

Identification of landslide potential based on Ground Penetrating Radar (GPR) data in Prambanan District, Sleman, Yogyakarta

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Abstract

The application of the Ground Penetrating Radar (GPR) method which was carried out in the Prambanan District, Sleman, Special Region of Yogyakarta was to determine the geometry of the slip plane of potential landslides. This method can see the contrast between the slip plane of the landslide and the landslide material that is above the slip plane. Measurements were made on field "A" consisting of 6 tracks and field "B" consisting of 7 tracks. The cross section of the radargram shows a penetration depth of about 6 - 7 meters, divided into 3 layers, namely, the S1 layer (soil), the S2 layer (transition zone), and bedrock. The depth of the slip field for potential landslides produced at the boundary layers of S1 and S2 is about 1 - 1.5 meters and the depth of the boundary layers for s2 and bedrock is about 2 - 3 meters. The geometry distribution map of the slip plane shows the type of landslide in the form of a translational landslide.

Keywords: Slip Plane; GPR Method; Radargram; Landslide Potential

1. Introduction

Indonesia is an area where many natural disasters occur, such as tsunamis, volcanic eruptions, earthquakes, and landslides. Of the several natural disaster events, one area in the Special Region of Yogyakarta, namely Prambanan District, was recorded as a landslide potential area with moderate, high and very high landslide hazard classes. (Figure 1) [1].

Landslides occur because of the process of soil mass movement that occurs due to disturbances in the balance of forces that can trigger equilibrium on a slope, namely the sliding force and the retaining force. The sliding force is usually influenced by the water content, while the retaining force is the weight of the soil mass [2]. One of the most influential factors causing landslides is the slip plane or shear plane. The slip plane is a plane that is the basis for the movement of the soil mass with a stationary mass, this slip plane is a watertight and slippery field, usually in the form of a layer of clay [3].

Based on the definition and classification of landslides [4] that mass movement is the movement of soil mass in an upright, horizontal, or oblique direction from its original position. Landslides consist of fall, topple, slide, slump, flow, horizontal motion or lateral spread, and creep.

Geophysical data support in this study is used to analyze and determine the geometry of the slip plane which is one of the causes of landslides. The geophysical data can use the Ground Penetrating Radar (GPR) method. This method utilizes electromagnetic waves, is non-destructive and has a high resolution of the dielectric contrast of the earth material and is capable of detecting subsurface vertical profiles with high resolution depending on the frequency used [5].

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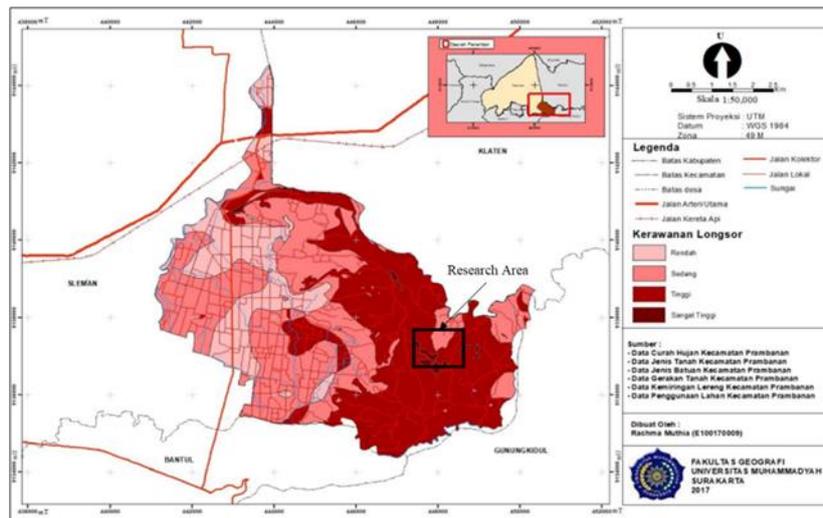


Figure 1 Landslide Hazard Level Map in Prambanan District [1]

The research [6] and [7] which was conducted using the geoelectric method, was able to determine the structure of the subsurface rock, identify the potential slip plane for landslides and the slope, based on the resistivity value. The results of the second study show the thickness of the unstable layer and the shape of the slip plane of potential landslides obtained from the distribution of rock resistivity values. The bedding begins with a very low resistivity at the top and high resistivity at the bottom. The slip surface is marked as a very low resistivity which lays above a higher resistivity. Research [8] which was carried out using the GPR method to determine the delineation of the potential slip plane for landslides based on the depth of the slip field detected in the radargram cross section.

The GPR method can describe the geometry of the slip plane of the landslide-causing factor with a cross-section of the GPR radargram horizontally and vertically. The depth of the slip plane geometry is known by combining velocity data with travel time data from radar wave propagation [9]. This method can see the contrast between the slip plane of the landslide and the landslide material that is above the slip plane, by observing the physical parameters that affect a material [10]. The purpose of this study was to analyze the GPR reflection response on the radargram cross-section to determine the depth and continuity of the slip plane of potential landslides, as well as the types of landslides that might occur in the study area.

2. Geology of Research Area

Physiographically, the Prambanan Hills include the height of Baturagung which is one of the sub-zones of the Southern Mountains at the northwest end. To the west, north and east the Prambanan Hills are bounded by the Klaten plain (± 100 m asl.) which is occupied by alluvial deposits from Mount Merapi. The shape of the Prambanan hills slopes to the west-southwest of the slope and decreases from 20° to 5° , while on the east-northeast side there is an escarpment with a slope of 25° - 50° . The rock layers that compose it are generally sloping to the west-southwest [11].

Prambanan hills are mostly composed of rocks which are included in the Kebo-Butak Formation, Semilir Formation and inseparable Volcanic Rocks (Figure 2) [11], there is an alternation between autoclastic breccias and pyroclastic breccias, both of which are andesite composition. Above the primary volcanic rock, conglomerate and pumice lapilli tuff are deposited. On the outside of the volcanic bomb it still shows a rough surface texture, while the inside often shows a concentric structure or fracture with a radial pattern, as a result of very fast cooling when erupted [11].

The stratigraphy of the study area shows that volcanic rocks are grouped into 3 rock units ranging from old to young, namely, lava and pyroclastic breccias, epiclastic breccias, and pumice tephra. The first rock unit is an activity in the construction stage of a composite volcanic cone composed of andesite, composed of alternating lava flows and pyroclastic breccia with andesite composition. The second rock unit was formed as a result of rework when the composite volcanic cone had died and experienced erosion, this rock unit was composed of breccia, conglomerate breccia and sandstone which predominantly also had andesite composition. While the third rock unit indicates the formation of a caldera as a stage of destruction of composite volcanic cones, with rock units in the form of tuff, lapilli, and pumice breccia [11].

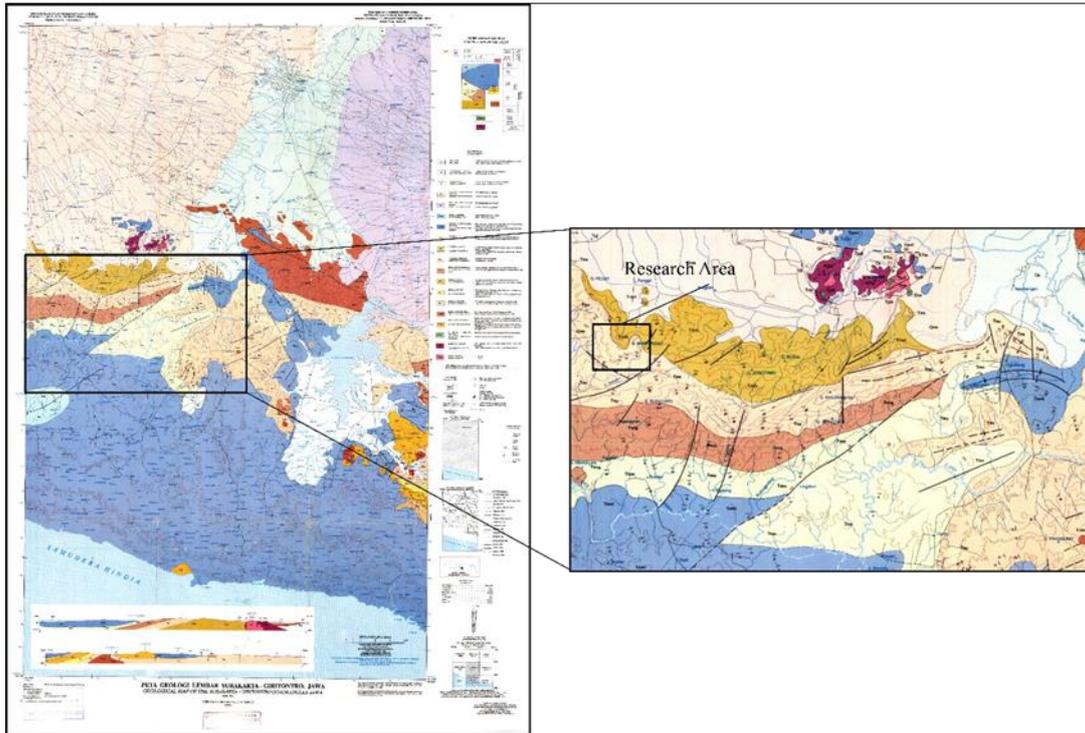


Figure 2 Geological Map Sheet Surakarta – Giritontro, Java [12]

3. Methods

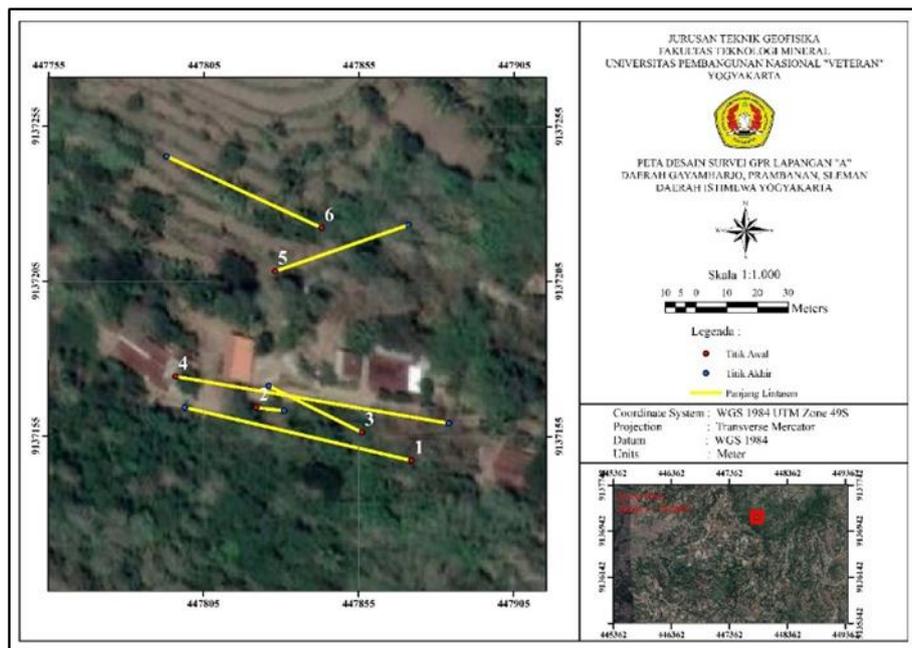


Figure 4 GPR Field Survey Design Map "A"

The systematics of this research is divided into three parts, data collection, data processing and data analysis (Figure 3). Ground Penetrating Radar (GPR) data in the form of raw data is processed using Reflexw 4.5.1 Software to get a cross-section of a radargram that shows a subsurface of the research area. Processing is carried out referring to basic processing [13] which consists of Static Corrections – Move Stratime, Subtract Mean (Dewow), Gain – AGC gain, Bandpass Butterworth, Background Removal, Fk Migration (Stolt), and Correct 3D Topographic.

The results of the radargram section show the path length and the depth of the layer shape from the differences characteristics of the reflection pattern and changes in the amplitude value caused by the dielectric constant value contained in a layer. The analysis is carried out by dividing the layer boundary based on the response of the amplitude in the cross section, based on the characteristics of the reflection pattern and the assumption of a range of physical parameter values including the value of the dielectric constant, conductivity, wave propagation velocity on the type of material in the research area.

The depth of the layer on the radargram section is made a geometric map of the distribution of the depth of the layer boundary and incision which will show the conceptual model profile of the depth and thickness of the geometry of the slip plane of potential landslides. The incision profile shows the types of landslides that are likely to occur in the study area.

The research was conducted in the Prambanan District, Sleman Regency, DIY using the Ground Penetrating Radar (GPR) method on Field "A" (Figure 4) with 6 tracks consisting of tracks 1-6 and Field "B" (Figure 5) with 7 tracks consisting of 7-13 tracks.

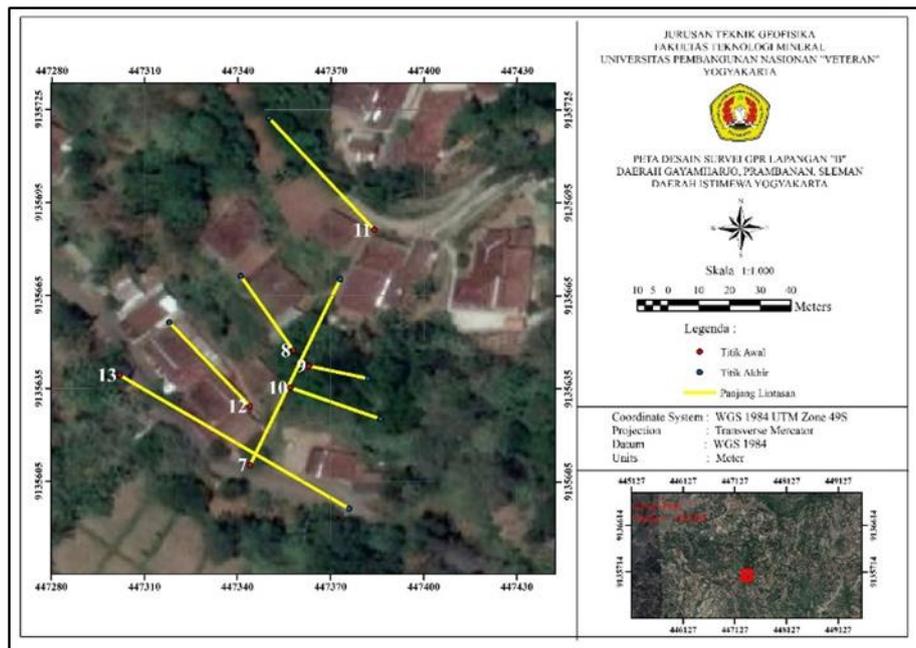


Figure 5 GPR Field Survey Design Map "B"

4. Results and discussion

Analysis on the radargram cross-section, by limiting the layers based on the contrast of the amplitude and characteristic of the reflection pattern. The existence of this amplitude contrast indicates a significant change in the physical parameters of the subsurface materials. This study divides into 3 layers which are indicated by the continuity of the red and green colored lines, and because of the amplitude contrast as seen from the sharp color intensity on the radargram cross-section and the characteristic reflection pattern (Figure 6).

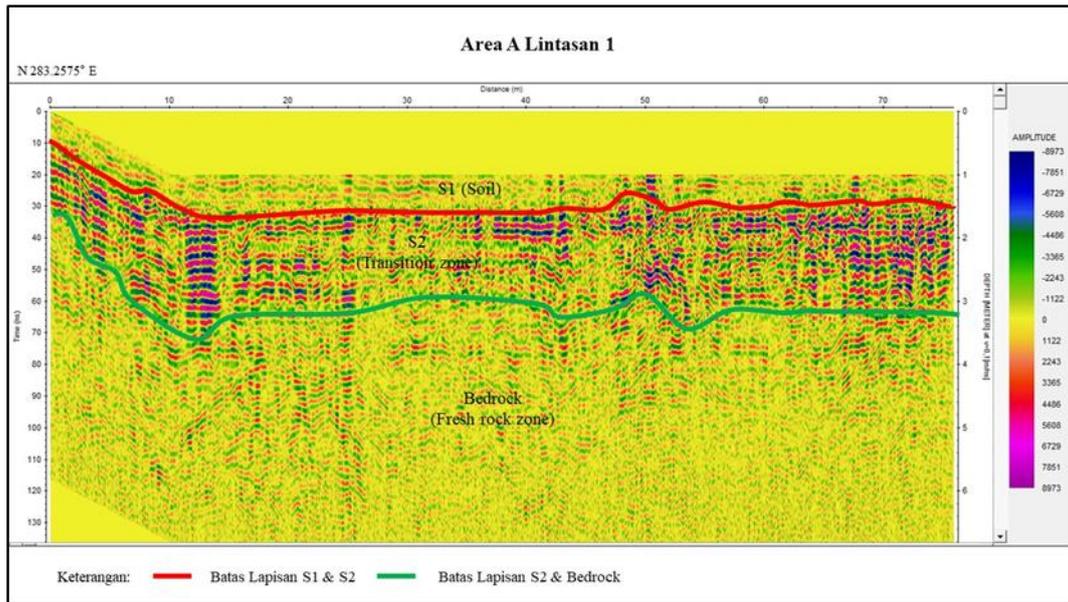


Figure 6 Cross-section of Field Radargram “A” Track 1

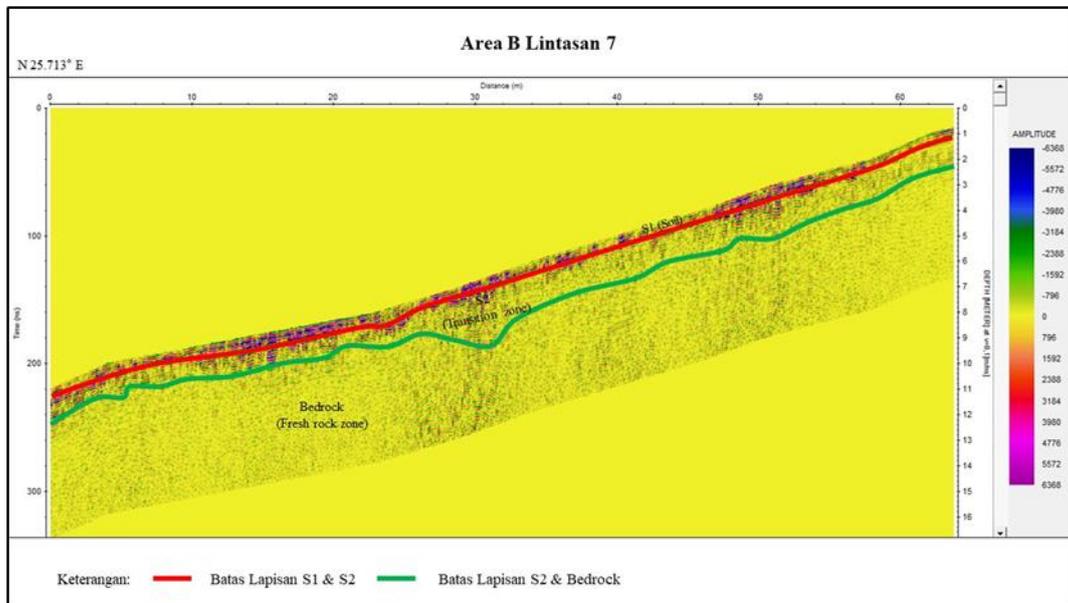


Figure 7 Cross-section of Field Radargram “B” Track 7

The cross-section of the radargram track 1 on field “A” (Figure 6) with a track length of ± 75 meters, azimuth of track N 283,2575° E and the penetration depth obtained reaches ± 6 meters. The cross-section of the radargram of track 7 on the “B” field (Figure 7) with a track length of ± 67 meters, azimuth of track N 25.713° E and a penetration depth of ± 6 meters. The cross section of the radargram shows the trajectory and speed of radar waves with subsurface depth based on the travel time of the waves from the transmitting antenna to the receiver which can also be referred to as Two Way Traveltime (TWT) [14].

The analysis to determine the potential for landslides that may occur in field “A” (Figure 8) and field “B” (Figure 9) is obtained from the results of the geometric distribution map of the layer boundary. The results of the A-A’ incision profile in the “A” field show a maximum height of 238 m and a minimum of 210 m, with a slope angle of 17° which is included in the steep category [15]. Field “A” is an indication of a layer that has the potential to experience landslides, namely layer S1, because the closer to the lower area the thickness is getting thicker and this layer is a weathered layer which is indicated as soil. The results of the incision profile B – B’ field “B” show a maximum height of 241 m and a minimum of 218 m, with a slope angle of 12° which is included in the steep category [15]. Field “B” is an indication of a layer that

has the potential to experience landslides, namely the S2 layer, because the deeper you go to the lower area, the thickness is getting thicker.

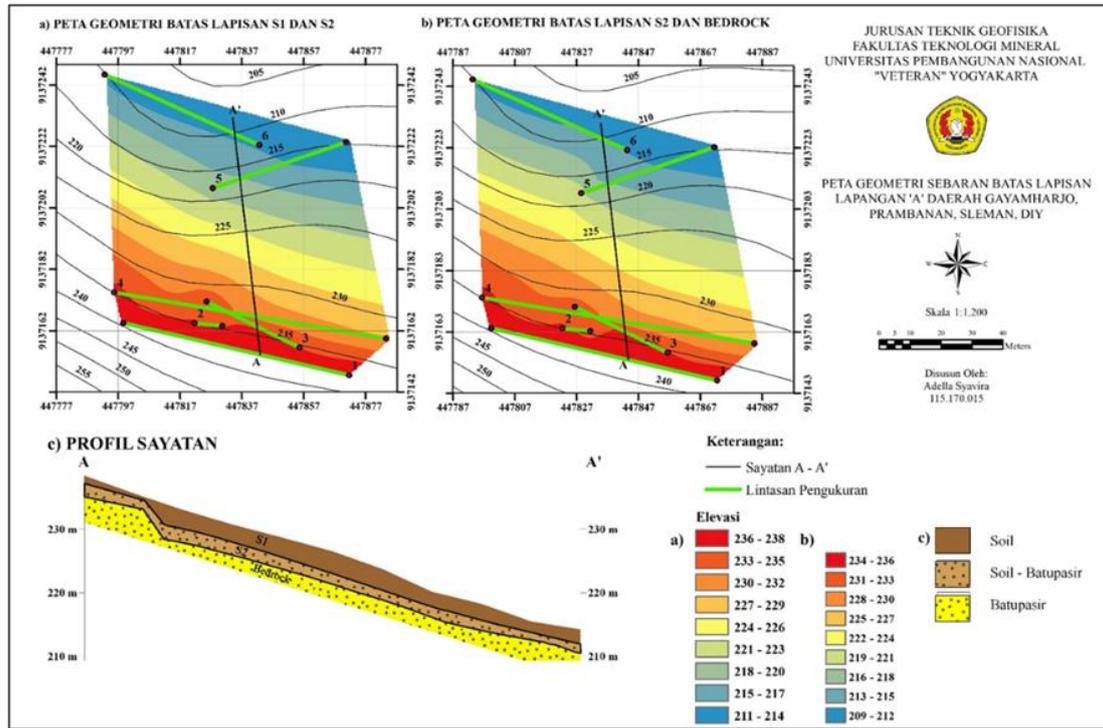


Figure 8 Map of Boundary Depth Geometry Layer of Slip Plane Potential Landslide Field "A"

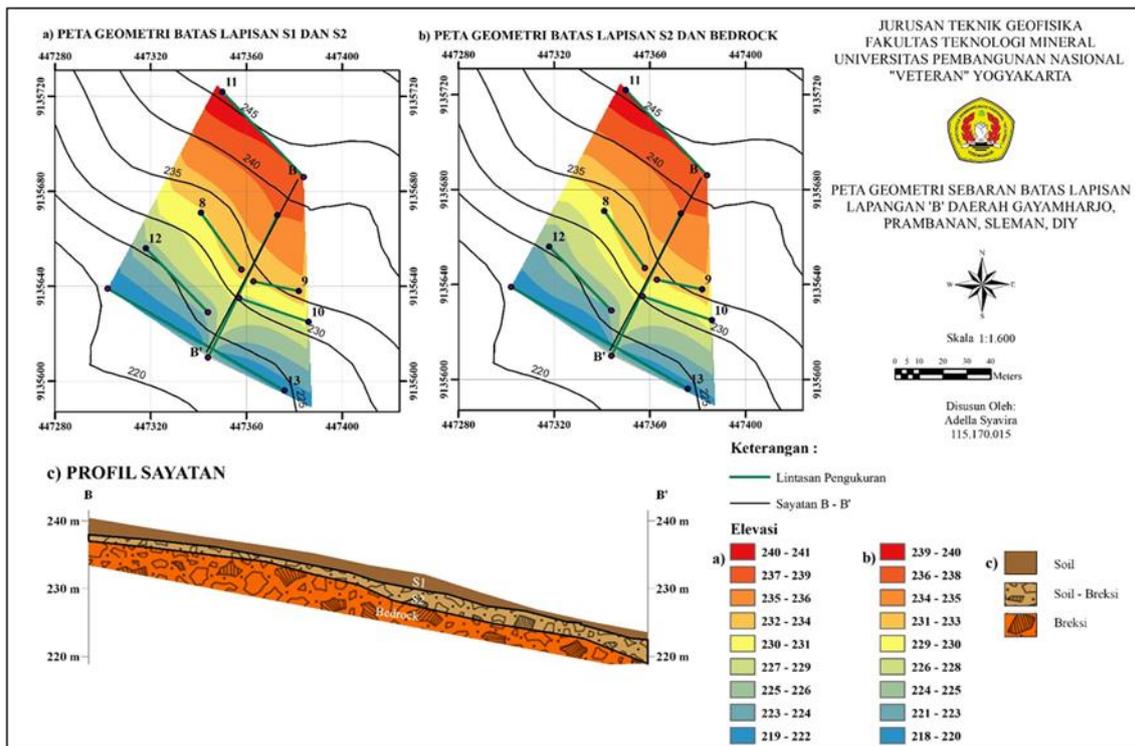


Figure 9 Map of Boundary Depth Geometry Layer of Slip Plane Potential Landslide Field "B"

Based on the model of the incision profile and the geometry of the slip plane obtained, field "A" and field "B" are at different heights. The lower part of the "A" field is heading towards the north, while the lower part of the "B" field is heading south. The results of the analysis that have been carried out, it is known that the types of landslides that may occur in field "A" and field "B" have the same type, namely the type of translational landslide. A translational landslide is the movement of soil and rock masses on a sliding plane that is flat or sloping. This needs to be watched out for in the lower part, namely the northern part of field "A" and in the lower part, namely the southern part, which is a potential landslide zone in field "B".

5. Conclusion

The results of GPR processing in the form of a radargram cross section get a depth penetration on the entire track of approximately 6 meters. It is also divided into 3 layers based on the amplitude contrast response and the characteristics of the reflection pattern, namely, the S1 layer (soil), the S2 layer (transition zone), and the bedrock layer (fresh rock zone). The depth distribution map of the geometry layer of the slip plane shows that the boundaries of the S1 and S2 layers are relatively shallow, approximately 0.5 – 1 meter, and the boundaries of the S2 and bedrock layers are relatively deeper, about 2 – 3 meters. The layer boundary depth map shows that each layer is relatively parallel. The incision profile A-A' describes the thickness of the layer which indicates the potential for landslides, namely the S1 layer. The incision profile B-B' describes the thickness of the layer that indicates the potential for landslides, namely the S2 layer. The results of the "A" and "B" field incision profiles show the type of landslide in the form of a translational landslide. Field "A" shows that low areas are getting to the north, while field "B" shows low areas getting to the south. This provides information on the direction of landslides that are likely to occur.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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