International Journal of Research and Review
Volume 11; Issue: 10; October 2024
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Research Paper

Landslide Identification on Tembalang-Jangli New Road, Semarang, Central Java Using Dipole-Dipole Configuration Resistivity Geoelectric Method

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DOI: https://doi.org/10.52403/ijrr.20241043

ABSTRACT

New roads are built to alleviate congestion that occurs in an area. Tembalang is one of the most densely populated areas in Semarang city. The research location is Tembalang-Jangli New Road. The construction of Jangli-Undip New Road aims to reduce congested vehicle traffic in Gombel and Meteseh, which causes frequent congestion. Therefore, subsurface identification using the resistivity geoelectric method of dipole-dipole configuration was carried out to know the cause of landslides at the research location. Data acquisition was carried out with 10 passes. The results obtained 5 (five) layers of subsurface constituent rocks on Undip-Jangli New Road based on their resistivity values, namely topsoil (0.105 - 1.0 Ωm), clay (1.11 - 6.29 Ωm), sandstone (8.52 - 20.0 Ωm), tuff (20.0 - 75.0 Ωm), and volcanic breccia (75.0 - 133 Ωm). The interpretation results show the sliding plane at a 6.76 - 24.8 m depth. The layer that acts as a slide plane is a clay layer. The existence of sliding planes detected in the trajectories A-A’, B-B’, C-C‘, D-D’, E-E‘, F-F’, G-G‘, H-H’, I-I‘, and J-J’ has great potential to cause soil movement or landslides with the type of sliding is rotation.

Keywords: *landslide, resistivity geoelectricity, dipole-dipole.*

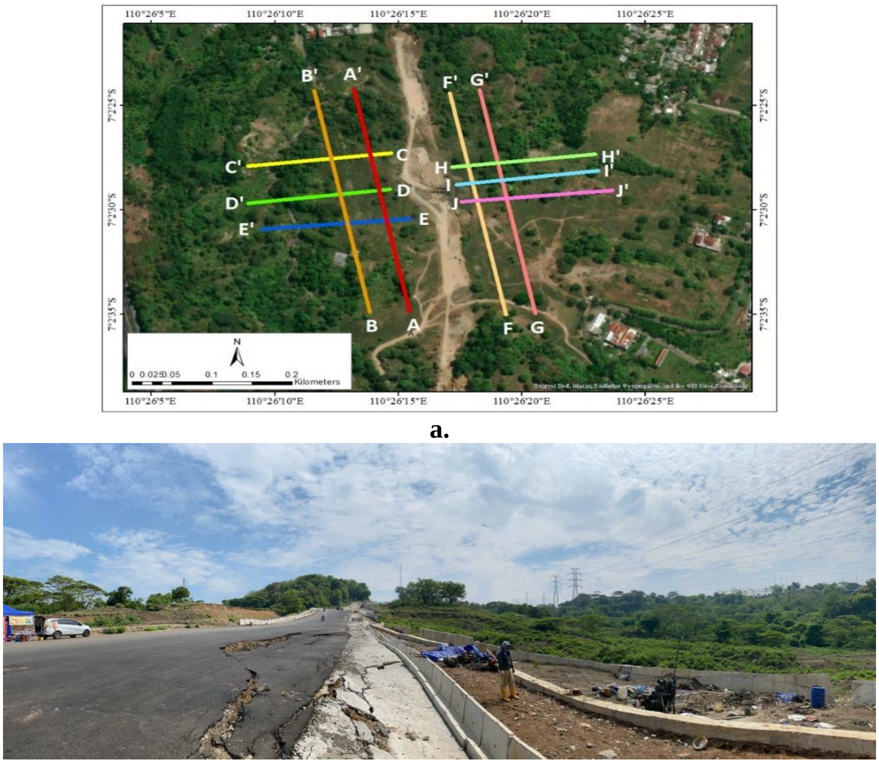
INTRODUCTION

Semarang is a unique city, divided into two regions with contrasting topography. The Semarang downtown area is directly adjacent to the coastal area, making it prone to tidal floods. the uptown Semarang area is a hilly area prone to landslides during the rainy season [1,2]. Landslides are masses of rock or soil that move down a slope due to loss of equilibrium force caused by several factors, closely related to geological conditions [3]. Landslides are often caused by high rainfall, steep slopes, movement, and poorly compacted soil. Landslides are a common problem in hilly areas with steep slopes [4]. Population growth leads to increased transportation needs and can cause congestion if the existing road capacity cannot accommodate the increasing number of vehicles [5]. The dense population is one of the factors that cause Semarang City to have a high level of population activity [6]. The construction of new roads is one of the ways that can be done to alleviate congestion. The road in Tembalang, Semarang, is an educational area integrated with residential areas and several public services. The new road was built by splitting the hill in the Jangli area. The manufacturing process was carried out in several stages considering the contours of the Tembalang - Jangli area were not sloping. The cutting and splitting of the hill were done by taking into account the degree of slope, however, the road has not been operating for long and has experienced cracks, subsidence, and landslides. The subsidence and landslide points can be found on the left side of the road from Tembalang. It is suspected that the subsidence was not caused by the over-capacity of vehicles traveling on the road.

Subsidence and landslides can be indicated by movement due to decreased density and compaction. Subsurface identification using geoelectrical methods can identify slip planes that cause subsidence. The geoelectric method is affordable and easy compared to other methods. Research in Vallcebre, Spanish Pyrenees, Cleveland Basin, UK, proved that geoelectric methods can identify subsurface clay layers. The resistivity application has been applied to roads that have collapsed in several areas **[7-11]**. The condition of the road, which collapses and landslides on the left and right sides is dangerous for road users. As a result of this problem, subsurface identification was carried out to determine the cause of subsidence in the new road area. The subsurface layer identification research was conducted using the resistivity method so that more appropriate treatment could be carried out according to the existing conditions. The result of the subsurface model is expected to be a reference for the opening of other new roads with similar topography.

MATERIALS & METHODS

The new Tembalang-Jangli road is located on the coordinate boundary of 7°02'17" - 7°02'48" S and 110°26'15” - 110°26'16” E. Tembalang sub-district is situated in the southern part of Semarang City which has an area of 39.47 km2 with a population of 193,480.00 people. Figure 1 is the data acquisition trajectory, carried out on the right and left sides of the road with different track lengths. In the North-South direction (tracks A-A', B-B', F-F', and G-G') and the East-West direction (tracks C-C', D-D', E-E', H-H', I-I', J-J').



a.

b.

Figure 1. Research area a) Geoelectric acquisition line on map b) The road condition

The electrode configuration used in this study is the dipole-dipole configuration because it has high sensitivity and is very effective in interpreting subsurface structures vertically and horizontally based on rock resistivity values [12]. The dipole-dipole configuration produces laterally more extensive subsurface features than the Wenner configuration in Malaysia [13]. The dipole-dipole configuration has advantages in its measurement results and speed. The dipole-dipole configuration is faster than the Wenner and Schlumberger configurations because it is multichannel and can test eight points from a single injection. Wenner and Schlumberger can only measure one point [14-15].

The dipole-dipole configuration uses a mapping measurement, which is the resistivity value of the subsurface cross-section laterally (horizontally). According to other research, the dipole-dipole configuration produces subsurface features that are more extensive laterally than the Wenner configuration [14-16]. The electrode arrangement of this configuration is C2 and C1 as current electrodes placed at the same distance as the potential electrodes P1 and P2, as shown in Figure 2.

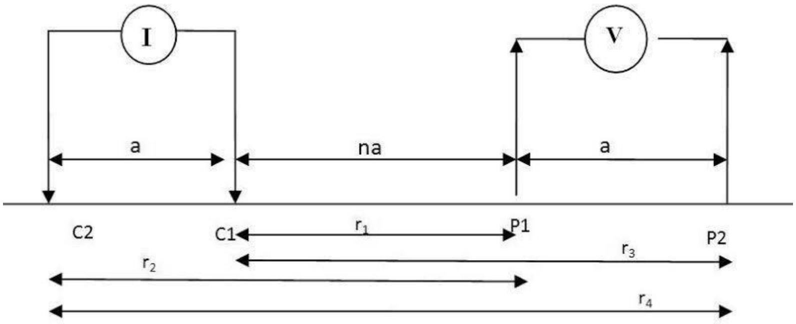


Figure 2. Electrode configuration

The acquisition obtained data in the form of voltage (V), current (I), and elevation values which were then calculated using Microsoft Excel and obtained the apparent resistivity value. The Excel data is then converted into *.txt form using Notepad. The data in *.txt form will be inputted in the Res2DInv application to be processed into a 2D resistivity cross-section model. Data processing in Res2DInv uses the inversion method with 7 iterations with different error values obtained. The 2D resistivity cross-section model obtained is correlated with the geological map of the research area as an interpretation material to estimate the position of the sliding plane depth.

The data interpretation stage begins with the physical reading of the resistivity value into a soil layer classification by matching the calculated resistivity value with the resistivity table in Table 1 and referring to existing geological information and previous research references [17].

Table 1 Rock Resistivity.

Material	**Resistivity (Ωm)**
Clay	1 – 100
silt	10 – 200
Mud stone	3 – 70
Quarst	10 – 2 x 10^8
Sandstone	1 – 1.000
Limestone	100 – 500
Lava	100 – 5 x 10^4
Water	0,5 – 300
Brecia	75 – 200
Andesit	100 – 200
Tuff	20 – 100
Conglomerate	2 x 10^3 – 10^4

Figure 3 is a geological map of the study area. The Tembalang - Jangli area is located in the Kaligetas Formation (Qpkg). Rock types found in the Kaligetas Formation include mudstone, sandstone, tuff, volcanic breccia, and lava [18]. The Kaligetas

Formation is of Quaternary age, composed of claystone units with abundant no fossils and Mollusca at the base. The upper part of the formation consists of pyroclastic units of Ancient Ungaran, namely tuffaceous sandstone, volcanic breccia, and lava, and claystone containing Mollusca and tuffaceous sandstone. The tuffaceous sandstone is yellowish brown with medium-fine grain size and medium porosity and is rather hard. The claystone is green, has low porosity, is moderately hard in the dry state, and crumbles easily when wet. Tuff is whitish-yellow with fine-coarse grain size and high porosity. Breccia has medium to high porosity and is hard and dense. Lava is dark grey, hard, and heavy. The Jangli - Tembalang area has a rock lithology composed of volcanic rocks and sandstones. Sandstone easily stores water and drains it. If the quantity and continuity of water increase, there will be an exogenic process in the form of erosion and transportation that causes a surface layer composed of sandstone to move [18-20]. To determine the depth of the sliding plane, the subsurface layer is divided into three based on its resistivity value. Clay has a resistivity value range of 1 - 100 Ωm, tuff has a resistivity value range of 20 - 100 Ωm, sandstone has a resistivity value range of 1 - 1,000 Ωm, volcanic breccia has a resistivity value range of 75 - 200 Ωm, and lava has a resistivity value range of 100 - 5 x10^4 Ωm [19].

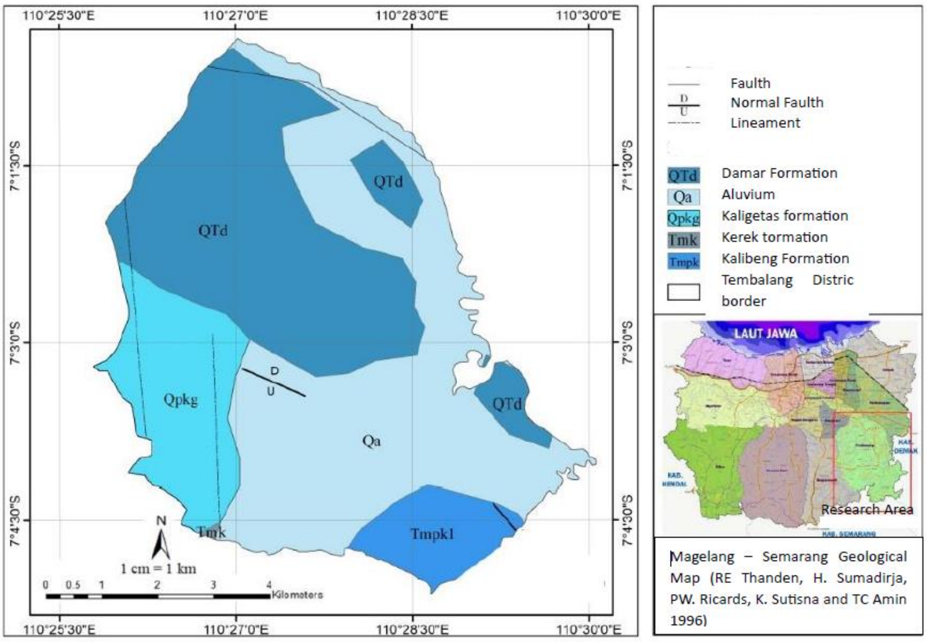


Figure 3. Geological map

RESULT

The dipole-dipole processing results in a subsurface resistivity model as shown in Figures 4 5 and 6. Figure 4 models the distribution of resistivity values in the AA' and BB' lines, which are north-south oriented. Line BB' is west of Line AA'. Line AA' has a deeper basin, which indicates a larger zone of low resistivity compared to the subsurface of Line BB'. The thickness of the soil layer is thicker. The plane of the slide is marked with a red dashed line. The clay layer has a resistivity of 5 - 10 Ωm, located at a depth of 15 - 30 m.

Figure 5 models the distribution of resistivity values in the lines CC', DD', and EE', an east-west trajectory. The CC' is north of the DD', and EE' lines. The CC' has a deeper basin, which indicates a larger zone of low resistivity than EE'. The line DD' has a shallower topsoil thickness. The slip plane is located at a depth of 10 - 20 m. The thickness of topsoil in the west is shallower than in the east.

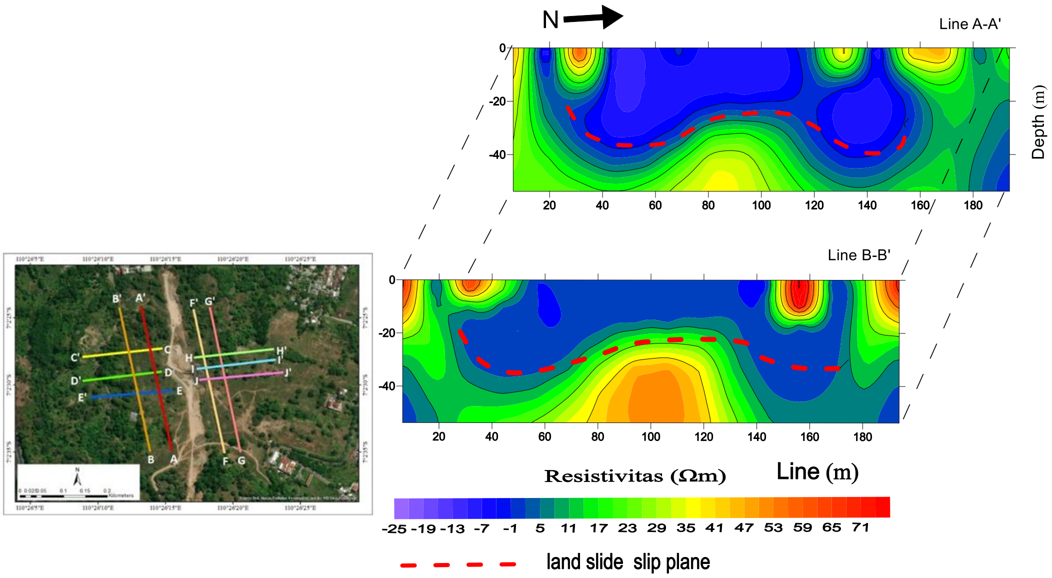


Figure 4. Resistivity model lines AA' and BB'

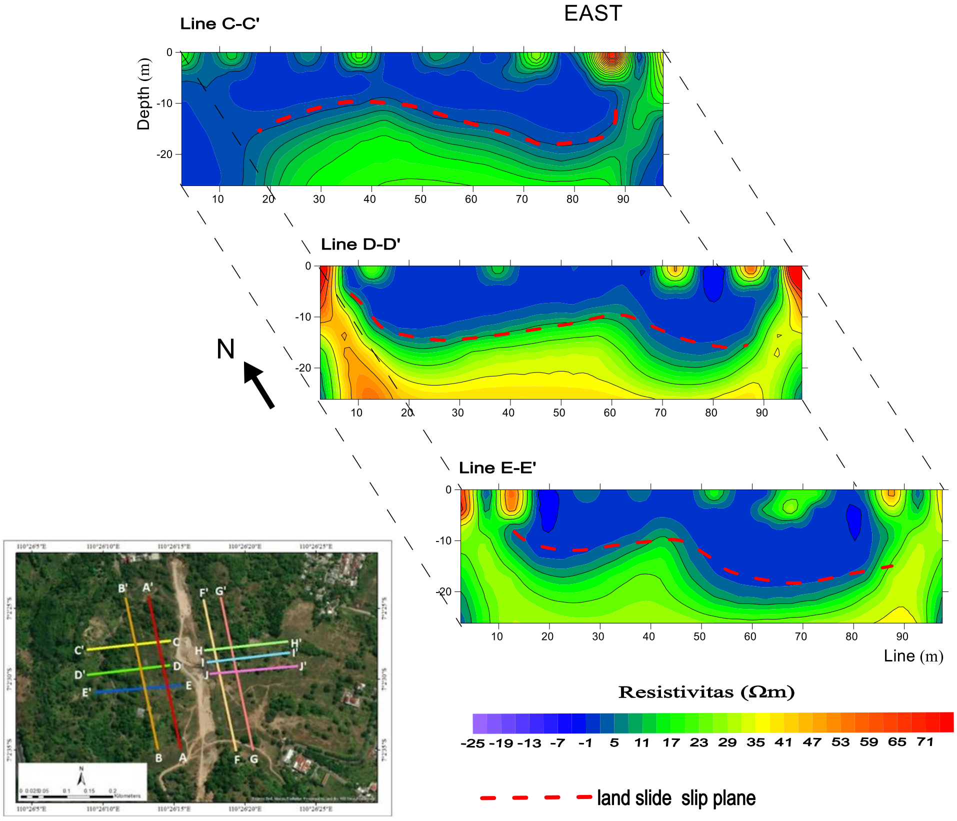


Figure 5. Resistivity model lines CC', DD' and EE'

The resistivity model east of the new road is mapped in Figure 6, which models the distribution of resistivity values in the lines FF' and GG'. The line FF' is the west side of GG'. The line FF' has a shallower basin and a low resistivity zone. The topsoil thickness will affect the entry of water, which can trigger landslides. The slide plane is marked with a red dashed line. The clay layer has a resistivity of 5 - 10 Ωm, located at a depth of 10 - 20m.

Figure 7 models the distribution of resistivity values in traverses HH', II', and JJ', traverses that run east-west. Traverse HH' is north of traverses II' and JJ'. Traverse HH' has a deeper basin which indicates a larger zone of low resistivity than the subsurface of traverse II'. Traverse JJ' has a shallower topsoil thickness. The slip plane is located at a depth of 15-25 m. The thickness of topsoil in the west is deeper than in the east.

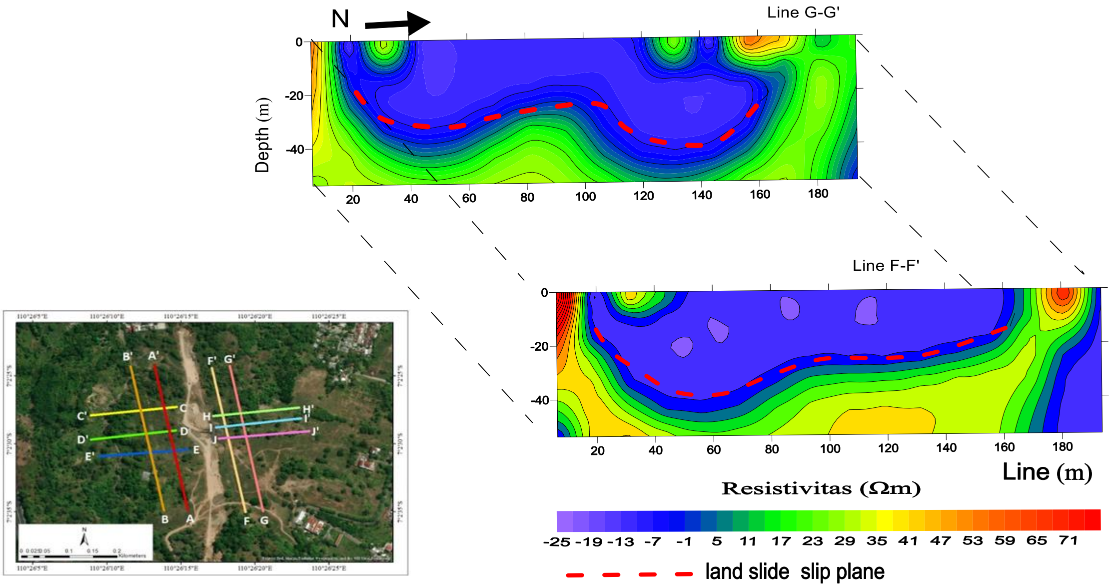


Figure 6. Resistivity model lines GG' and HH'

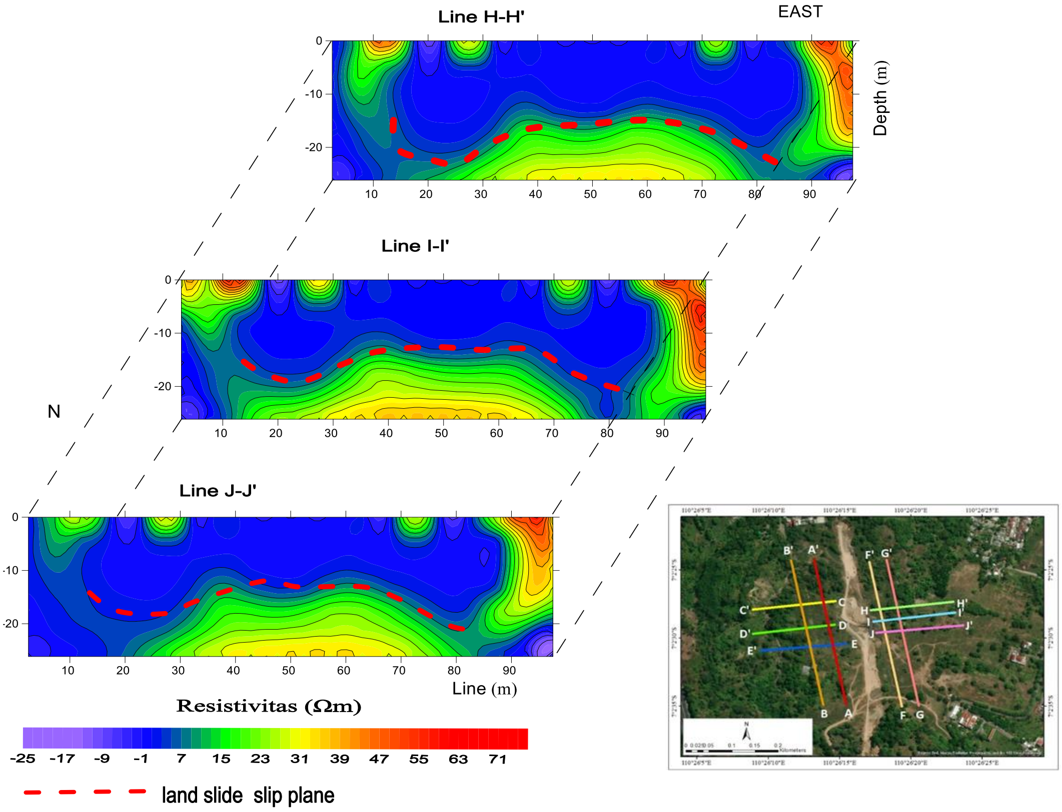


Figure 7. Resistivity model lines HH', II' and JJ'

DISCUSSION

The results showed a considerable contrast in specific gravity between the constituent layers. The conditions of a sliding field are characterized by layers, that have contrasting rock-specific resistivity close to each other [21,22]. The interpretation results of the trajectories A-A', B-B', C-C', D-D', E-

E', F-F', G-G', H-H', I-I', and J-J' show the existence of land movement, namely the type of rotational avalanche, where the sliding plane is concave. The slide plane is characterized by the presence of two rock layers that have contrasting specific gravity values. When the upper layer has lower specific resistance, than the lower layer, an avalanche will likely occur, because the layer will easily erode and flow, especially if it is supported by a steep enough field and high enough rainfall in the area **[23,24]**. The layer that acts as a sliding field is the clay and lies between two rock layers. The two layers have contrasting values of specific resistance, namely topsoil and sandstone. Clay has a high porosity density and low permeability so that it cannot pass water, and its texture is rather hard in a dry state and easily destroyed in a wet state. This clay layer is the cause of the land subsidence that caused Jalan Baru to collapse.

The Tembalang-Jangli Semarang road is in an area with moderate ground motion vulnerability. Areas that rarely experience landslides have a medium ground motion susceptibility value. Moderate ground motion vulnerability has sloping topography (5 - 15%) to very steep (50 - 70%). This is by the slope map of the Tembalang sub-district **[2,19,22]**. The Tembalang-Jangli New Road is in class II or sloping (8 - < 15%) to class III or rather steep (15 - < 25%). One factor that influences the level of landslide hazard is the topography. Road construction in this area is done by cutting the hills in Jangli so that the stability of the slope is disturbed. Also, the presence of vehicles crossing this road with a fairly dense number adds to the load on the ground surface which can increase the driving force of landslides.

Research on landslide potential on the Tembalang-Jangli New Road has also been conducted using the microtremor method, showing high amplification **[24]**. High amplification indicates weathered rock and soil conditions support landslides **[25,26]**. The rock type on the resistivity track has a low resistivity value. Rocks with low resistivity have a high conductivity value, meaning that the water content in the rock is higher. According to other landslide research, landslide materials are characterized by low resistivity. Rocks with low resistivity tend to store water, while landslide fields are materials with high resistivity **[26 – 29]**.

CONCLUSION

The 2D model results show that the model of the constituent rock layers consists of topsoil, clay, sandstone, tuff, and volcanic breccia. The interpretation results show the sliding plane is located 6.76 - 24.8 m below the surface. From the data processing results, the layer that acts as a sliding plane is the clay layer. The existence of a sliding plane, detected on all lines/cross-sections, has great potential to cause ground movement or landslides.

Declaration by Authors

Acknowledgment: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest

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How to cite this article: Leony Chandra Anindita, Rina Dwi Indriana, Agus Setyawan. Landslide identification on Tembalang-Jangli new road, Semarang, central java using dipole-dipole configuration resistivity geoelectric method. *International Journal of Research and Review*. 2024; 11(10): 469-477. DOI: *https://doi.org/10.52403/ijrr.20241043*

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