Identification of Subsurface Lithology in Sendang Mulyo, Purwoharjo Village, Samigaluh Subdistrict, Kulon Progo Regency

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Abstract. Research aimed to determining the lithological conditions subsurface of landslide areas in Sendang Mulyo, Purwoharjo Village, Samigaluh Subdistrict, Kulon Progo Regency by geoelectric and microseismic methods. The research had been conducted after knowing the subsurface lithology conditions, it could anticipate landslides as disaster mitigation. The location of research is on a hillside in Purwoharjo Village. The research located on that area because the history landslides. The area is the longest landslide and had a major impact on the villagers that located below the hill. The research used a set of resistivity geoelectric devices with Syscal brands and microseismic devices Digital Portable Seismograph brands TDL-3035 type Taide brands. In geoelectric method used 5 lines, 2 lines 150 m from north to south, 2 lines 120 m and 1 line 100 m from east to west, while the microseismic method used 30 points with spaces of 10-100 meters. The results of the geoelectric method are obtained lithology of clay material with resistivity of 0.16 - 160 Ω.m, sand material with resistivity 160 - 1093 Ω.m, sandstone material with resistivity 1093 - 8000 Ω.m, and a andesite material with resistivity of 8000 - 122165 Ω.m, while the results of the microseismic method obtained clay rock material having a value of $V_s$ between 406.33 m/s and 742.52 m/s represented by the dark blue spectrum. In the middle landslide has a depth of clay material up to 33 meters. The results showed that subsurface lithology in the area is prone to landslides, because it is suspected that there is a sliding field at a depth of 33 meters. This is supported by the presence of andesite rocks which spread at a depth of 20 meters and above the andesite material, there is clay material that quite thick.

1. Introduction
In the past few years there had been a landslide in the hills of Menoreh Kulon Progo. In 2004, at least 15 people died and material damage occurred such as houses, agricultural land and transportation routes. Inclined of landslides in the area is supported by the incidence of Cempaka Tropical Cyclone at 28 - 30 November 2017 on the southern island of Java. This incidence causes the potential for landslides in Kulon Progo Regency to be higher. The Geospatial Information Agency (BIG) in collaboration with the Regional Disaster Prevention Agency (BPBD) of Kulon Progo Regency made rapid mapping in parts of Samigaluh, Kalibawang and Girimulyo Districts. According to historical landslides there are longest landslide in Samigaluh by the storm, exactly in Sendang Mulyo, Purwoharjo village [1].

One of natural disaster is landslide. This disaster impact in damage to residential land, disruption of traffic lanes, damage to agricultural land, damage to bridges, irrigation and other physical infrastructure. Landslides in general are a geological phenomenon which land movements as rock falls or land lumps [5]. Landslides happen when the incentive force on the slope is greater than the barrier force. Barrier forces are generally influenced by rock strength and soil density, while the incentive force is influenced by the magnitude of slope, water, load and rock type specific gravity.
Knowledge of subsurface lithology is very necessary to anticipate of the inclined area to natural disasters, especially for landslides and as a landslide mitigation. The method that can be used to determine subsurface lithology is geoelectric resistivity and microtremor. Geoelectric method is one of the geophysical methods that knows the nature of electricity in the earth by injecting electric current, then measuring the potential difference and current that occurs used electrode configuration, so that the rock layer beneath the resistivity value is obtained [10]. Subsurface lithology is obtained from the distribution of layers resistivity, which has been compared with resistivity tables [9]. Microtremor is a very small and continuous ground vibration that originates from a variety of vibrations such as, traffic, wind, human activities and others [3]. Microtremor is based on recording microseismic signals to determine the parameters of dynamic characteristics (damping ratio and natural frequency) and the transformation function (frequency and amplification) of buildings. Microtremor observation can be used to determine the characteristics of the soil layer based on the parameters of the dominant period and the amplification factor. Nakamura [7] states that the value of the reinforcement factor (amplification) of the soil is related to the contrast ratio of the surface layer impedance to the layer below it. If the contrast impedance ratio of the two layers is high, the reinforcement factor value is also high, and vice versa. Microtremors can also be used to determine the type of soil based on the level of violence [8], if the smaller the dominant period of land, the greater the level of violence or the land that has a dominant period the greater the soft or soft nature. Marjiyono [4] states that, amplification is directly proportional to the value of the horizontal and vertical spectral ratio (H/V). HVSR techniques (Horizontal to Vertical Fourier Amplitude Spectral Ratio) in microtremor data analysis have been widely used for studies of local effects and microzonation. HVSR is one of the easiest and most inexpensive ways to understand the structural properties of subsurface layers without causing disturbance to these structures [6].

2. Method
This research used dipole-dipole geoelectric resistivity method with dipole-dipole configuration. The research used resistivity data on five lines. To confirm the result, this research used microseismic method with microtremor 30 data of measurement points. The research location is in the Sendang Mulyo, Purwo Harjo village, Samigaluh subdistrict, Kulon Progo regency of Yogyakarta. The site was located at 7°41'47.26'' S - 7°41'44.63'' S and 110°10'29.37'' E - 110°10'31.19'' E. Based on the geological structure, Purwoharjo Village has the Kebo Butak Formation. This formation generally consists of conglomerates, sandstones and clays [2].

The measurement data from the geoelectric method are potential values (ΔV), the current strength (I), and the space (a). These data used to knowing the geometry factor (K) and resistance (R) values so that the value of apparent resistivity (ρa) is obtained by the equation ρa = kΔV/I, k is geometric factor of dipole-dipole configuration. The equation to get the value of geometric factor is k=n(n+1)(n+2) πa, with n = 1,2,3,4,5, and 6. To obtained the true resistivity, the next step is processing the data using Res2DinV software. Microtremor data is obtained by measuring microtremor signals and then analyzed using HVSR (Horizontal to Vertical Spectra Ratio) to get the H/V curve . The H/V curve is used to determine subsurface lithology with predominant frequency values and amplification values. Vs (shear wave velocity) values obtained in Vs ground profiles using the Dinver program to classify the types of subsurface layers of the study area.
3. Result and Discussion
   a. Geoelectric Method
      1) First Line
         The first line is 150 m long with the northeast to the southwest with located at 7°41′44.78″ S, 110°10′33.11″ E to 7°41′46.58″ S, 110°10′28.84″ E. The space between electrode is 10 meters, 76 datum points are obtained. The depth of the subsurface structure is up to 21.8 meters. The results of the interpretation are obtained by changing the iteration several times until an interpretation is approaching the actual field conditions. On the first line, it is carried out until the 5th iteration with a value of 10.1 rms.

![Cross Section Resistivity of the First Line](image)

Figure 1. Cross Section Resistivity of the First Line

Based on Figure 1 there are four layers of material, clay material with resistivity of 1.14 - 130 Ω.m. There are a few layers of sand at a depth of 2 meters and 7 meters at a distance of 45 meters from the starting point with resistivity of 160 - 1093 Ω.m. At a depth of 17 to 18 meters, sandstone layers were found with resistivity from 1093-1923.5 Ω.m. At a depth of 20 to 21 meters, bedrocks were found with andesite material which had a resistivity of 11988.6 Ω.m. On this line a sample such as clay is taken at a distance of 40 meters from the starting point in 1 meter depth.

2) Second Line
   The second line is at 7°41′43.79″ S 110°10′31.55″ E to 7°41′47.16″ E 110°10′28.09″ E. The length of this line is 150 m with the northeast to the southwest while the spacing between the electrodes is 10 meters. This line obtained 76 datum points data. The target of the depth is 21.8 meters below.
On the second line (Figure 2) there are 3 layers of materials. Clay layer with resistivity $1.62 - 158 \ \Omega \cdot m$. Sand material is dominant on the surface with resistivity $160 - 901 \ \Omega \cdot m$. This sand material is also found in depths of 10 to 20 meters. At a certain depth, around 15 meters there are sandstones that have a resistance of $1093 - 2677.7 \ \Omega \cdot m$. Sample such as clay rock found at a distance of 40 meters from the starting point and 30 cm depth.

3) **Third Line**

The length of the third line is 120 m from the north to the south. The distance between the electrodes is 10 meter. The depth target is 21.8 meters below. In this line there are fewer data from the previous lines, which are 52 datum points. Model iterations are needed to get the interpretation results that are close to field conditions and in this research, iterated 6 times with value of rms is 7.7.
On the third path (Figure 3) there are only 2 layers. There is a clay layer with resistivity $1.26 \cdot 160 \ \Omega \cdot m$ and a few sand materials found. Located at a depth of 5 meters with a distance of 25 meters from the starting point of the research, at a depth of 10 meters at a distance of 25 meters from the first electrode, and there is also a meter to 55 meters in depth. There is also a layer of sand with a resistivity of 160 to 918 $\Omega \cdot m$. In this line, samples are taken at 90 meters from starting point and 1 meter depth such as clay rocks.

4) Fort Line
The length of the fourth line is 120 m from the north to the south. Located at $7^\circ41'44.65'' \ S \ 110^\circ10'28.93'' \ E$ to $7^\circ41'48.17'' \ S \ 110^\circ10'29.93'' \ E$. Space between electrode is 10 meters. The amount of data obtained is the same as the third line, which is 52 datum points. The iterations used on this line are 4 with the value of rms is 8.6.

![Figure 4. Cross Section Resistivity of the Forth Line](image)

On this fourth line there are only 2 types of layers. The resistivity of clay layer is $0.38 \cdot 160 \ \Omega \cdot m$. There found sand material on the surface with resistivity value of 160 - 239.02 $\Omega \cdot m$. On this line, samples taken such as darker clay at a distance of 80 meters from the starting point and a depth is 20 cm.

5) Fifth Line
Line along 100m stretch from northeast to southwest with the position of $7^\circ41'46.55'' \ S \ 110^\circ10'28.24'' \ E$ to $7^\circ41'46.55'' \ S \ 110^\circ10'31.40'' \ E$. The spacing between electrodes is 10 meters. The data obtained are fewer than the previous lines, which are as many as 36 datum points. The depth target obtained on this line is the same as the previous lines, which are 21.8 meters. In this fifth line, it is iterated 5 times and produces a large value of rms which is 23.4. More iterations can be done, so that smaller rms are obtained, but this does not produce an interpretation that is close to the field conditions.
On the fifth track (Figure 5) there are 4 layers. The resistivity of clay is 0.16 – 141 Ω.m and there are sandstone layers at a depth of 5 - 10 meters with resistivity 160 - 404 Ω.m. At a depth of 2 meters sandstones can be found with a resistivity of 3532 Ω.m. There is a bed rock at the end of the first meter. The bed rock form of andesite material with the depth 1 meter that has high resistivity as 122165.10 Ω.m. On this line a sample such as clay is taken at the 25th meter, one meter of the depth.

The correlation showed that till the depth of 21.8 meters, there is not found the slip plane. Based on the combined results of the line can be identified that the material is clay with a bond between weak particles and has a resistivity <160 Ω.m, then the area is called weak zone. This zone can be used as a reference for vulnerability to landslides in an area. However, if you look at the field conditions, it can be predicted that there is a skid field because some sandstone is found in the first line. The result of the correlation with the field for the first line, it is possible that there is a slip plane because some sandstone is found along the end of the first meter on the first track. However, it cannot be proven by the parallel correlation of the line in this research because the second line is difficult to reach.

b. Microseismic Method

The microseismic method was carried out by measuring microtremor signals at 30 research points. The result of the measurement is the value of $V_s$, 3D modeling from the ellipticity curve method (Figure 6). The location has lithology composed of soil layers having a value of $V_s$, between 51 m/s to 309.86 m/s which is represented by the purple spectrum in almost all surfaces of the research location with a thickness of about 10 meters. Clay materials has a value of $V_s$, between 406.33 m/s and 742.52 m/s which is represented by the dark blue spectrum. In the middle part which is the location of the landslide in 2017 has a depth of clay material up to 33 meters. In addition to these two materials (soil and clay), breccia and pumice materials were found to a depth of 70 meters with a value of $V_s$, with a range of values between 814.17 m/s to 1478.64 m/s represented by a green spectrum, with a fairly thick material distribution dominated in the western region of the research point. Bed rock material as dacite and andesite has a value $V_s$, between 1628.34 m/s to 2283.84 m/s are represented by yellow to red color spectrum and only found on the southwest side of the hill.
Figure 6. 3D Model of Subsurface Lithology

Viewed from the results of the incision (Figure 7) on the location of the landslide there is still a layer of clay to a depth of about 33 meters. This can be one of the reasons that the location is still prone to landslides, in addition with other landslide factors such as rainfall, earthquakes and others that caused the vulnerability of the area to landslides to increase.

Figure 7. Distribution Incision of $V_s$
Based on the results of the geoelectric method, it was found that the area had lithology which was dominated by clay material, besides that in some points there were materials such as sand, sandstone, and andesite rocks exposed at the bottom of the hill. The lithology resulted were supported by the resulted of the microtremor method. In lithological mikrotremor research resulted of the research area is dominated by a layer of clay soil and rock, in addition to the material contained brecci, pumice, desit and andesite on the hill the other with varying depths.

4. Conclusion
The conclusions of this research were Sendang Mulyo, Purwoharjo Village, Samigaluh Subdistrict, Kulon Progo Regency, which had subsurface lithology dominated by clay material with resistivity (0.16 - 160) Ω.m and te value of \( V_s \) 51 m/s up to 309.86 m/s. In addition there is sand on the surface material with resistivity (160 - 1093) Ω.m and value \( V_s \) 406.33 m/s to 742.52 m/s. At several points of the research there were also sandstones with resistivity (1093 - 8000) Ω.m and value of \( V_s \) 814.17 m/s to 1478.64 m/s. The most basic layers predicted is the slip plane such as andesite material with resistivity (8000 - 122165) Ω.m and value of \( V_s \) 1628.34 m/s to 2283.84 m/s. The research area has the potential for landslides. The results of the research stated that the area was dominated by clay which in the phenomenon of landslide would have a major impact on the population. This was worsened through historical facts of landslides in the previous year. In addition, the area has a dominant underground structure with clay, with a sediment thickness estimated at 20 m and supported by geographical factors that showed the slope is > 45° as well as fracture of land on the hill during the dry season.

5. References

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