Brief Communication: Rapid Assessment of landslide events based on UAV photogrammetry: The 9 January 2021 Cimanggung Landslide, Sumedang, Indonesia

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ABSTRACT

The landslide incident in Cisarua Village, Cimanggung District on January 9, 2021, is one of the natural disasters which is quite concerning to see the victims. This rapid mapping is focused on identifying changes in the shape of the affected area and slope faces before the landslide and after the incident. The brief mapping uses the DJI Mavic Pro model UAV that flies at an altitude of 50 meters and 150 meters above the ground with an overlap of 80% and covers an area of 3 ha. Aerial photo processing will produce output in the form of orthophoto images and digital elevation models (DEM) of landslide affected areas. The result of geometric observation showed that the land surface was covered with an area of 3,789 m^2. The measured flat length ranges from 120 meters and 32 meters wide. There is also a slope angle after and before the landslide of 2.8 degrees. Analysis of the causes of landslides in terms of geomorphological aspects shows the landslide affected areas that are right in the hilly valleys coupled with buildings that cover the surface water flow from high rainfall. In addition, the analysis of the causes of technical geological analysis shows that landslides can occur due to differences in soil types with different physical properties so that the two soils are not bound by cohesion forces between soils.

Keywords: Cimanggung Landslide; UAV Photogrammetry; Geomorphology, Engineering Geology

INTRODUCTION

As well-known, landslide events occurred at Cihanjuang Village, Cimanggung District, Sumedang, on 9 January 2021. The first landslide occurred in 16:00 WIB, followed by the second landslide in 19:00 WIB. This incident took 40 death toll and heaped tens of buildings, consisting of houses and public facilities. The initial prediction from witnesses and survivors is the slope that is relatively steep and without adequate vegetation, causing the land to be eroded by high-intensity rain a few days before.

Landslide often occurs in slopes with critical stability. Principally, a landslide phenomenon is a natural process where the slope finds natural balance. However, the problem is that this event takes victims, both death and material losses. Regarding the landslide, short mapping of the location and extent of surface deformation caused by landslides can provide important indications of the rapid response of civil protection authorities and to rescue and recovery operations. The design and implementation of an effective slope monitoring system on the surrounding buildings are vital, where this system will generate suggestions concerning geotechnical engineering required (Giordan et al., 2013). The study focused on analyzing the changes in the shape of the slope face before and after landslides. The analysis included aspects of slope geometry, local geomorphology, and technical geological analysis exposed to landslides' slope faces.

Most post-event landslide change maps are prepared through field mapping and/or visual analysis of aerial photographs taken immediately after the landslide event (Guzzetti et al., 2012). However, by the short mapping method and safety reasons, the slope movement potentials remain. A remote sensing technique provides an effective alternative for semi-quantitative or quantitative assessment from the land area and deformation (Singleton et al., 2014). The remote sensing method used was the image acquisition taken from the unmanned aerial vehicle (UAV). The acquisition results were images to be processed into 3D models of earth surface and ground level.

Besides the above points, this study is also expected to reveal the causes behind the landslide events.

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The Regional Engineering Geological Map

In the Regional of Engineering Geological Map of West Java published by the Geology Agency in 2013, landslide affected areas are categorized into the weathered of breccia rock geology characteristic. Regionally, this breccia group is formed from Holocene Volcanic Rocks (Qv), Mount Neogene (Tnv), Early Miocene Sedimentary Rocks (Tlss), Pliocene Sedimentary Rocks (Tlvs), Late Miocene Volcanic Rocks (Tmvs), Late Eocene-Miocene Volcanic Rocks (Temv), Volcanic Rocks Pliocene (Tpvs), Oligo-Miocene (Tomv) Volcanic Rocks, and Tertiary (Early Miocene) Sedimentary Rocks: Tlss, Tmvs, and Tmev.

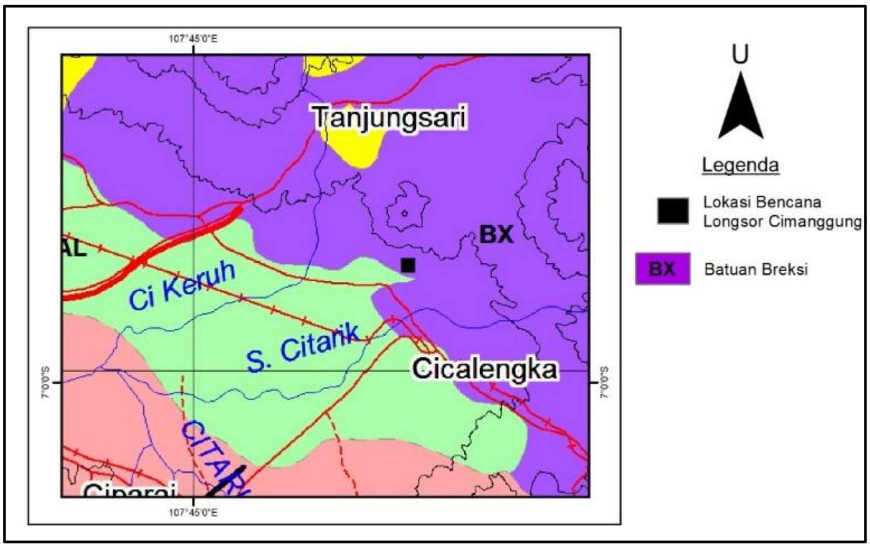

Figure 1. Landslide affected locations on Regional of Engineering Geological Map of West Java with a 1:500.000 scale.

The lithology exposed around the study area was in the form of generally lightly weathered volcanic breccia, blackish gray-brownish, grained sand-crust, angled-angled grains, andesite components, basalt and pumice, and volcanic glass, open packaging, sandy tuff base mass, solid, compact, hard.
The weathering soil was generally thin (<1.00 m), in the form of clay-sandy clay, reddish-brown, soft-firm, medium-high plasticity, low soil permeability, 2.00-4.50 m thick, CH group.
The hazards caused by geological processes that may occur in this group are generally landslides (especially on open land), and the soil's swelling nature can cause cracks or collapse of buildings.

METHODOLOGY

The data sources used in the study were the combination of primary and secondary data. Primary data were images from the unmanned aerial vehicle (UAV) of the DJI Mavic Pro model, processed into the image of landslide affected areas and digital elevation model (DEM). Field observation and field photo taking were conducted to add data to support the geomorphology and technical geology interpretations. Secondary data utilized were the area image before landslides downloaded from Google Earth, digital elevation model with an 8.25-meter resolution from the DEMNAS website, Technical Geology Map of West Java with a 1:500,000 scale from the Geology Agency, and the map of the Indonesian terrain in Sumedang Regency from the Geospatial Information Agency (BIG) website at a 1:25,000 scale.

UAV Instrument

The UAV employed was the multirotor UAV type (quadcopter). The UAV technology used in the study is illustrated in Figure 2, while its specifications are described in Table 1. The UAV in this study, i.e., the DJI Mavic Pro model, is the latest generation drone from DJI. This drone is compact with high complexity level.

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Figure 2. DJI Mavic Pro UAV Drone

Table 1. DJI Mavic Pro Specifications

Spesifikasi	Keterangan
Weightt	25,9 oz
Max Speed	40 MPH
Flight Time	27 minute
Camera	C4K, 24 fps, 4K, 30 fps
Jarak terbang	Sampai radius 7 Km
Image Max Size	4000 x 3000
Photo	JPEG, DNG
Video	MP4, MOV, (MPEG-4 AVC/H.264)

Acquisition and Processing of UAV Images

The study's field data collection was carried out in landslide affected areas at Cihanjuang Village, Cimanggung District, on Monday, 11 January 2021, at 11.00 AM. During the data collection, the drone flew at a 50-meter height and 150 meters above the ground level with an 80% overlap, covering 3 ha with a flight duration under one hour. This drone generated 125 photos. A flight with different height was performed to anticipate void data or poor quality data.

The photo quantity generated by the drone depends on the drone's flying height and its overlap. The higher the drone flies, the fewer photos are generated because the resolution captured is small. For the drone overlap, the higher the overlap, the better the results. The drone flying method is determined by the pilot operating the drone. During this short mapping, the drone flew with a zig-zag flying method with parallel lines in each line, where the drone followed a predetermined flying path using the Pix4D application in the pilot's gadget. The steps in collecting high-resolution image data using drone and processing data are presented in Figure 3. It was started by determining the area of interest (AOI) and drone flying method, then obtaining the aerial pictures to be processed into a complete mosaic using the Agisoft Metashape Professional software with an output of Digital Elevation Model map and images of landslide affected areas.

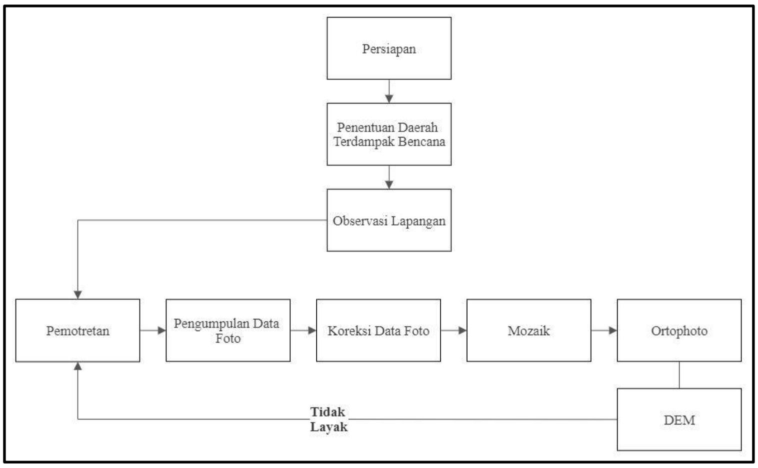

Figure 3. Flow diagram of the acquisition process and image data processing of the UAV drone

Field Observation

The field observation step was carried out after aerial photo acquisition. This activity included observation of land conditions, fracture areas around the landslide crown, and building conditions. These data sharpened the analysis since they became the landslide event evidence from the landslide type, movement direction, and landslide cause aspects.

RESULTS

As presented in Figure 4, landslide affected areas are clearly defined from the aerial photo-taking using the UAV drone, marked by the red line. The east area (number 1) is the area affected by the first landslide due to a critical slope that failed to withstand a load

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of rainwater filling the soil pores. Then a subsequent landslide occurred even more severely than the first landslide. Calculation of the flat area of the total landslide affected area shows that land covered 2267 m^2 in the first landslide and 1522 m^2 in the second landslide. Therefore, the total landslide area covering the earth's surface was 3.789 m^2. The measured flat length ranges from 120 meters and 32 meters wide. A flat area is an area that is calculated on a 2D surface or a map without considering the slope of the slope. However, the slope of the slope has its discussion because the landslide incident will change the profile of the slope.

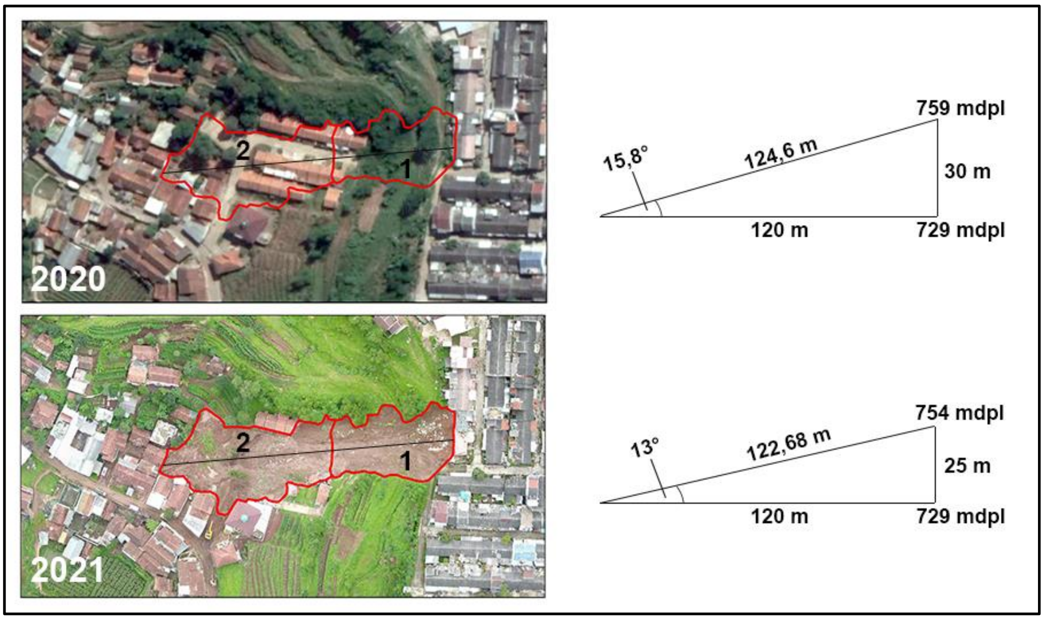

Figure 4. Results of aerial photo-taking using the UAV drone with slope measurements before and after the landslide.

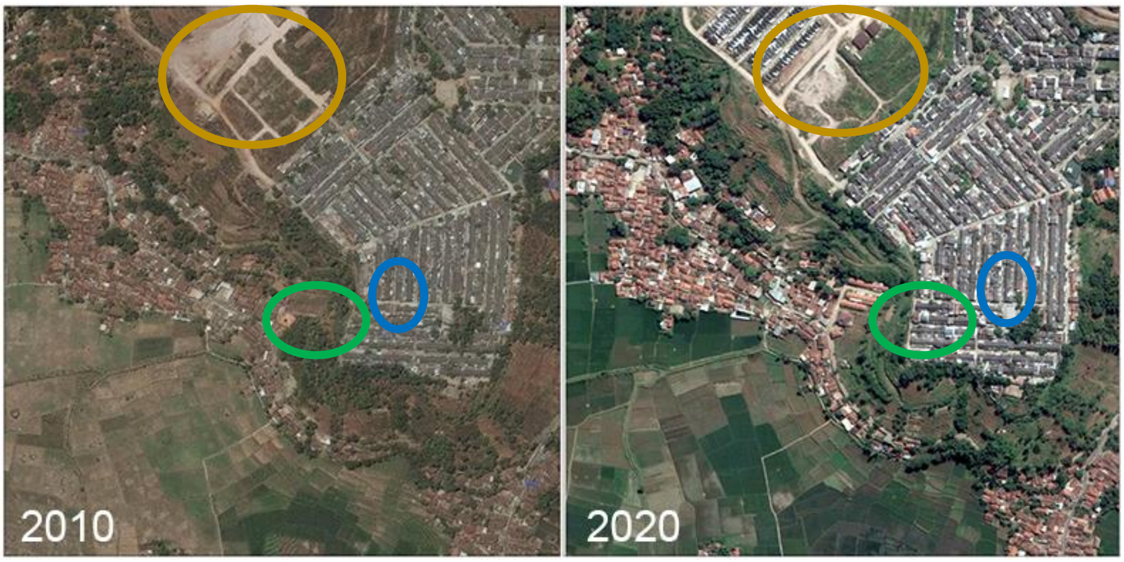

Figure 5. Local 10-year development comparison in landslide affected areas.

In Figure 3, there is a comparison of the slope profile between secondary elevation data before landslides (above) taken from the DEMNAS website with an accuracy of 8.25 meters and slope profiles after the landslide event taken from primary elevation data from aerial photo processing with an accuracy of less than 1 meter. Calculation results demonstrate a difference in slope angle for 2.8 degrees. Of course, this figure becomes valid with the available data until the primary elevation data is found with the same accuracy so that the profile comparison becomes apple to apple.

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On the other hand, one of the human considerations in choosing a living place is the visual aspect or beautiful scenery. Therefore, some developers often develop development into hilly areas so that their products have a salable power. For example, in Cisarua Village, Cimanggung District, although several houses and even complexes had been built before 2010, the comparison above shows that property development in the area is continuing and massive. The green building was built in 2018, the blue building was built in 2012, and the brown complex has developed since early 2019. The above observations were made with google earth imagery. Hills are rainwater catchment areas where there should be development restrictions to maintain downstream rainwater quality. Therefore, civil development should consider geomorphological and environmental geology aspects.

DISCUSSION

Geomorphological Analysis

The geomorphological aspect of the landslide is also essential. When viewed from the contours produced by processed UAV drone data, the landslide affected area was right in the slope's valley area. Even with rainwater intensity that fell in early January, the valley turned into surface water flow or an intermittent river. The water flow from the top of the hill will descend into the main river below through the slope. In the field observations, the authors also found that water flowed down through the bush in the slope's direction. Therefore, with the existing conditions, there is an allegation that the landslide cause is the slopes losing their bearing force due to the accumulation of rainwater held back by the building bordered by the main landslide that the slopes become heavier in weight and cannot withstand their weight. It continues a few moments later the soil pressure from the first landslide material will increase the load from the subsequent landslide area, so, naturally, subsequent landslides can occur because water that is held at the beginning of the building enters the ground under the second landslide area and causes the soil to lose its binding capacity. The last process that can be viewed from a morphological aspect is the massive land-use change that develops in the area, causing the flow volume of surface water to increase. It is undoubtedly dangerous for buildings that are elevated below it.

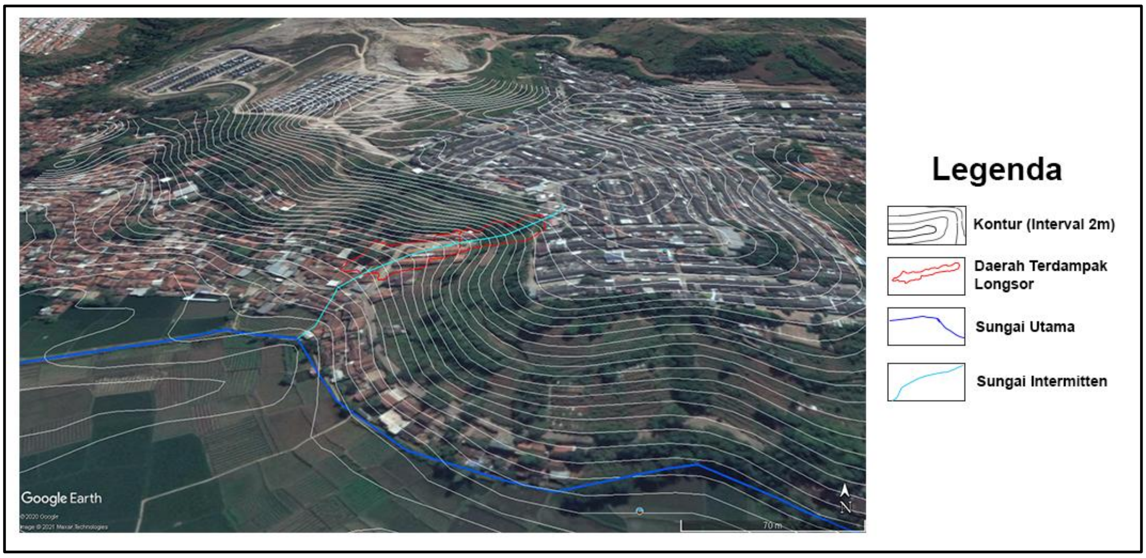

Figure 6. Morphology display of aerial photo image (Google Earth) of the landslide affected area (red) in local.

Engineering Geological Analysis

Apart from morphological aspects, the engineering geology approach can also determine the suspected causes of landslides. When viewed from photo A in Figure 7, there was a significant difference in the soil's color and could be seen as megascopic or massive. The color difference indicates two types of soil adjacent to one another. Indeed, natural soil will gradually darken because of the organic content in it. However, the anomaly found indicates that soil X was not natural land on the hill, but additional land buried to level the surface

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aiming so that the land could be used for house construction. Soil Y was a natural soil resulting from weathering of rocks. The two soils were not held together by the cohesion force because of their different physical properties. Therefore, differences in soil types are an indication of landslides.

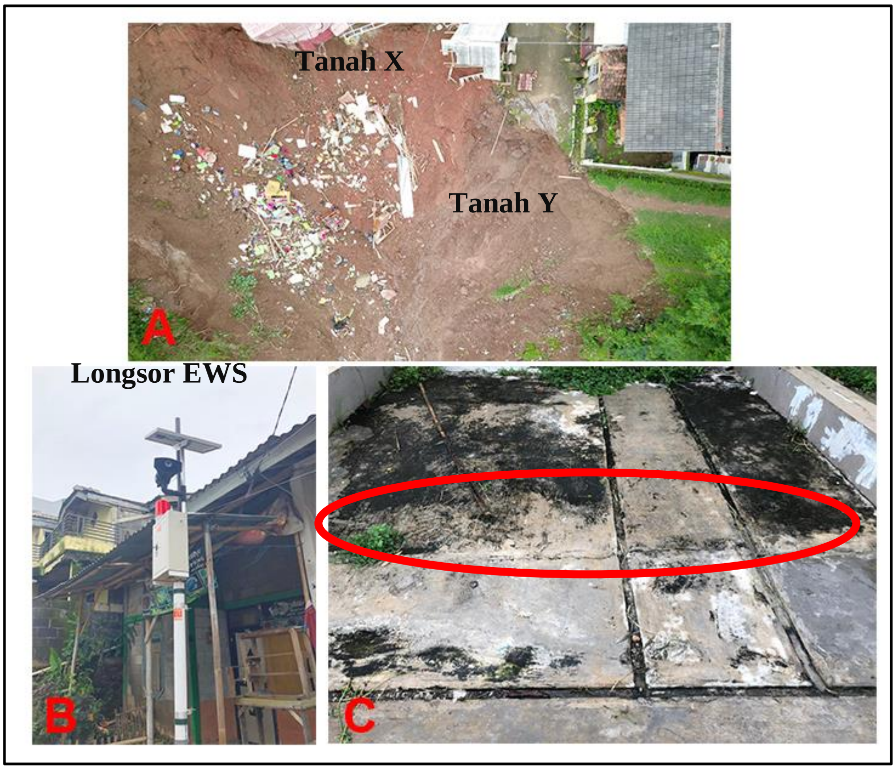

Figure 7. Field observation results from the technical geology aspect and risk mitigation of the affected area

Figure C shows cracks along with the building not affected by landslides around the landslide crown. Cracks or fractures indicate the direction and type of landslide. This evidence shows that landslides can occur in the slope direction or the area of the slope segment of the hills. Even though it is only a fracture, the area is still vulnerable for some time since the landslide occurred. Therefore, mitigation measures must be implemented quickly to minimize further casualties, both mental and material, from areas that are potentially affected by further landslides.

One form of mitigation tool is seen in part B of figure 7, i.e., the Landslide Early Warning System (LEWS) prepared by the Agency for the Assessment and Application of Technology. This tool's mechanism is quite simple, the main pole with solar panel components and transistors will translate the movement of the two iron stakes connected to the rope so that if one of the iron pins moves, the siren will sound. The sound of sirens indicates that movements remain present from the ground surface, and the surrounding area still has potentials for further landslides.

CONCLUSION

From the data and data explanation above, this rapid mapping study has several conclusions:

1. Landslide affected areas at Cihanjuang Village Cimanggung District had the CH land type with a grain size of clay-sandy clay, reddish-brown, soft-firm, medium-high plasticity, low soil permeability, and 2.00-4.50 m thick according to the regional technical geological map of the West Java sourced from the Geological Agency in 2013
2. The flat area calculation of total landslide affected areas shows that land covered 2267 m^2 in the first landslide and 1522 m^2 in the second landslide. Hence, covering the earth's surface for 3.789 m^2. The measured flat length ranges from 120 meters and 32 meters wide. The difference in slope angle before and after the landslide was 2.8 degrees.
3. The observation of google earth images temporally around the

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landslide area shows that property development in the area is continuing and massive.

4. The cause of landslides is not certain. However, several triggering factors could be the reasons for this disaster: a) closure of the surface water flow path by buildings so that with high rainfall, water will enter the ground and burden the slopes not to withstand their weight. b) There are differences in soil types at the landslide crown. The two soils are not held together by the cohesion force because of their different physical properties. Therefore, differences in soil types are an indication of landslides.

SUGGESTIONS AND ACKNOWLEDGMENT

With the completion of this study, the authors are aware that there are several shortcomings. This study aimed to briefly explain how landslides in Cimanggung can occur and describe changes in the earth's surface in the area. However, to ensure the process of landslide occurrence in a detailed and precise manner requires in-depth engineering geological studies such as observing fractures in the sliding field, testing soil samples, and tracing intermittent river flows.

The author also expresses condolences to the families of the victims left behind for the landslide incident. The author also thanks lecturers and colleagues from the Faculty of Geological Engineering, Padjadjaran University, to prepare the article.

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