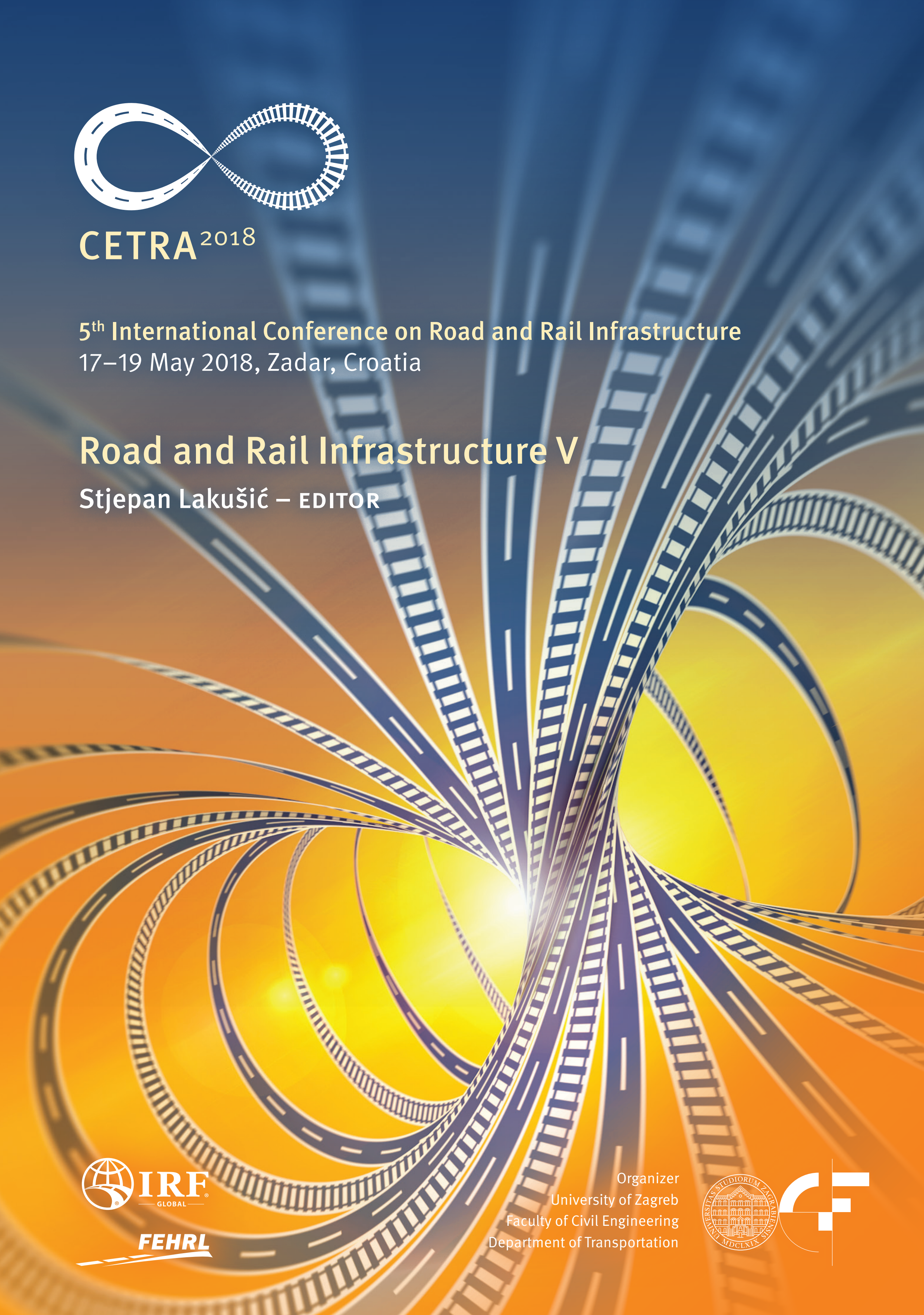

CETRA2018

5th International Conference on Road and Rail Infrastructure

17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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Road and Rail Infrastructure V

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CROATIAN EXPERIENCE IN APPLICATION OF UAS FOR LANDSLIDE REMEDIATION MEASURES

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Abstract

Unmanned Aerial System (UAS), also known as 'drone', has found many applications in various sectors of human activity. Drones were shown useful since they can be used for remote investigations in very simple manner. They can be navigated by the operator from the ground or they can conduct an investigation by themselves in programmed flight path. In the Republic of Croatia, drones have recently been effectively used as part of investigative work for the purpose of design and remediation measures in many landslide areas. Northern part of Croatia is characterized by a large number of landslides which can cause serious damage to buildings and transportation infrastructure, personal injury and traffic delays. In order to detect features linked with landslides (boundaries, cracks, etc.) a drone technology is applied and was shown as very effective, with some examples shown in this paper. Not only that overall cost of the investigation is lower, but 'bigger picture' of landslide areas is taken in consideration. Also, increase of safety is also significant since engagement of additional personnel is avoided, which was previously inevitable since they needed to examine 'dangerous to reach' areas in order to detect features linked with landslides.

Keywords: UAS, landslide, remediation, investigation, Croatia

1 Introduction

A landslide is defined as "the movement of a mass of rock, debris, or earth down a slope" [1]. Landslides are a type of "mass wasting", which denotes any down-slope movement of soil and rock under the direct influence of gravity. Landslides are divided into the following types, see Fig. 1:

- Fall – landslides that involve the collapse of material from a cliff or steep slope with rapid to extremely rapid rate of movement. Falls are caused by erosion processes or earthquakes.
- Topple – landslides that involve the forward rotation and movement of a mass of rock, earth or debris out of a slope with rapid rate of movement.
- Flow – the most destructive and turbulent form of landslide. Flows have a high water content which causes the slope material to lose cohesion, turning it into a slurry. There are five basic categories of flows: debris flow, debris avalanche, earth flow, mud flow, creep. Combination of two or more of the above categories is known as a complex landslide.
- Slide – mass movements, where there is a distinct zone of weakness that separates the slide material from more stable underlying material, with moderate rate of movement. The two major types of slides are rotational and translational slide.
- Spread – this phenomenon is characterized by the gradual lateral displacement of large volumes of distributed material over very gentle or flat terrain with rapid rate of movement. Failure is caused by liquefaction which is ground failure or loss of strength that causes

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otherwise solid soil (usually sands and silts) to behave as viscous liquid. Liquefaction is mostly caused by earthquakes. Spreads usually have rapid rate of movement [1].

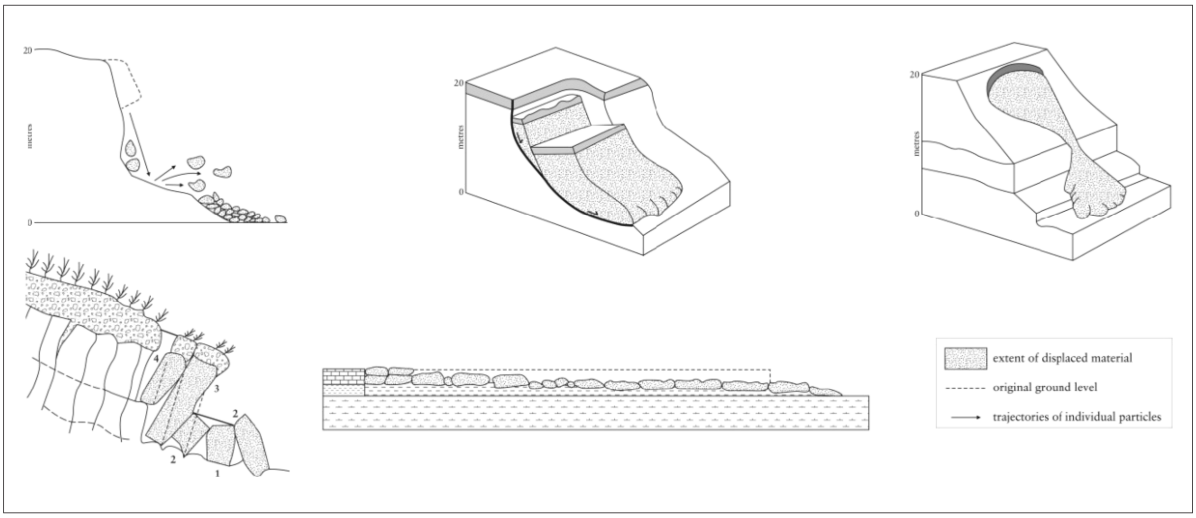

Figure 1 Types of landslides: (1) fall; (2) topple; (3) a slide; (4) a spread; (5) a flow [1]

Landslides can move slowly (millimeters per year), or can move quickly and disastrously, as is the case with debris flows. Debris flows can travel down a hillside at speeds up to 320 kilometers per hour (more commonly 50-80 kilometers per hour). The movement of landslide can be described from extremely slow (less than 15 millimeter per year) to extremely rapid (more than 5 meters per second) [2], Table 1.

Table 1 Description of landslide movement [2]

Description	Velocity [mm/sec]	Typical Velocity
Extremely rapid	$> 5\times10^{3}$	> 5 m/s
Very rapid	$> 5\times10^{1}$	> 3 m/min
Rapid	$> 5\times10^{-1}$	> 1,8 m/h
Moderate	$> 5\times10^{-3}$	> 13 m/month
Slow	$> 5\times10^{-5}$	> 1,6 m/year
Very slow	$> 5\times10^{-7}$	> 16 mm/year
Extremely slow	$< 5\times10^{-7}$	< 16 mm/year

2 Equipment used in investigation

2.1 DJI Phantom 2 Vision +

This UAS (Unmanned Aerial System) has four propellers (quadcopter) and is equipped with a camera attached to the bottom that can record high-resolution images or high-definition video, see Fig. 2. It also comes with many other features for recording digital imagery. A user can control the device using a remote control connected to almost every smartphone, where live preview from the drone's camera can be streamed. By using live preview supplied to the smartphone, operator can navigate the drone even when it is out of a direct line of sight.
Pix4Dmapper is software that converts thousands of aerial and oblique images into geo-referenced 2D orthomosaics and 3D surface models and point clouds. With its advanced automatic aerial triangulation based purely on image content and unique optimization techniques, Pix4Dmapper software enables any UAS or camera to become a professional mapping and surveying tool [4].

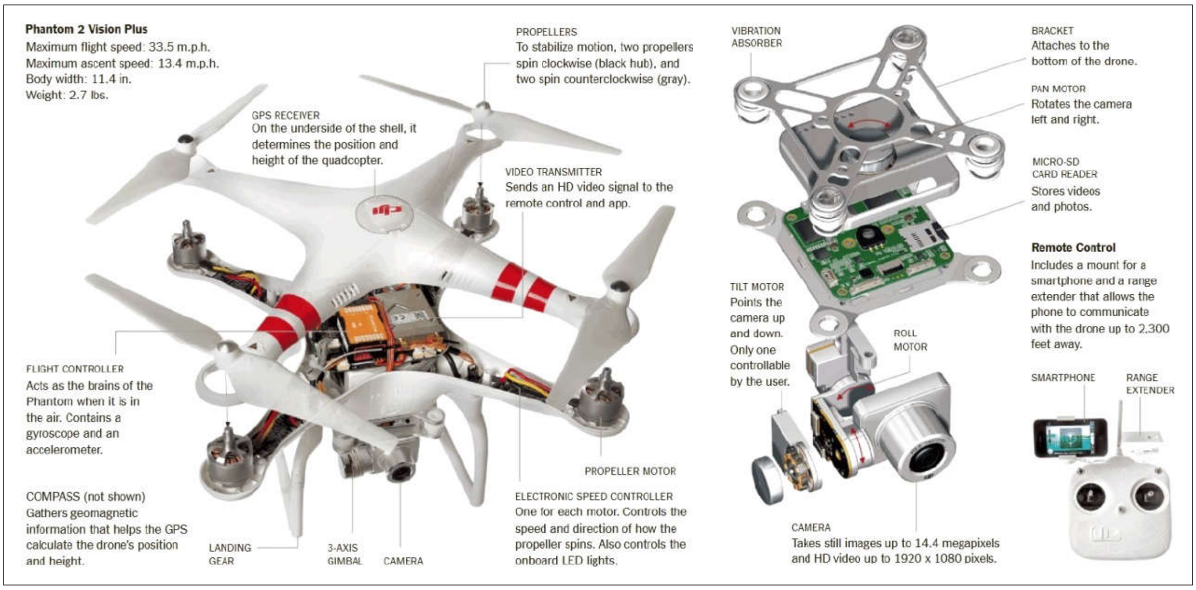

Figure 2 Parts of DJI Phantom 2 Vision+[3]

3 Experience in using UAS on landslide analysis in Croatia

The Classified European Landslide Susceptibility map v1.0 (ELSUS1000, 1 × 1 km resolution) covers 26 EU member states, Norway and Switzerland as well as the non-EU Balkan countries. The Croatia territory was also analysed within ELSUS 1000 and it was evaluated, reviewed, updated and improved with regional data sets, see Fig. 3 (a). Experience and knowledge of experts about characteristic landslide occurrences for each region were taken into consideration and as a result Landslide susceptibility map of Croatia (LSMC) was created, see Fig. 3 (b). [5]

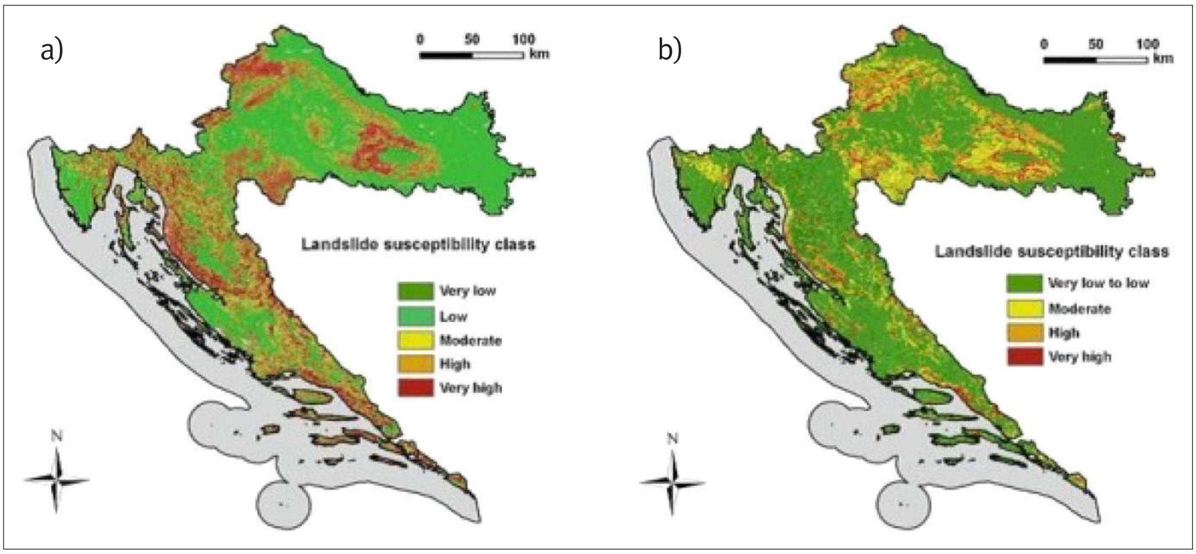

Figure 3 Landslide susceptibility map of Croatia: a) according to ELSUS; b) according to LSMC [5]

3.1 Analysis of Doljan landslide

Doljan is situated in northern part of Croatia, which is according to landslide susceptibility map known as a part of Croatia with a high, to very high landslide susceptibility class. Notch Doljan is situated in km 80+320, railway track R201 Zaprešić – Čakovec between railway stations Novi Marof – Turčin. Due to the rainy season, on the right side of the Doljan notch landslide appeared. Sliding material currently is activated, moving in larger quantities and has a tendency to slide towards the railway line. Geological and geotechnical research works, see Fig. 4, concluded that the main cause of sliding is inadequate regulation of drainage water from the slopes of the notch. The surface zone has been registered predominantly clay material with very high plasticity and very low permeability.

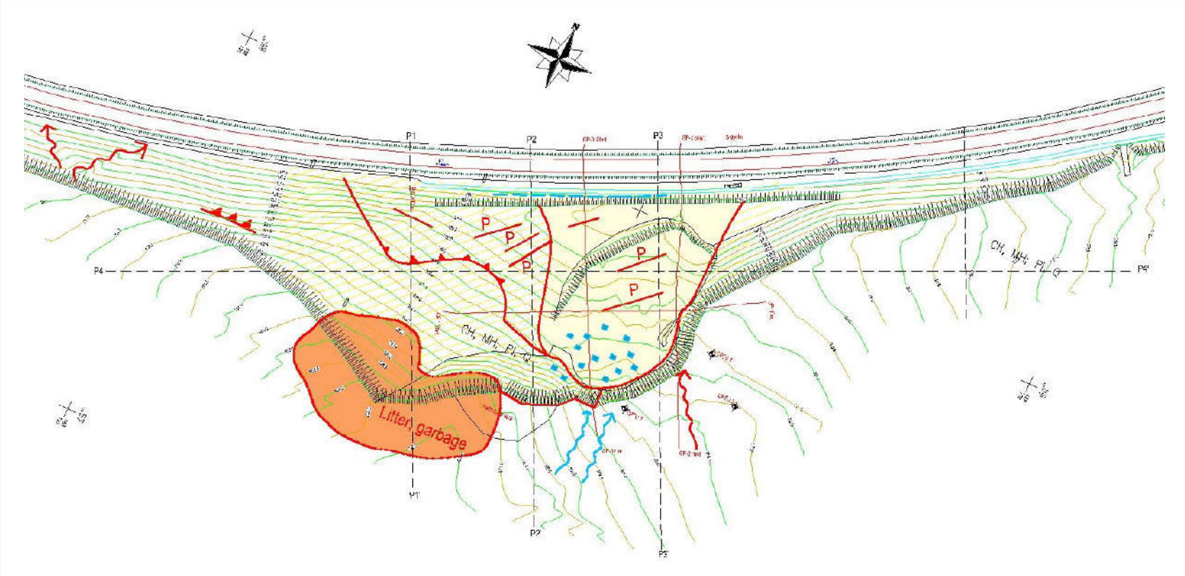

Figure 4 Engineering geological mapping

The rate of leakage is extremely small, which causes a significant increase in pore pressure and a decrease in shear strength, reaching the upper limits of the stability of the slope. The purpose of the project was to develop remediation and reparation design in that location which would ensure permanent stability of the notch.

Upon arrival at the location the first step is connecting drone with smartphone through wireless connection and uploading the map of the location to smartphone in purpose of getting prepared autonomous flight of aircraft. To prepare autonomous flight it is needed to set up dimensions of mapping area, flight orientation and altitude as well as drone airspeed. After the pictures are taken, drone returns to the home point and begins uploading georeferenced photos with all necessary parameters needed for orientation of images as they were at the time of exposure on the smart phone or tablet computer. By uploading such georeferenced images taken from air in Pix4Dmapper it displays flight path and the position of each photo that was taken, see Fig. 5.

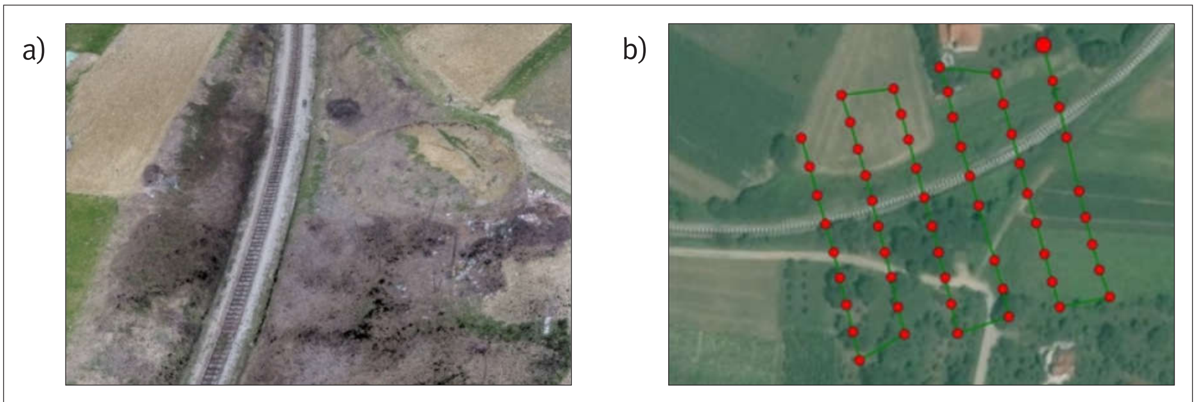

Figure 5 a) Picture of landslide taken from DJI Phantom 2 Vison+; b) flight plan and positions where images were taken

Photo processing, generating point cloud and orthophoto map takes place automatically by Pix4Dmapper. Software generates orthophoto map, Digital Surface Model (DSM) and 3D view of the terrain in the form of a point cloud. This way generated orthophoto map and point cloud allows us to produce cross sections, see Fig. 6, contour drawings, measuring areas and volumes, see Fig. 7, directly in the point cloud model and export to other different CAD and GIS format.

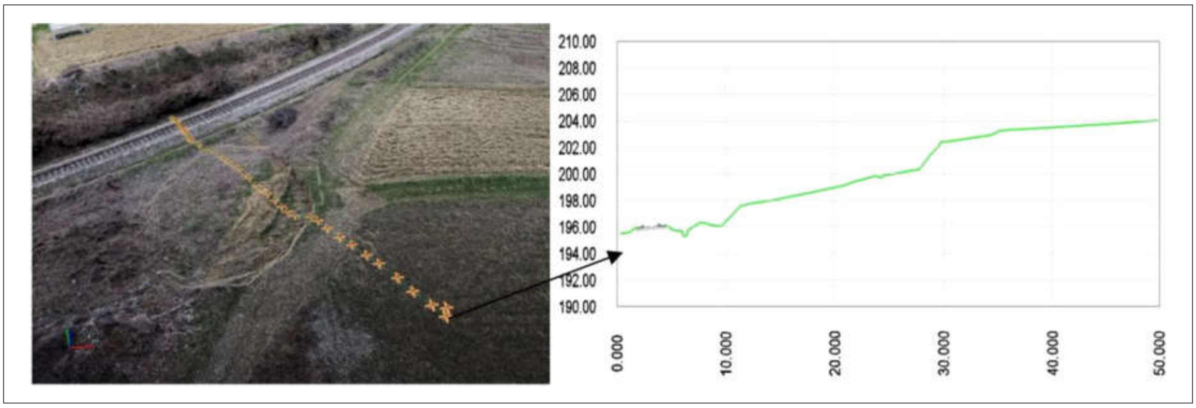

Figure 6 Defining cross – sections at Doljani cutting [6]

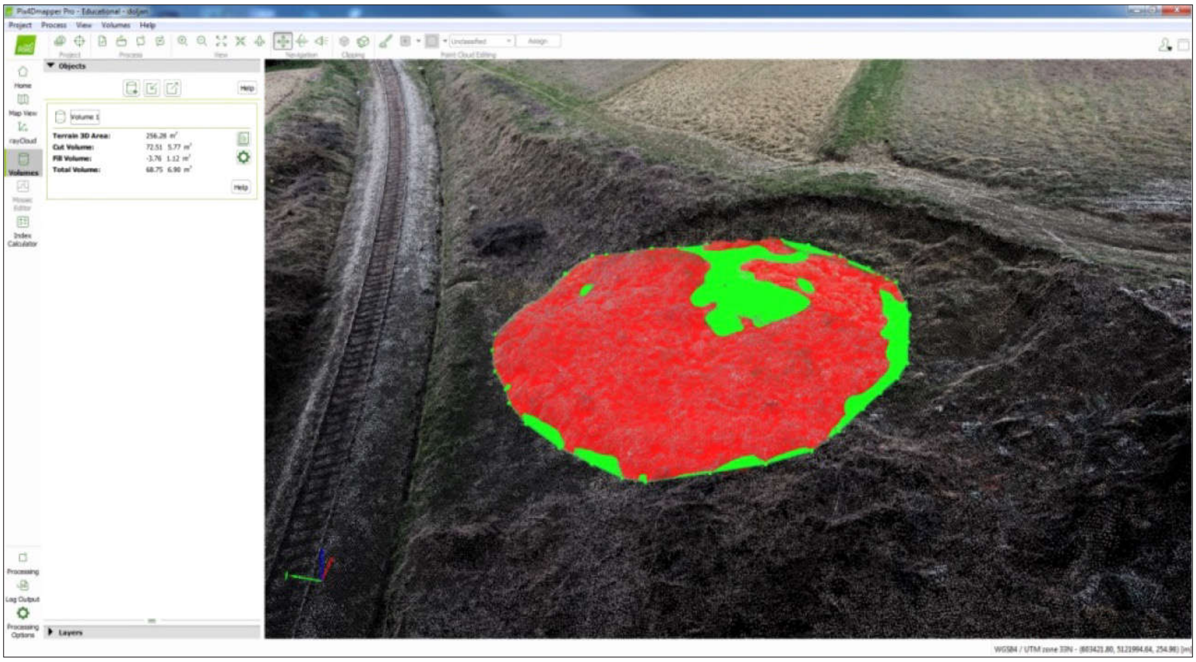

Figure 7 Volume generated in Pix4Dmapper

By analysing several remediation measures it was concluded that an optimal solution was to design stone type embankment which would ensure adequate drainage of rainwater , with final finishing with hydroseeding, see Fig. 8. There are three phases in remediation of the instability. The first phase includes the bulk excavation and removal of bad material present in the field. The second phase includes the filling of the stone material to the height of the berm, and then final and third stage is filling with stone material to the final height.

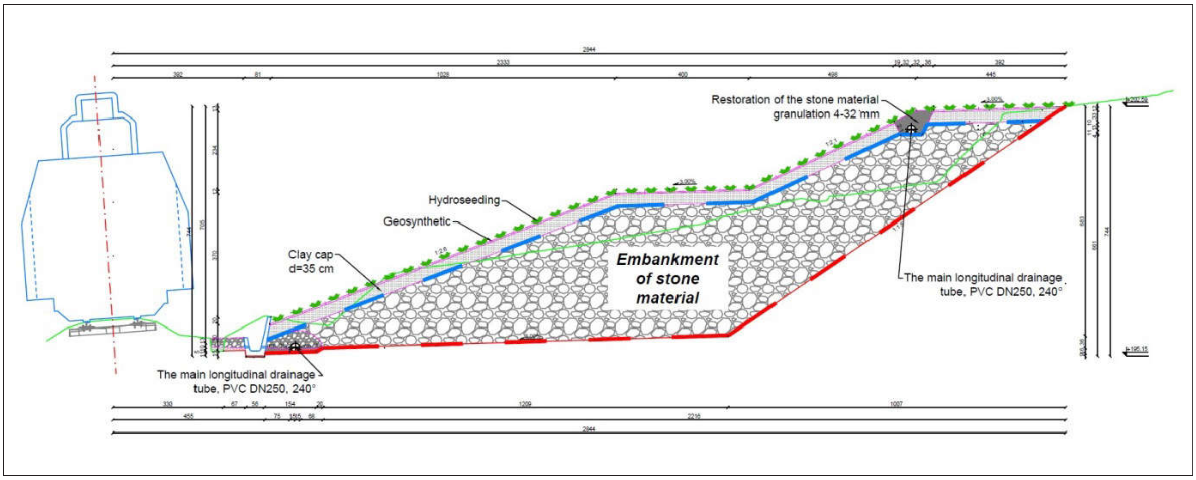

Figure 8 Cross section after remediation measures

4 Conclusion

Application of UAS can be very useful in process of remediation measures for landslides. Their use is especially appropriate in case of hardly accessible sites where implementation of traditional survey procedures can sometimes prove hazardous. Also, the operator can share the images photographed by UAS in real time with persons at other locations which opens up many possibilities in analysing landslides and making decisions. Pix4Dmapper allows us to produce cross sections, contour drawings, measuring areas and volumes directly in the point cloud model and the export to other different CAD and GIS format. This increases the speed of analysis of landslides and deciding on remediation measures.

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