled with a slope of 5 to 12%. The slightly wavy surface indicates the occurrences of geodynamic phenomena - landslides. From a geological aspect, the area of interest is a part of the region of the neogenic tectonic columns and the area of the intramountain basins. There occur sediments with the character of fine-grained soils. Landslides in this area have the character of active frontal landslides along rotary and combined shear surfaces (TOMETZ et al, 2010).

Landslides of different stages disrupt the territory. The morphological features of the older landslides are covered by anthropogenic activity and the processes of slope modelling of non-sliding character. Based on general knowledge of engineering geology this territory can be characterized as follows (TOMETZ et al, 2010):

- Territory builds quaternary (deluvial-eluvial) and neogenic sediments (high-plastic clays, less medium-plastic clays).
- In the locality, the atmospheric precipitation has an impact to the occurrence of slope movements.
- The groundwater level is at different depths (1 - 22 m below the terrain) and has a surface tension character. At the time of increased precipitation, it can climb up to the surface in the observation boreholes.
- Shear surfaces are located at depths of 3 to 17 m under the terrain.
- Anthropogenic impacts related to the weakening the heal of the slope (excavations and cuttings), loading the top part of it (construction of new homes), as well as poorly drained rainwater from the roofs of residential buildings and reinforced surfaces, have affected by the stability of the territory.

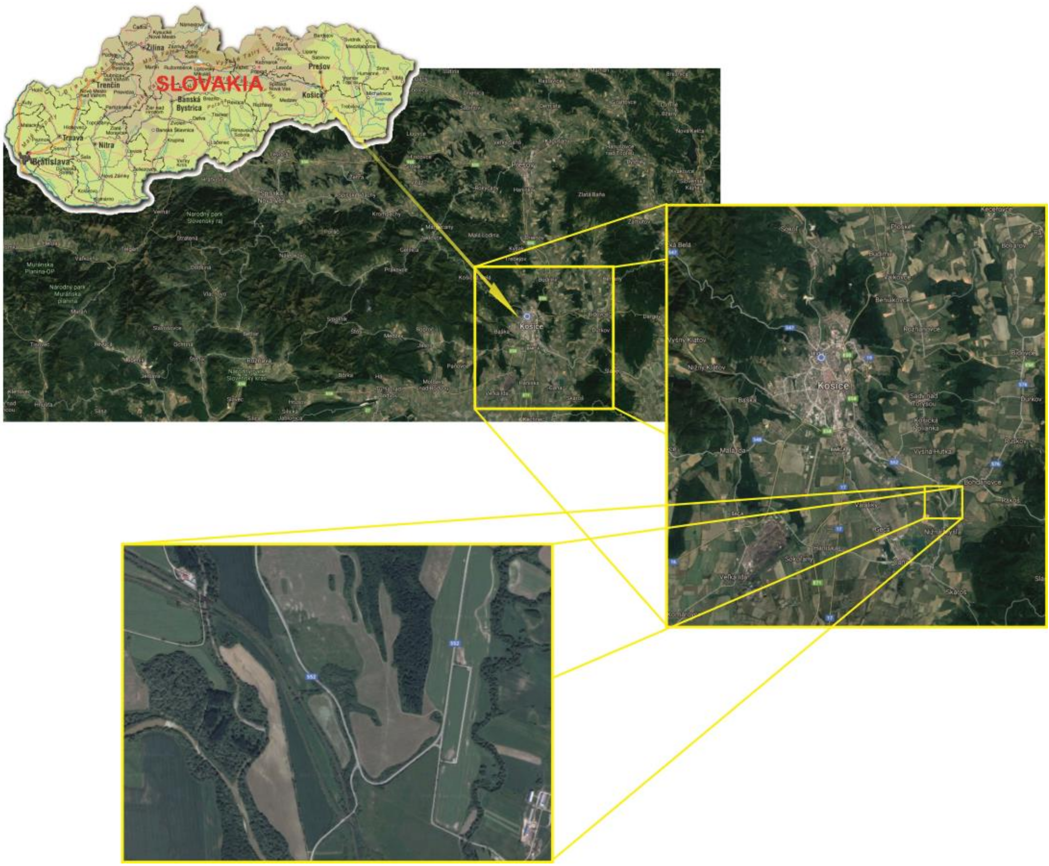

Fig. 1. The geographical position of the area.
Source: Own study.

The landslide in Nižná Myšľa was one of the most significant geodynamic phenomena in the territory of the Košice Autonomous Region. It was widely documented during extensive floods in 2010. The landslide in Nižná Myšľa occurred on 4.6.2010, and its consequences on the anthroposphere and the environment of the village were disastrous. It should be to tell that this was an extraordinary situation with an acute danger status to the lives of inhabitants and their property - residential houses and other objects in the cadastral territory of the municipality. The landslide was mainly due to long-term and heavy rainfall between 10 May and 5 June 2010.

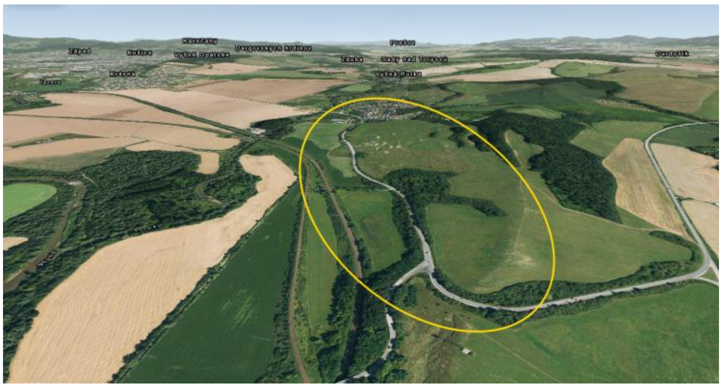

Fig. 2. View on the area of interest.
Source: Own study.

The research aimed to verify the usability of UAV photogrammetry in the documentation of the landslide area and the identification of morphological changes with damage to the road infrastructure due to the activation of the landslide. The accuracy with which the low-cost UAV DJI Phantom 4 can capture these changes was tested. The road communication between the municipalities of Nižná Myšľa and Nižná Hutka and the adjacent landslide area located northeast of this communication was surveyed (Fig. 2). Traces of landslide are visible on both sides of the road in this area (Fig. 3).

Fig. 3. Observable landslides on area Nižná Myšľa.
Source: Own study.

Photogrammetric data collection using UAS

The data collection was performed using the DJI Phantom 4 quadcopter (Fig. 4). This UAS device belongs to the category of "cheap" UAVs. It contains as well a built-in GPS module, a gyrocompass and a 12Mpx DJI HD camera. The camera is mounted on a 3-axis gimbal. The whole flight was pre-programmed by the Android application Pix4D. Three flights in different heights were realized in total. Each took about 15 minutes. A total of 363 aerial images were created. Specifications of the UAS are stated in Table. 1

Image processing and modelling

The aerial images were graphically modified before processing in specialised photogrammetric software. The adjustment consisted of the following features: white balance correction, Noise reduction, and Chromatic aberration correction. Subsequently, the images were processed in the Agisoft PhotoScan® software (Fig. 5). Agisoft PhotoScan® is photogrammetric software for efficient 3D image processing to create detailed point cloud and high-quality, textured, 3D scene model. Work in this software environment is relatively simple and the outputs generated are highly accurate (Fig. 6). For these reasons, Agisoft PhotoScan® has become wide-spread software in a relatively short time.

Table 1. DJI Phantom 4 – technical parameters.

Aircraft	
Weight (Battery & Propellers included):	1380g
Max Ascent / Descent Speed:	6m/s / 4m/s
Max. flight speed:	20m/s
Max. flight time:	28 min.
Camera	
Operating Environment Temperature:	0°C-40°C
Sensor size:	1/2.3"
Effective Pixels:	12 Megapixels
Resolution:	4000×3000
Gimbal pitch	-90° to +30°
Remote Control	
Communication Distance (open area):	CE Compliant: 3,5km; FCC Compliant: 5km

Source: Own study.

Fig. 4. UAV - DJI Phantom 4.
Source: Own study.

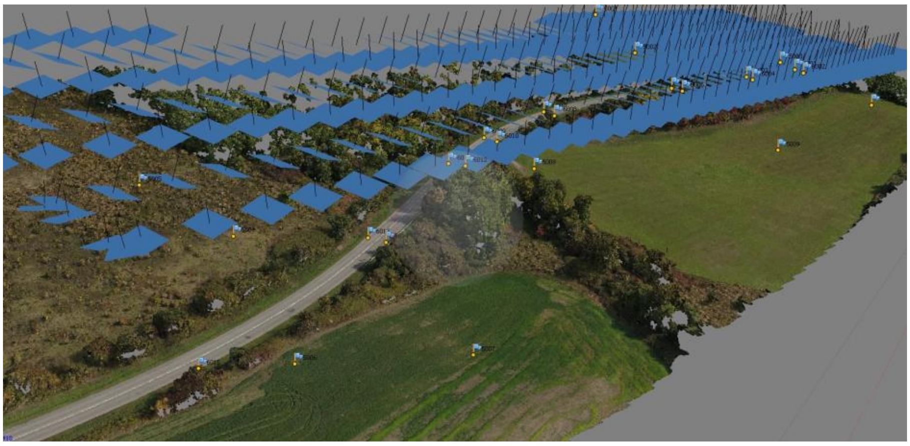

Fig. 5. Image processing in Agisoft PhotoScan® with positions of images.
Source: Own study.

Two products of processing were used. Dense point cloud and the final product of the entire process is a textured 3D model that faithfully displays the terrain (Fig. 6). The generated model can be exported through export filters to different formats, depending on the needs of the next processing.

In final 344 images were processed in our research. A total of 10 ground control points (GCP) (Fig. 5 and 6) were used to transform the frame into the S-JTSK coordinate system. The GNSS Leica 900CS gave the coordinates of GCP. The results of the photogrammetric data processing show the following characteristics:

- GSD resolution is 2.04 cm/pixel.
- The error in the position of the measured point in the image is 0.259 pixels.
- The quadratic average of the residue at the GCP is 0.017 m.
- Longitudinal image overlay was 80% and 60% lateral.

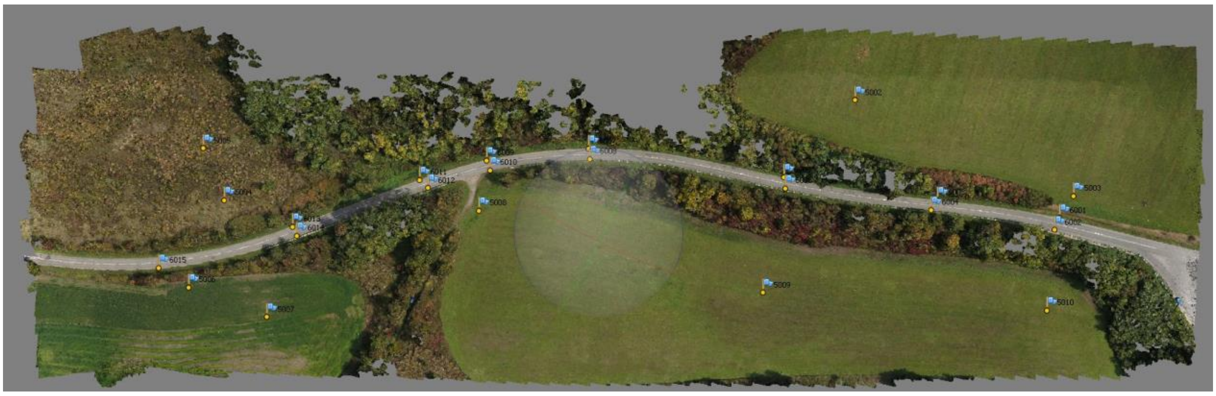

Fig. 6. Textured 3D model with the position of the GCP.
Source: Own study.

Results and discussion

In the last period, the permanent impact on the population has in particular climatological and consequently geological threats. The first step is risk analysis, which is a prerequisite for understanding the threats and, of course, for effective risk management (BLIŠŤANOVÁ, 2017). In the area of risk management, the evaluation of the risks of the landslides - the risks that cause geodynamic phenomena – has an important role (MESÁROŠ et al, 2015; URBAN et al, 2017). Geodynamic phenomena, especially landslides, have caused considerable damage in Slovakia in recent years. For this reason, it is still an essential task of geodesy to monitor these phenomena by the methods which are as effective and as accurate as possible. Just in the field of monitoring of landslide areas, modern methods of data collection, for example, INSAR, LIDAR, and UAV photogrammetry, where their significant advantage is, in particular, the speed of data collection, density of surveyed points and their financial availability.

To assess the suitability of low-cost UAV photogrammetry as an alternative method to classical terrestrial geodetic methods, we have researched the landslide area near village Nižná Myšľa. The surface was documented using a low-cost UAV to perform repeated measurements with a time span of about half a year and then evaluate the results. The first measurement was realized in autumn 2017, and its results are presented in this article. Further measurements will be made in the autumn of the 2018 year.

From the aspect of the accuracy, the goal was to verify the error with which we can model the object by the photogrammetric measurement. The test results of pixel heights obtained by photogrammetric data processing indicate that low-cost UAV photogrammetry as a data acquisition method provides the precision of height determination near terrestrial laser scanning (PUKANSKÁ et al, 2014). However, the UAV use, it should be noted that their commercial deployment in practice is in the Slovak Republic regulated by relatively strict legislation. Performing commercial aviation operations related to aerial photography is subject to authorisation by several institutions and offices. This fact can be discouraged for many subjects who would like to take an active part in this progressive method of the collecting geodata.

Although it is not natural for us to make forecast maps of geological hazards and risks, it is only a matter of time when it becomes a necessary. With progressive urbanisation and an increasing need for greater living comfort, structure designers are forced to cope with increasingly complex engineering and geological conditions in the assessment of land, underground, line, water, and other types of construction. The correct location of the building, with a thorough knowledge of the current state of the geological environment, but especially the assumption of geological processes in the future, with the emphasis on geobarriers, can be a means of saving the high financial costs of future remediation and, last but not least, increasing the safety of the population. The monitoring of flood risks using the UAV and the predictive map of geological hazards is, therefore, an ideal basis for urban planning of individual localities (LUCIEER et al, 2014).

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References

ARCDATA PRAHA, *Družicová data* [on line]: http://download.arcdata.cz/doc/druzicova_data.pdf (access 15.08.2017).

ARDI, N. D., IRYANTI, M., ASMORO, C. P., NURHAYATI, N., & AGUSTINE, E. 2018. *Mapping landslide potential area using fault fracture density analysis on unmanned aerial vehicle (UAV) image*. Paper presented at the IOP Conference Series: Earth and Environmental Science, 145(1).

BLIŠŤANOVÁ, M. 2017. *Hodnotenie bezpečnostných rizík prírodného charakteru na Slovensku.* Košická bezpečnostná revue, 1: 1-17.

MESÁROŠ, M., ĎURICA, T., LOŠINCZI, P., BLIŠŤANOVÁ, M. 2015. *Possibilities for protection of critical infrastructure prior to geohazards.* International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM.

CRUDEN, D. M., VARNES, D. J. 1996. *Landslide types and processes,* In: K.A. Turner, R.L. Schuster (Eds.), Landslides: Investigation and Mitigation, Special Report 247, Transportation Research Board, Washington, p. 36-75.

ČABALOVÁ, D., BALIAK, F., KOPECKÝ, M. 1999. *Geológia*. Bratislava: STU,. p. 142-143.

GARIANO, S. L., GUZZETTI, F. 2016. *Landslides in a changing climate*. Earth-Science Reviews, 162: 227-252.

KRŠÁK, B., BLIŠŤAN, P., PAULIKOVÁ, A., PUŠKÁROVÁ, P., KOVANIČ, Ľ., PALKOVÁ, J., ZELIZŇAKOVÁ, V. 2016. *Use of low-cost UAV photogrammetry to analyze the accuracy of a digital elevation model in a case study*. Measurement, 91: 276-287.

KYŠEĽA, K., BLIŠŤAN, P., KOVANIČ, Ľ. 2013. *Využitie vybraných geodetických metód pre zameranie povrchových banských prevádzok s cieľom tvorby ich 3D modelov*. In: Fórum mladých geoinformatikov 2013: recenzovaný zborník príspevkov. 2- 3 May 2013, Zvolen. - Zvolen: Technická univerzita, p. 1-10.

LUCIEER, A., JONG, S.M.D., TURNER, D. 2014. *Mapping landslide displacements using Structure from Motion (SfM) and image correlation of multi-temporal UAV photography*. Prog. Phys. Geogr., 38(1): 97-116.

NEMČOK, A. 1982. *Zosuvy v slovenských Karpatoch.* Bratislava: VEDA SAV.

NEX, F., REMONDINO, R. 2013. *UAV for 3D mapping applications: A review*. Applied Geomatics, 6(1): 1-15.

NIETHAMMER, U., JAMES, M. R., ROTHMUND, S., TRAVELLETTI, J., JOSWIG, M., 2012. *UAV-based remote sensing of the Super-Sauze landslide: Evaluation and results.* Engineering Geology, 128: 2-11.

PAVELKA, K. 2009. *Fotogrammetrie 1,* 1st ed.; Česká technika, Praha.

PUKANSKÁ, K., BARTOŠ, K., SABOVÁ, J. 2014. *Comparison of survey results of the surface quarry spišské tomášovce by the use of photogrammetry and terrestrial laser scanning*. Inzynieria Mineralna, 15(1): 47-54.

REMONDINO, F., BARAZZETTI, L., NEX, F., SCAIONI, M., SARAZZI, D. 2011. *UAV photogrammetry for mapping and 3D modeling–current status and future perspectives.* In: H. Eisenbeiss, M. Kunz, H. Ingensand (Eds.). Proceedings of the International Conference on Unmanned Aerial Vehicle in Geomatics (UAV-g) Zurich, Switzerland.

ROSSI, G., TANTERI, L., TOFANI, V., VANNOCCI, P., MORETTI, S., & CASAGLI, N. 2018. *Multitemporal UAV surveys for landslide mapping and characterization.* Landslides, 15(5): 1045-1052.

STUMPF, A., MALET, J. P., KERLE, N., NIETHAMMER, U., ROTHMUND, S. 2013. *Image-based mapping of surface fissures for the investigation of landslide dynamics.* Geomorphology, 186: 12-27.

TOMETZ, L., BLIŠŤAN, P., HARABINOVÁ, S., LEŠŠO, J., NYÁRHIDY, J., TUROVSKÝ, F. 2010. *Nižná Myšľa – havarijný zosuv, inžinierskogeologický prieskum.* Manuskript GEOTON s.r.o., Košice, p. 59.

URBAN, R., ŠTRONER, M., BALEK, J. 2017. *Realization of geodetic network for monitoring of landslide area near Třebenice.* In: 17th International Multidisciplinary Scientific Geoconference SGEM 2017 Geodesy and Mine Surveying. Sofia: STEF92 Technology Ltd., p. 531-538.

WWW.1: *Zosuvy a iné svahové deformácie* [on line]: http://www.minzp.sk/sekcie/temy-oblasti/geologia/zosuvy-ine-svahove-deformacie.html (access 15.06.2018).

ZÁRUBA, Q., MENCL, V. 1987. *Sesuvy a zabezpečování svahů*. Praha: Academia.