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TOPOGRAPHIC MAPPING OF SLOPES IN LANDSLIDE PRONE AREAS USING THE SCHLUMBERGER CONFIGURATION GEOELECTRICS TECHNIQUE

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ABSTRACT

Landslides in Lembang in 2020-2021 were influenced by intense heavy rainfall. The surface contours in the village are generally in steep surface conditions with varying slope angles. The purpose of this study was to determine the surface contour in two dimensions by using the geoelectric method with Schlumberger configuration. The first stage was carried out by recording data on 5 tracks with 3 parallel tracks up to 75 m, one track intersecting the other track area up to 60 m and one track next to the landslide at 52.5 m. The results showed that the resistivity of the rocks varied between 0.465-1952 Ωm. Interpretation of rock 0.465-21.5 Ωm as clay and sand, 22-146 Ωm as sandstone, dry gravel, 156-380 Ωm as andesite, basalt and 389-1952 Ωm as granite, diorite, limestone. The contrasting differences in the variation of the values on each track are known as slip planes. Slip planes have been found on 5 tracks with depths ranging from 6 to 12 m. The results of the 2-dimensional surface modelling that has been carried out show that the research area has the potential for landslides.

Keywords: Rainfall, 2 Dimensional Modeling, Slip Field

INTRODUCTION

Landslides are one of the natural disasters that often occur in areas with hilly topography, especially in areas with high levels of rainfall (Dou dkk, 2015). West Java has varied surface contours with surrounding mountain ranges that form a large geological basin known as the Bandung Basin (Brahmantyo B, 2005). In 2021, West Java was hit by high rainfall compared to other provinces so that several areas in West Java experienced landslides and placed West Java at number 1 in the landslide disaster (BNPB 2021, BMKG 2021). Especially the Lembang area which has been hit by landslides 4 times in 2021 (Nasrullah H dkk, 2023).

The phenomenon of landslides occurs when the soil layer loses its stability, areas with higher elevations generally have steeper slopes. Steep slopes increase the gravitational force acting on soil or rock material, thus increasing the possibility of soil mass movement along the slide plane. During heavy rainfall, rainwater soaks into the soil and increases the pore water pressure around the slip plane. This reduces the frictional force between soil particles, so the soil becomes water-saturated and loses its strength. As a result, the mass of soil or rock above the slide becomes unstable and moves down the slope, causing a landslide. Slide planes are formed due to various factors such as geological structure, soil type and water content in the soil.

Mitigation efforts can be made to detect slip planes on slopes that aim as basic information for the application of geotechnical engineering techniques. Identification of sliding planes can use geoelectric methods. Geoelectricity is one of the geophysical techniques with the working principle of injecting electric current into the ground surface through electrodes and then measuring the potential difference produced by rocks on the ground surface. Variations in resistivity will be measured to reflect differences in the type and condition of subsurface materials in each surface layer. The contrasting resistivity values between the upper and lower layers are known as slip planes. The geoelectric method has various configurations, this research uses the Schlumberger configuration which aims to determine the sliding plane in each layer with a more effective depth.

RESEARCH METHOD

This research was conducted in a potential landslide area in Jayagiri Village, Lembang Subdistrict, West Bandung Regency as shown in Figure 1. (Situmorang H dkk, 2022).

The Schlumberger configuration was used to acquire the field data. (Telfoord, 1976, Zhu T dan Feng R, 2009, Jamaluddin dan Ummar 2017), as shown in Figure 1. With a parallel path length of 75 m, a trajectory that intersects another trajectory region by 60 m and the track next to the landslide 52,5 m. Each traverse has varying surface elevations with the spacing between electrodes used ranging from 5 m, 4 m and 3 m.

The application of the geoelectric formula can be seen in the following equation:

$$\rho_a = K\frac{\Delta V}{I} \quad (1)$$

$$K = \pi an(n+1) \quad (2)$$

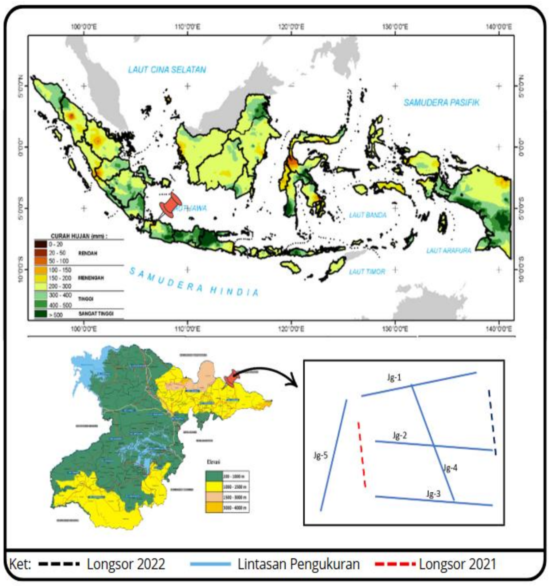


Figure 1.Research Location

Where K is the electrode configuration geometry factor, Variation of pseudo-resistivity value (ρ_a) can be calculated from the measured current value (I) and the measured potential difference (ΔV) in the soil layer. The calculated resistivity value is not the true resistivity of the subsurface, but the 'apparent' resistivity and the 'true' resistivity are a complex relationship. In order to determine the true subsurface resistivity from the apparent resistivity value there is an 'inversion' problem factor.

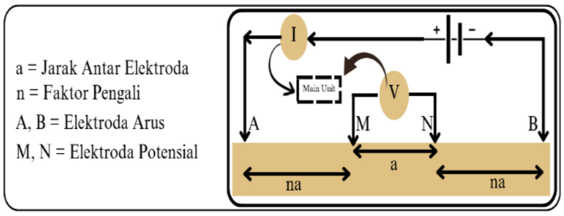
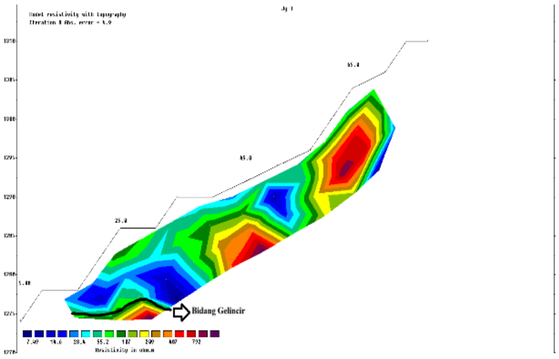


Figure 2. Schlumberger Configuration Geoelectric Method

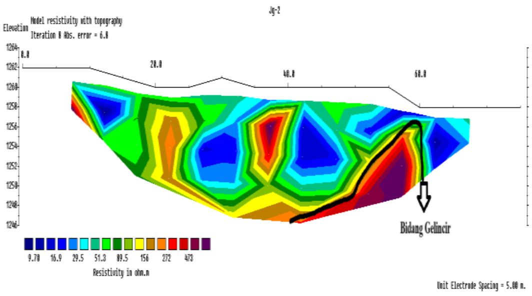
RESULT AND DISCUSSION

2-Dimensional Modelling with Slipping Planes

The actual resistivity distribution of each depth is obtained from the inversion process that has been carried out through the Res2DINV programme. The 2-dimensional modelling using the Res2DINV program is very effective by minimising the difference between the calculated and measured apparent sections of the resistivity data. The RMS obtained ranges 1,3-10,4 %. The modelling results can be seen in Figure 3 and the slip planes in each traverse. The range of resistivity variations obtained is around 0,465-1952 Ωm.



(a)



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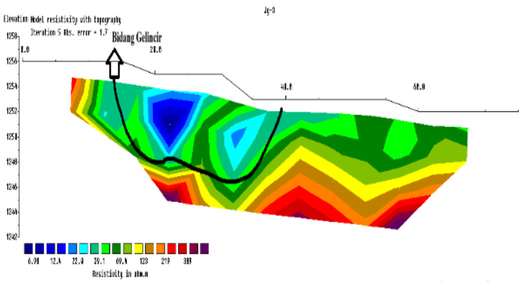

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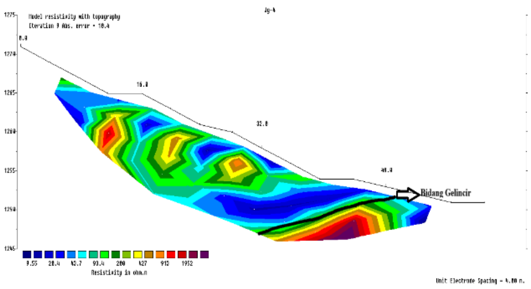

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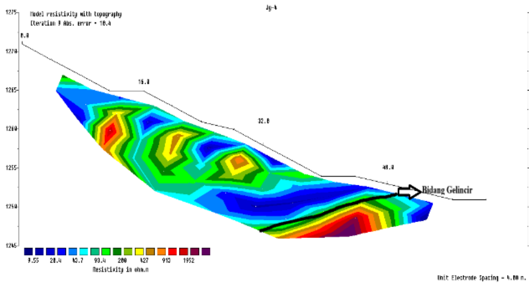

(e)

Figure 3. 2-dimensional trajectory modelling a) Jg-1, b) Jg-2, c) Jg-3, d) Jg-4, e) Jg-5.

Discussion

The data results presented show 2 topics of discussion (i) changes in variations in the value of sensitivity and (ii) determination of the sliding field. (i) This research is a follow-up research that has been carried out in the previous year, with a slide field on 3 tracks. After 6 months since the study (Situmorang H et al, 2022) was conducted, a new landslide occurred around the study site due to high rainfall for ±4 months in the area. Data addition of 1 new traverse next to the landslide in 2021. Geoelectric method with Schlumberger configuration is very effective to detect surface to depth ±15 m with path length ±75 m. So it is very important to identify the subsurface materials such as clay, solid rock layers, sand. This application is done to understand the subsurface conditions and produce 2-dimensional surface contours. There is a change in the resitivity variation range at Jg-1 to Jg-4 with respect to the previous study.

Changes in the resistivity variation range can result from several factors such as heavy rainfall. Prolonged heavy rainfall causes significant water infiltration into the soil, increasing pore water pressure and reducing soil shear strength. This process decreases soil resistivity, as water conducts electricity more easily than dry soil. A study assessing rainfall-induced landslides using an arbitrary dipole-dipole observation system found that slope resistivity changes significantly during landslide incubation, formation and development (Yue M dn Zhu G, 2024). Landslide activity can cause redistribution of subsurface materials and alter the internal structure of the slope. This movement can expose deeper material, which was previously more resistive to increased moisture, thus reducing its resistivity. In addition, the mixing of materials during landslides can create zones with varying resistivity values, which contributes to the observed changes.

(ii) Early understanding of the exact causal factors associated with landslide occurrence is necessary for mapping landslide vulnerability (Guzetti et al., 1999). Some studies (Custanzo et al., 2012) show that manual selection of causal factors by subject specialists is considered the best approach, but is slightly subjective. So far there are no common criteria or guidelines available on how to identify and select a number of factors that cause landslides. Because of this factor, many researchers use several different causal factors to generate landslide prone maps. Some published papers on the subject found that 20-60 factors have been used to build an initial framework for understanding landslide potential. However, most often 10-15 factors are used based on the availability and accessibility of information (Lee et al., 2008). Therefore, some researchers narrow down the factors based on knowledge of the trigger mechanisms involved. For example, earthquake-induced landslides as the main factor and associated triggering factors such as rainfall, surface contour and soil condition. Therefore, this study uses the triggering factor of sliding plane as the initial framework of landslide potential. The slip plane is found at a depth of 8 m for Jg-1, 12 m for Jg-2, 7 m for Jg-3, 6 m for Jg-4 and Jg-5. The slip plane can be recognised at the difference of low resistivity variation to high resistivity. The range of low resistivity variation in the sliding plane ranges from 0,465-79,2 Ωm and high resistivity ranges from 93,4-1952 Ωm.

The contrasting subsurface resistivity variations were detected as slip plane layers. Estimated rock types at low resistivity are clay, sand and dry gravel. This is in line with the distribution of soil types in West Bandung and soil tests that have been carried out by (Situmorang H dkk, 2022). The characteristics of clays are known for their ability to absorb water well so that they will undergo rapid changes from solid to liquid. The change causes weight gain and reduction in shear strength on slope stability. The combination of thick clay layers and high elevation requires careful geotechnical assessment to evaluate slope stability. Geotechnical assessment can be done by testing the kinetic and mechanical characteristics of the soil. Although clay is identified, its shear strength, plasticity index, liquid limit and moisture content can vary significantly. These parameters directly affect slope stability calculations.

The application of geoelectric method is an effective, cost-effective, and detailed solution about the subsurface contour condition and makes it as the basis of understanding for further geotechnical investigation and disaster prevention strategies in areas with high landslide susceptibility.

CONCLUSION AND SUGGESTION

Landslides that have occurred in the Lembang area in 2020-2021 were triggered by high rainfall and sloping surface contours. This research has successfully detected the sliding plane on all five lines. The slip plane is found at a depth of 8 m for Jg-1, 12 m for Jg-2, 7 m for Jg-3, 6 m for Jg-4 and Jg-5. The measurement results that have been carried out have changed the value of the resistivity variation of the research that has been carried out. This is caused by landslides that have occurred so that the material layer shifts in each layer. The range of resistivity values that have been obtained are then grouped into 4 parts. The low value of resistivity variation is in the upper layer with a depth ranging from 2-5 m, while the high value of resistivity is in the range of 12-16 m depth. The results of this research can be used as an initial strategy for mitigating landslides in upland areas. In order to determine the mechanical and kinetic properties of the soil, soil tests can again be carried out in the sliding plane area. The surface stability of the slope can be determined by re-examining these properties. This can be a basic approach to the design of engineering solutions such as retaining walls or other techniques.

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