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Assessment of selected active landslides in Slovakia in 2011

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Abstract

Slope failures, especially landslides, represent one of the most important geodynamic phenomena in the Slovak Republic. The 21 190 slope deformations registered up to now cover 2 575.912 km^2 which correspond to 5.25 % of the total area of Slovakian territory. A lot of new slope failures evolved after heavy rainfalls in the year 2010. Their total number in the Eastern Slovakia achieved 577. According to socio-economic significance of the slope deformations about 138 of them were designated for engineering geological investigation. The investigation of 38 sites was performed up to the end of 2010. About 22 landslides which threatened and damaged housing estates or other buildings, infrastructure as well as safety and health of citizens were reported by the mayors of villages. The contribution evaluates three selected slide sites (Ruská Nová Ves, Kojšov and Vinohrady nad Váhom) from the point of engineering geological conditions, main causes of landslides generation and presents their basic characteristics. Based on this evaluation the investigation and remediation works are designed.

Key words: hazardous landslides, inventory, assessment

Introduction

Slope deformations represent one of the most significant geodynamic phenomena in the territory of the Slovak Republic. Their total number so far detected, achieves 21 190 (Kopecký et al., 2008). Summary area of these deformations reaches 2 575.912 km^2, representing 5.25 % area of Slovakia. From the point of view of basic types of slope movements (Nemčok et al., 1974), the sliding dominates (landslides of various types), which prevails over creep (e.g. block failures) and rock-fall.

Annually, the landslides not only threaten, but also damage the agricultural land and grown crops, the built-up territories and buildings of every type. In addition to the direct damage to property, they hamper also the economic activities. Indirect damage shall include the costs of the investigation and exploration of sliding slopes, damaged objects, land, crops, river beds, etc. In some cases they even threaten the health and lives of people. Such a situation occurred in 2010. As a result of extreme rainfall, which in May and June of that year exceeded the mean values on more than four times (Pecho et al., 2010), there were generated catastrophic floods and a large number of slope deformations, landslides in particular. Total number of registered and documented slope deformations in 2010 in Eastern Slovakia reached 551 (Liščák et al., 2010; along with the landslides in the city of Košice and Nižná Myšľa this number reached 577). Up to 127 of them were marked with high (3) or very high (4) socio-economic relevance (according to Marzocchi et al., 2009). The total damage caused by these landslides can be estimated at several tens of million EURO. Of all there should be mentioned the landslides in Nižná Myšľa and Kapušany. Only the legendary landslide in Handlová (the years 1960–1961) was more severe than the landslide in Nižná Myšľa in our modern history. In Myšľa the landslide destroyed dozens of family houses, local communications, and engineering networks and still threatens the other residential and farm buildings. As a result of serious static damage 39 family houses were demolished, of which 26 were removed. In Kapušany 8 family houses were destructed, 6 of them have already been removed. In both municipalities a building ban had to be declared.

On the basis of the assessment of the socio-economic relevance by the turn of 2010/2011 the first 38 landslide sites were identified by the Ministry of the Environment of the Slovak Republic (MoE SR) for preliminary engineering geological survey (Jánová et al., 2011). The result of the exploration works were remediation proposals to ensure the long-term stability of slopes and to eliminate further damage to property, or threats to the population.

This contribution deals with the assessment of the engineering geological conditions, the main causes of the emergence and the essential characteristics of the active landslides at three selected sites – Ruská Nová Ves, Kojšov and Vinohrady nad Váhom. The result of the evaluation is a draft of exploratory and remedial works. In selected amount, the 22 active landslides evolved or re-activated again in 2011 (Fig. 1), we accounted in particular for the degree of their socio-economic relevance, i.e. the degree of damage and danger to residential and other objects, as well as to the population, but also the media coverage of the events.

Inventory and assessment of landslides in 2011

In the course of 2011 mayors of municipalities reported 36 landslides to the Ministry of Environment SR, or directly to the State Geological Institute of Dionýz Štúr in Bratislava and Košice (Tab. 1), which jeopardized, or even damaged residential and other buildings, engineering networks and the population. In most cases these were landslides documented in 2010, with the activity re-occurring in the year 2011. The exception were the landslides Babín, Harichovce, Lipovany, Liptovská Štiavnica, Lodno, Stráňavy, Stredné

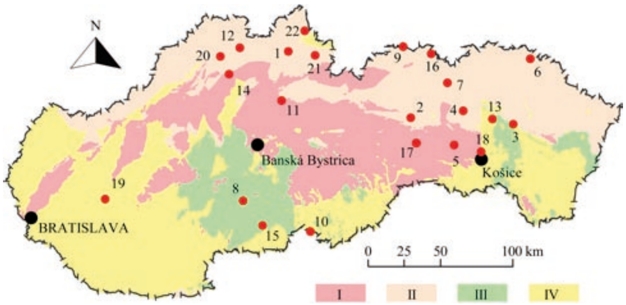

Fig. 1. Situation of landslides registered at the territory of Slovakia in 2011. I – Region of core mountains; II – Region of Carpathian Flysch; III – Region of Neogene volcanites; IV – Region of Neogene tectonic depressions; 1 to 21 – landslide sites (see Tab. 1).

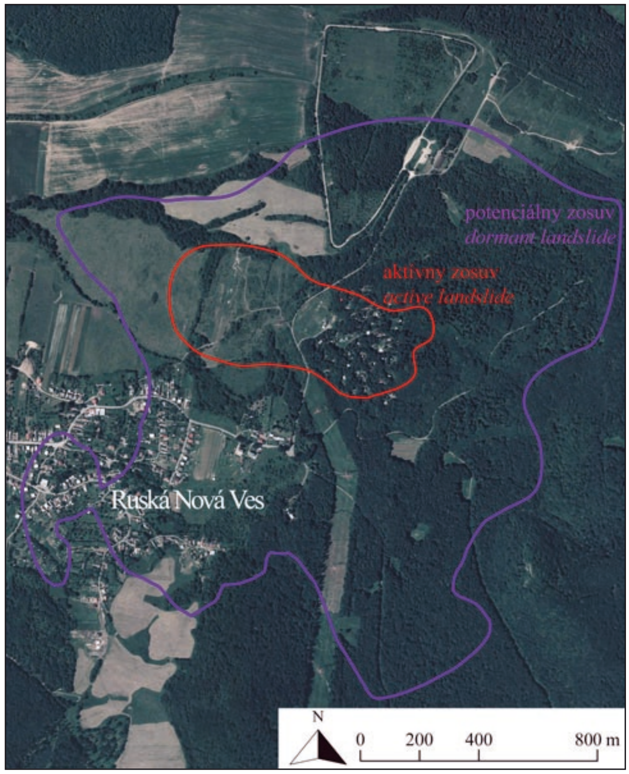

Fig. 2. Situation of landslide evolved in 2010 and re-activated in 2011, Ruská Nová Ves. The active landslide damaged 20 holiday cottages and engineering networks in the local forest-park (No. 13 in Fig. 1). December 2011.

Tab. 1
Review of sites with active landslides occurrence (reported to and assessed) in 2011

Site (Labelled as in Fig. 1)	Reporting date	Reconnaissance date	Registration in the Atlas of Slope Stability SR (Šimeková et al., 2006)
1. Babín	1. 12. 2011 (MoE SR)	9. 12. 2011	no
2. Harichovce	15. 3. 2011 (P. Bajtoš)	29. 3. 2011	no
3. Hlinné	28. 1. 2011 (MoE SR)	7. 2. 2011	no
4. Chminianska Nová Ves	25. 3. 2011 (MoE SR)	15. 4. 2011	no
5. Kojšov	14. 3. 2011 (Citizen)	12. 4. 2011	no
6. Krajná Poľana	9. 3. 2011 (MoE SR)	14. 3. 2011	no
7. Krivany	1. 8. 2011 (MoE SR)	3. 8. 2011	no
8. Krupina	13. 1. 2011 (MoE SR)	14. 1. 2011	no
9. Lesnica	31. 3. 2011 (MoE SR)	31. 3. 2011	no
10. Lipovany (2 landslides)	17. 2. 2011 (MoE SR)	24. 2. 2011	no
11. Liptovská Štiavnica	14. 3. 2011 (MoE SR)	22. 3. 2011	yes
12. Lodno	28. 2. 2011 (MoE SR)	3. 3. 2011	no
13. Ruská Nová Ves	15. 12. 2011 (MoE SR)	20. 12. 2011	yes
14. Stráňavy	28. 2. 2011 (MoE SR)	3. 3. 2011	yes
15. Stredné Plachtince	3. 2. 2011 (Mayor)	9. 2. 2011	no
16. Sulín (9 landslides)	23. 11. 2011 (MoE SR)	9. 12. 2011	no (5 landslides) yes (4 landslides)
17. Švedlár (2 landslides)	9. 3. 2011 (MoE SR)	14. 3. 2011	no
18. Ťahanovce	9. 8. 2011 (RO E Ke)	9. 8. 2011	no
19. Vinohrady nad Váhom (5 landslides)	30. 3. 2011 (Mayor)	28. 4. 2011	yes
20. Vranie	28. 2. 2011 (MoE SR)	3. 3. 2011	yes
21. Zabiedovo	28. 11. 2011 (MoE SR)	–	yes
22. Bobrov	28. 12. 2011 (MoE SR)	–	yes

Note: MoE SR – Ministry of Environment SR; (RO E Ke) – Regional Office of Environment – Košice

Plachtince, Vranie, however, also these were active in the past. All the reported landslides were examined directly at their sites by the ŠGÚDŠ workers, registered and evaluated on the basis of the available information on the geological, geomorphological, hydrogeological, and engineering geological conditions. The main objective of the evaluation was to assess the socio-economic relevance of the sliding sites (category R1-R4), necessity of realization of exploratory works, or their scope and the proposal of remedial measures. In the case of some of the sites there were proposed immediate remedial measures to prevent imminent danger to inhabitants and to eliminate further deterioration of assets (Krajná Poľana, Lesnica, Sulín, Vinohrady, Liptovská Štiavnica, Lipovany, Stredné Plachtince). The reports from the inventory were drawn up separately for each of the landslide site (the number of landslides at some of the sites was 2, 5 or even 9) and sent to the Section of Geology and Natural Resources MoE SR and at the same time to the mayors of the respective municipalities. Besides the GNSS devices also the orthophotomaps from free version of the Google Earth 6.2 (Figs. 2, 6 and 9) were used to visualize the location of landslides.

Site Ruská Nová Ves

The active landslide is located northeast of the Ruská Nová Ves Village (Fig. 2). It evolved after excessive precipitation in May and June 2010. However, it had not been reported as an emergency landslide, therefore it did not get into the MoE SR database of 2010 and was not assessed, nor its socio-economic relevance. The result of ongoing slide activity in 2011 were several residential buildings damaged along with over 20 holiday cottages, access roads, playground, engineering networks (water and electrical connections), wells, hedges, forest cover etc. In the active landslide there is also the recently built VHV mast (Very High Voltage – 400 KV – Fig. 3). The static damage of several huts has been evaluated as serious (Fig. 4). One cottage had to be even demolished (Fig. 5). The seriousness of the situation asked for a site stability analysis (Spišák et al., 2011). Due to the high material damage, but also out of concern about the threat to the security of the inhabitants (6 buildings are permanently inhabited), on 16. 12. 2011 the mayor declared in the village the emergency situation. The Section of Geology and Natural Resources MoE SR entrusted the State Geological Institute of D. Štúr (15. 12. 2011) to carry out a comprehensive engineering geological assessment of the site. The assessment consisted of reconnaissance of the landslide territory, the archive study (Petro et al., 1984; Šimeková et al., 2006) and the mentioned site stability analysis.

Geomorphological and hydrogeological conditions

In the sense of a geomorphological subdivision (Mazúr et al., 1986), the territory belongs to the subunit Šimonka, which is a component of the unit Slanské vrchy Mts. The

Fig. 4. Static breach of the cottage in the forest-park near Ruská Nová Ves. Photo Ľ. Petro, December 2011.

Fig. 3. Jeopardized VHV mast (400 kV) erected in 2011, located in the transportation part of the active landslide. Photo Ľ. Petro, December 2011.

Fig. 5. The remnants of the cottage demolished due to serious damage by landslide in the forest-park near Ruská Nová Ves. Photo Ľ. Petro, December 2011.

landslide territory is located at the foot of the volcanic mountain range, its northwestern part. Its surface is rough and ragged, marked by numerous elevations and depressions. The head scarps of the landslides reach the volcanites margin. Some depressions are wetlands; others have the character of occasional pools of smaller dimensions. Frequent presence of long and deep-incised gullies testifies to the ongoing indepth erosion by local creeks. Činaloš creek with its left tributary flows directly through the landslide territory. Water in the slope originates both from the rainfall, as well as numerous nearby springs. These occur mostly at the contact of Neogene, or Quaternary sediments with volcanites. The natural drainage of the territory takes place through a network of creeks, which finally mouth into Sekčov, the left inflow of the Torysa river. The annual precipitation total at this site reaches around 700 mm (Faško and Šťastný in Miklós et al., 2002).

Geological setting

In the geological structure of the landslide territory there are involved marine clays and claystones, locally the calcareous and silty ones, of green-grey and grey colours. Karoli (in Kaličiak et al., 1991) ranked them in the Mirkovce Formation (the Early and Middle Badenian). At the surface these sediments are of the clay character of green-shaded colour and they often contain calcareous nodules. They represent a fossil weathering crust reaching a thickness of 1–3 m. From the statistical evaluation of hundreds of samples, it is obvious that high plastic clays of firm consistency dominate (Petro et al., 1984). They are overlain by coluvial (deluvial) sediments; their thickness verified by boreholes and trial pits attains 1–12 m. From the granulometry point of view they are clayey-stony deposits with variable content of the sharp-edged fragments (at places stones and boulders) of andesites (16–66 %). The clays are medium and high-plastic (Petro et al., 1984).

Landslide characteristics

The active landslide is a component of an extensive landslide territory in the vicinity of Ruská Nová Ves, which was identified in the framework of a detailed (1 : 10 000) engineering geological research in the early 1980s (Petro et al., 1984). This wider area of a potential landslide reaches the dimensions of approximately 1 900 (length) x 1 800 m (width) (Fig. 2). The depth of the basal slide surface was verified in 12–15 m (occasionally up to 20 m) below the surface. The main scarp reaches to the flanks of the volcanic massif, where sudden change of a dip (from 6° to 15°) takes place at the contact of volcanic and sedimentary rocks. The height of the main scarp reaches 5–8 m. The active landslide, located in the central part of the potential landslide (sites Ľadová and Kamence) attains 850 (length) x 380 (width) m; total area affected by sliding is 117 619 m^2. The landslide occurred after extreme precipitation in May and June 2010 and the manifestations of its activity have persisted up to the present. From the North and South, the landslide is limited by erosion gullies; three creeks are incised in the landslide body. The head wall reaches a height of 0.7–1.5 m. The middle (transportation) part is wavy, bumpy and rugged, with numerous elevations and depressions, wetlands and even one small lake. The front end is less distinct and gradually fades out on the slope. On the basis of morphological manifestations we assume the course of the slip plane at a depth of 6–8 m.

Cause of landslide generation

The extreme rainfall in the year 2010 can be regarded as the main cause of the formation of the landslide. The monthly rainfall totals reached in the vicinity of Ruská Nová Ves in May 251–275 mm and in June 141–160 mm (Pecho et al., 2010). The overall stability of the slope is significantly degraded by surface water derived from precipitation and local springs; this penetrates downward and saturates the zone of slip plane. The water not only deteriorates the strength properties of the soil, but it generates also the buoyancy effect. The surcharge of the slope by buildings (cottages and inhabited houses), inappropriate interventions in the slope (unsecured cuts) and the absence of drainage system for water tapped from roofs of buildings also detract the overall stability of the slope.

Prevention against sliding

The measures to stabilize the sliding slope were designed in the scope of the site assessment drawn up by the end of 2011 (Spišák et al., 2011) and they included:

– removal of artificial small lake situated within the landslide body at one of the holiday cottages;

– elimination of infiltration of water from roofs and paved areas into basement, realized through a conduction of the water tapped into the erosion gullies at the edge of the landslide body;

– cleaning up the deeper erosion gullies in order to ensure the drainage of surface water;

– adjustment of slope in the main scarp area of the active landslide, i.e. the backfill of open fractures and alleviation of the slope angle.

It should be noted that the final design of remediation will pursue the results of implemented engineering geological survey which should include drilling, reaching up below the basal slip plane (minimum 15 m), laboratory tests of soils and slope stability calculation in one or two profiles.

Locality Kojšov

This landslide evolved in 2006 and was activated after extreme precipitation in May and June 2010. Whereas it had not been reported as an emergency landslide, therefore it did not get into the MoE SR database of 2010. It was the owner of the family house (No. 274) who announced the landslide to the workers of ŠGÚDŠ in Košice on 14/03/2011. A survey of the landslide was carried out guided with the mayor of the municipality on 12/04/2011. The landslide territory is located at the eastern outskirts of Kojšov (Fig. 6)

Fig. 6. Situation of landslide evolved in 2010 and re-activated in 2011 at the eastern ouskirts of the Kojšov Village (No. 5 in Fig. 1).

on the west slope. The landslide lobe heavily damaged the rear wall on the slope edge and the roof of the family house No. 275 (Fig. 7a, b). Serious static breach of the house required the construction of a wooden supporting structure in order to prevent further damage (Fig. 8). The owner of the house removed the accumulated soil from and partly beneath the roof and uncovered the uppermost part of the rear wall. In addition, he dug out a shallow ditch in order to conduct away the water seeping out from the slope. Despite these efforts these immediate remedial measures cannot be regarded as sufficient. Due to the geological structure and the nature of the terrain not only the house No. 275 is still threatened, but also the house located to the north of it (No. 274).

Geomorphological and hydrogeological conditions

The site is located in the eastern part of the Volovské vrchy Mts. According to Mazúr et al. (1986) it belongs to the unit of Kojšovská hoľa. The territory is situated on the right slope of the Kojšovský potok brook valley, which drains the whole area. The morphology is very uneven, partly obscured by the forest cover. Annual precipitation at this site reaches around 800–900 mm (Faško and Šťastný in Miklós et al., 2002).

Geological setting

The sliding slope behind the family house No. 275 is built of grey and grey-green chlorite-sericite phyllites, eventually with intercalations of graphite-sericite phyllites, and fine-granular basaltic metamorphosed pyroclastics, which are affiliated to the Prakovce Member of the Smolník Formation of the Gelnica Group (Grecula et al., 2009). The rocks are schistose, weathered and at the surface strongly deteriorated into sharp-edged fragments. The fragments reach even the size of boulders (>200 mm), which use to fall off the slope. The phyllites are overlain by clayey-stony deluvial sediments of a thickness of 0.5 – 1.5 m. Two wet spots occur in the slope, indicating groundwater seeping out of the massif. The water flowing downslope gets below the foundations of the family house despite the interim surface ditch (Fig. 7b).

Landslide characterisitics

The landslide territory is located on a quite steep (15°) and partially wooded slope. The landslide can be characterized as equidimensional with shallow (about 1.5–2.0 m b.s.) course of composite slip plane. Its dimensions are 40 (width) x 30 m (length). Mobilized are the slope clayey-stony sediments along with the weathered phyllites. Larger pieces of rocks (stones and boulders) fall out sporadically of the slope and roll downslope. The main scarp is uneven and has a height of 1.0–2.0 m. Above it there is the overhead electrical wire. The middle transportation part is uneven, dissected and at places the slip plane is exposed (Fig. 7a, b). The original lobe of the landslide, which reposed on the family house No. 275 and damaged it, was partially excavated away by the owner. In two spots groundwater seepage has been identified, which contributes to the instability of the entire slope.

Fig. 7a, b. Views of the active landslide and damaged family house No. 275 in Kojšov. Photo Ľ. Petro, April 2011.

The morphology above the main scarp of the landslide has the nature of the depression and this is the infiltration contributing area through which the precipitation infiltrates the rock mass.

Cause of landslide generation

As the main cause of the landslide reactivation we consider the extreme rainfall in May (>300 mm) and June (>200 mm) of 2010 (Pecho et al., 2010). Among the other natural causes there should be noted the underground water (two spots with groundwater seepage), which act as uplift force and, at the same time, it weakens the soil bonds and the overall stability of the slope. During heavy rains the depression above the main scarp conducts the collected water directly towards the landslide. Among the anthropogenic causes we have to mention in particular the undercutting of the slope foothills and deforestation of the slope due to the high voltage wiring installation.

Prevention against sliding

In view of the persistent real threat to family house No. 275 and the safety and health of its inhabitants, it is necessary to implement as soon as possible the rehabilitation of the landslide slope. We would propose the following measures:

1. The adjustment of the slope and the removal of dangerous overhangs in the upper part of the main scarp along with removal of projecting and released boulders.

2. Excavation of a deep ditch (at least at the level of 30 cm below the surface of the base), 80–100 cm wide in the bottom part and approx 60 cm in the upper part, at least 60 cm from the family house. The excavated ditch should be left open as short as possible. In the case of rain, it is necessary to prevent the inflow of water into it.

3. Building up (in the excavated ditch) a revetment wall made of crushed stone, which should protrude at least 1 m above the bottom of the roof. The slope of the revetment wall should be around 80° tending into the slope. Behind the wall at the level of its base there should be placed a drain tube (diameter at least 100 mm) within gravel packing. In the body of the revetment wall the lateral drainage pipes of a diameter about 50–60 mm should be installed at a distance of about 1.5–2 m.

4. The incorporation of about 1 m high fence of thick metal mesh into the top of the revetment wall, which would collect the falling stones and fragments.

5. Excavation of about 50 cm deep drainage ditch for conduction of surface water off the landslide body and family houses, about 15 above the head scarp of the slip. In order to avoid the water infiltration into the slope, it should be paved with prefabricated or polyethylene elements.

6. Afforestation or grassing of the slope.

7. Ban of wood-cutting on the slope in the wider vicinity of the landslide.

Final remediation work should be carried out under the supervision of an experienced expert, and supported by the results of a quite simple engineering geological survey, which would include verification of the groundwater depth in slope and the determination of the physico-mechanical properties of the soils.

Fig. 8. Landslide-generated static breach of the rear wall of the family house No. 275 in Kojšov. Photo by homeowner, April 2011.

Site Vinohrady nad Váhom

Re-activated landslides in the Vinohrady nad Váhom again are components of a wider landslide territory between Hlohovec and Sereď. This 18 km long strip of landslides is known especially thanks to the extensive engineering geological survey in connection with the projected Water Works Sereď – Hlohovec (Otepka et al., 1983).

Geological setting

From the geological point of view the wider territory is built of Neogene sediments (Pliocene), which are covered by Quaternary deposits of different thicknesses. The Neogene layers of clays and sands (Dacian – Romanian)

Tab. 2
Registration of landslide territories in Vinohrady nad Váhom

No. *	Slide territory	Width [m]	Length [m]	Area [m^2]
1	Paradič	47.00	21.00	801.13
2	Kamenica	136.00	39.00	4 353.42
3	Pomorová	55.40	42.30	1 685.23
4	Pri Kate	31.70	18.00	445.55
5	Pográň	58.00	90.00	4 114.46

* – labelling in Fig. 9

Fig. 9. Re-activated landslides of the year 2011 in the local parts of the village Vinohrady nad Váhom. (No. 19 in Fig. 1). 1 – Paradič; 2 – Kamenica; 3 – Pomorová; 4 – pri Kate; 5 – Pográň.

achieved several meters of thickness with an abundance of sandstone, sporadically conglomerate horizons (Otepka et al., 1983). From the point of view of slope stability, Nemčok (1982) characterizes the alternation of impervious clays and water-bearing sands as a structure suitable for the development of slope failures. The concentration of water in the more pervious sandy layers creates horizons with groundwater and the buoyancy force acts against less stable landslide materials. In addition, the territory is dissected tectonically into the series of blocks with different vertical displacement. These upward movements were accompanied during the whole Quaternary period (until now) by the intensive lateral erosion in the peripheral parts of the Nitrianska pahorkatina Upland.

The Quaternary rocks in the landslide territory are represented by fluvial deposits of the Váh river, eolian--deluvial and proluvial sediments (Otepka et al., 1983). The fluvial loams fill the uppermost part of the alluvial plain. They are formed by clayey and sandy deposits of variable thickness. Downwards the sands occur, often even with a gravel. In the elevated territory of the Nitrianska pahorkatina Upland, on eolian-deluvial and deluvial sediments are present, mainly loess and loess-like loams, less eolian sands. The deluvial sediments are incoherent, forming irregular caps with a thickness of 1 to 1.5 metres. In the outlying parts of the alluvial plain, in the areas erosion gullies mouthing proluvial cones have developed.

The landslide material is derived from the Quaternary and Neogene sediment; it has the character of the clay to clayey loam, or the mixture of clayey and sandy material. Its thickness is quite variable in the territory.

The territory is drained by the Váh river, which in this section has had a character of braided river and has created numerous oxbows and levees elevated about 1 to 3 m. The left tributaries are intermittent, and are active in the periods of snow melting and heavy rainfall.

Inventory of landslides

The re-activation of landslides was recorded in the spring months of 2011, when several parts of the municipality of Vinohrady nad Váhom were jeopardized,

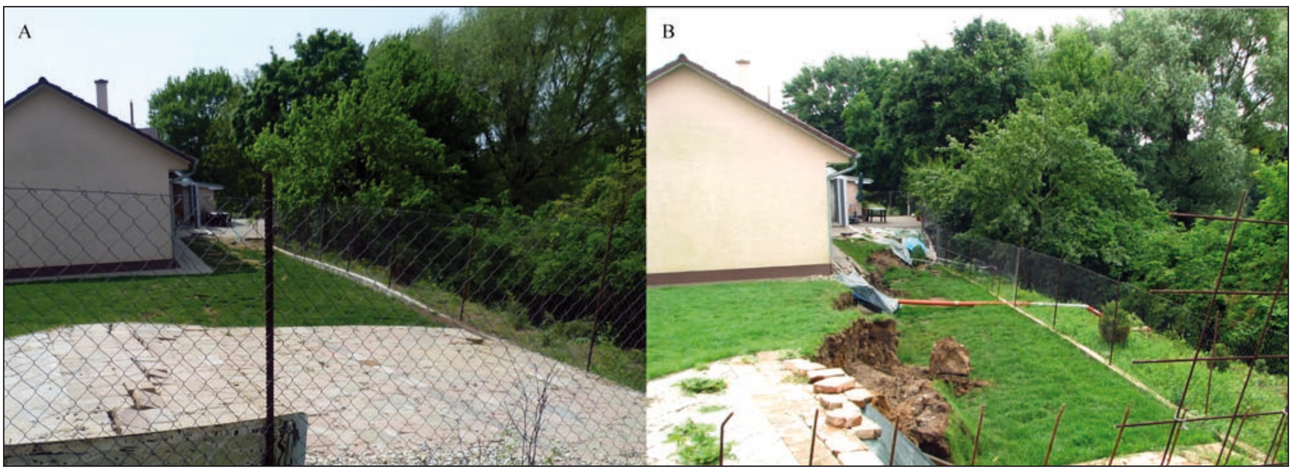

Fig. 10. Family double-house endangered by the landslide in Vinohrady nad Váhom – part Kamenica. A – recorded on 28. April 2011 (Photo M. Bednarik); B – recorded after Declaration of Emergency Situation, 22. June 2011 (Photo P. Ondrejka).

mainly the local communication and the gas piping. In the local part Kamenica, the landslide threatened the family double-house. The communal representation was forced to ask for help the Ministry of the Environment, which in turn (by means of the Section of Geology and Natural Resources) asked the State Geological Institute of Dionýz Štúr to carry out survey, the documentation and geodetic levelling of the five sliding partial territories. A survey was carried out on 28. April 2011.

The landslides in the local parts Paradič, Kamenica, Pomorová, pri Kate and Pográň (Fig. 9) are located on the relatively steep and densely bushed western slopes. The landslide, which developed in the local part of Kamenica (Fig. 10), represents a serious threat to the double-house No. 711/712, whereas the head scarp is located in its immediate vicinity, directly below its north-western wing. In the other areas of the village the local communication was threatened.

For the field mapping, as far as the conditions permitted, we used a GPS device of the GIS category. The dense stands in some parts of the landslide territory hampered the application of this technology. The movement in the ground deteriorated frequent occurrences of wetlands. Thanks to the above facts it was not possible to ensure complete outlines of reactivated landslides. The contours of the affected territory were finalized over ortophotomap documents, thereby making it possible to achieve the required accuracy. The basic characteristics of the registered landslides are listed in Tab. 2.

The landslides in local parts Paradič and Pográň are of flow shape with well developed head scarp 4–5 m high. In the local parts of Pomorová and pri Kate there developed equidimensional landslides with the height of the head scarp around 3 m and relatively short transportation areas. The landslide in the Kamenica area has a character of an extensive slide with locally well developed head scarp and wide-opened lateral fractures. At the time of registration, the southern part of the head scarp reached to the north--west edge of the family double-house No. 711/712. The retrograde development of this disturbance would cause a static breach of the double-house and it has represented a serious threat to other houses, along the street above in slope and also to local communication. A negative omnipresent phenomenon observed in the sliding territories Paradič, Pomorová and Kamenica were surges of groundwater, in particular the head scarp zones. This water flew into uneven morphology of the landslides and fills up the depression and saturated the sliding masses.

The reconnaissance campaign identified the active status of all landslides. On the kinetic activity suggests the presence of open transverse cracks within sliding masses, and their progressive development, as well as frontal lobes with significant deformation of the territory surface.

Cause of landslides generation

According to Otepka et al. (1983) the territory represents the third generation of landslides, which occupy a contiguous strip bounded by the edge of the Nitrianska pahorkatina Upland and alluvial plain of the Váh river. Bednarik in his study (2007) ranked this area to the territory with a very high and high degree of landslide hazard. At this point it should be noted that such territories are especially sensitive to anthropogenic interventions and due to inadequate implementation of construction activities re-activation of fossil or potential landslides takes place.

During the April registration we have concluded, the inappropriately targeted anthropogenic activities were one of the main factors that contribute to the destabilization of the territory. This was in particular the creation of illegal landfills in the areas of head scarps of the potential slope failures. The residents of the village had adopted the ill practice of waste deposition in the vicinity of local communication in order to prevent its destruction. Moreover, in the territory of interest also intensive construction of family houses has taken place. The constructions themselves represent a surcharge to the slope, attenuated by backfilling of the depressions and other earthworks.

Another cause is inappropriate or insufficient drainage of surface and waste waters. In the local part the public sewerage is missing, therefore sewage and draining within the local part Kamenica is dealt individually, usually by means of a cesspit (Dobrovoda, 2010), or low-capacity biological treatment plants. The field reconnaissance, but also the interviewing the local inhabitants, showed that a considerable part of the sewage is discharged directly into the ground through the so-called catch-drains. Similarly, precipitation waters captured from the roofs of existing buildings are also conducted into the underground infiltration. In addition, as the result of previous sliding events the whole environment is fractured; the open cracks represent the preferred paths for infiltrating surface water. This fact allows the saturation of deeper sandy sediments in the earth massif.

Design and realization of remedy measures

In view of the fact that the landslides have threatened the objects with a high socio-economic value, it was necessary to prevent the development of this negative phenomenon by appropriate countermeasures. Part of the report of the reconnaissance has been a proposal of countermeasures in the safe conduction of sewage and precipitation water from existing and future structures. Deflection of the waters was designed in the sub-surface drain utilizing a favourable inclination of the territory to the future treatment plant of waste water. Another countermeasure was intended to minimize the terrain surcharge by fills, or by building further structures in the area of head scarps, or directly within landslides.

After ongoing very adverse development of motion activity there occurred in the part Kamenica the direct threat to the family double-house (Fig. 11) and the serious damage to the road communication. The status of the 22. June requested the Declaration of the Emergency Situation. Subsequently, the Ministry of Environment

Fig. 11. Head scarp of the landslide Pográň with illegal landfill. Photo M. Bednarik, April 2011.

instructed the State Geological Institute of D. Štúr to execute engineering geological survey and immediate emergency countermeasures.

In a very short time in the most affected part of the Kamenica landslide the works were launched aimed at draining the slope (Liščák et al., 2011). With the assistance of the Army of the Slovak Republic 6 surface drainage ditches were manually excavated through the inaccessible terrain reaching a total length of 428 m and a depth of 0.5 m. Through these ditches a substantial part of the waters in the landslide territory was channelled out of the landslide into the alluvial plain deposits of the Váh River.

The biggest problem was the rescue of the family double-house, which is found directly on the head scarp of the landslide. After the implementation of the engineering geological survey there was designed and implemented anchored micro-pile wall (Fig. 12). The groundwater table level was drawn down by subhorizontal drainage borehole V-8 directly below the double-house at a depth of about 7 m.

In the landslide territory there have been designed additional rehabilitation measures, implementation of which is envisaged in the spring months of 2012.

Fig. 12. Remedial works aiming on the rescue of the family double-house No. 711 a 712 (construction of the anchored micro-pile wall). Photo I. Dananaj, June 2011.

Conclusions

In 2011, the State Geological Institute workers registered and surveyed a total of 22 sites with occurrences of sliding, in particular landslides. There were registered brand new landslides, resulting in a given year (sites Lesnica, Chminianska Nová Ves, Krivany, Lipovany), the landslides incurred after extreme rainfall in May and June 2010 and activated in 2011 (sites Ruská Nová Ves, Sulín, Krajná Poľana, Krupina), and landslides with the consistent activity since 2010 (sites Švedlár, Hnilec). Some landslides have been known already for a longer period (Vinohrady), some of them (Vranie) have been even with remedial measures. The common feature of all landslides was a threat to the living and other buildings, infrastructure, population or even the direct material damage (Ruská Nová Ves, Sulín, Kojšov, Vinohrady nad Váhom, Lipovany, Krupina). The threat raised by both mayors of the villages and the residents was communicated to the Section of Geology and Natural Resources MoE SR, which consequently ensured the registration and evaluation of the socio-economic seriousness by the ŠGÚDŠ experts. The most dangerous landslides registered (in category R4), will be inserted into the plan of survey and remediation.

The registration of active landslides in 2011 on our territory has established a number of important facts.

1. Despite the relatively dry year of 2011, more precisely its second half, a number of new landslides evolved and several landslides with motion recorded in the year 2010 have been re-activated again.

2. The main triggering factor of some new landslides was the lateral stream erosion (Lesnica, Krivany, Chminianska Nová Ves, Sulín, Švedlár, Hlinné, Babín). Remediation of these landslides will not be effective without modifying its creeks.

3. The inappropriate anthropogenic activity (surcharge of head scarps, change in the groundwater regimen) has contributed to the process of landslides mobilizing at the sites Vinohrady nad Váhom, Krupina, Babín, Kojšov.

4. From the Tab. 1 there is clear that the majority (21) of registered/assessed landslides is not recorded in the Atlas of Slope Stability SR (Šimeková et al., 2006) as a slide or an area prone (susceptible) to sliding. Based on the inventory results it will be possible to update further the database of existing landslides. Also this fact emphasizes the relevance of ongoing landslide inventory and investigation.

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