International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 10, 2020
ISSN: 1475-7192

Investigation of Landslide Vulnerability on Prambanan using Vertical Electrical Sounding

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ABSTRACT- *The aims of this research to identify potential weak zone of landslides on Prambanan based on the geoelectric resistivity technique of Vertical Electric Sounding (VES) Schlumberger configuration. Data was collected as much as 7 point sounding ; each Spreading AB has a length of 80 meters. The location of landslide is near from resident house. Therefore evaluation using resistivity method is needed to identification vulnerability of landslide. There are 7 of data acquisition. Based on the inversion result, contrass resistivity zone identified as diferent border of layer. Based on 2D resistivity modeling results indicate that the slip field is at a depth of 1.02-7.8 meters in the form of weathered Tuffaceus Sandstone.*

Keywords- *sliding surface, geoelectricity, Schlumberger configuration, Vertical Electric Sounding, resistivity zone*

I INTRODUCTION

Indonesia which is around the equator line has two seasons every year (dry season and rainy season) that occurs almost half a year under normal circumstances. However, it has been observed in the recent years that the dry season lasts longer than normal circumstances due to the effect of global warming that result in more frequent

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Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

landslides [1-4]. Landslides are geological phenomenon that involves movement of a mass of rock, earth or debris due to soil erosion [5-9]. Landslides happen due to interaction between local geology and high rainfall intensity conditions result in significantly different landforms with varying degree of susceptibility to land sliding [10-14]. Landslides can triggered by rainfall, earthquakes, volcanic activities, changes in groundwater, disturbances and change of slope profile by construction activities or combinations of these factors, landslides did not a happened naturally but it was a result of human actions [15-18] . Landslides in mountainous terrain often occur during or after heavy rainfall, resulting in the loss of life and damage to the natural and/or built environment [19, 20].

Sleman Regency is one of the regencies in DIY Province, Indonesia which is 72.11% of its area consists of mountains and hills with altitude between 100-2,500 meters above sea level, with a very steep slope above> 40% of 1,526 km2 [21]. According to Lutfia fajria (2017), 24.70% of sleman district areas (1010,39 ha) are included in the category of areas with high landslide vulnerability [22]. In 2011, the landslide disaster in Sleman Regency resulted in 34 housing units buried, casualties of 4 people, with the extent of landslide prone areas reaching approximately 3,303 ha. In 2012, landslides destroyed 40 homes and left 3 people dead [21].

The geo-electric resistivity method is one of the most used in Landslide studies shallow investigation. Therefore, this method can be utilized for the survey of landslide prone areas, especially to determine the thickness of the layers that have the potential of landslides and the lithology of layers of subsurface rocks [5, 23, 24]. Marsudi etal. (2018) employed Schlumberger configuration method to survey the geology structure under the surface based on the variation on the specific resistivity or resistivity of the rocks in Bukit Permai Singkawang [7]

Landslides may be considered as common natural hazards, in many cases leading to significant economic losses and even fatalities. The identification of high risk areas is important in landslide prediction and mitigation. Hence, there is a need for landslide geophysical mapping for identification of potential landslide areas. The present study is an attempt towards development of a landslide methodology by using resistivity method in Prambanan to efforts to control the vulnerability of landslides in the study area.

II METHODS

This study was conducted in Kecamatan prambanan. In this study geoelectric resistivity with schlumberger configuration method was used, as can be seen in Figure 1. The distance between the electrode potential of "MN", while the current electrode and the electrode potential in outer (AB) In general, the apparent resistivity values [10] can be written as:

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

with ρa : apparent resistivity (Ω.m), ΔV : potential difference (volts), I : a current (A), k : geometry factor for the Schlumberger configuration.

Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

$$k = \pi\left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right] \qquad (2)$$

The result that obtained from the measurement is resistivity value which then calculated to obtain resistivity value as data analysis. Resistivity value is processing by IPI2win software with qualitative VES two layer interpretation. With idea current flow can consider to refract in subsurface layer boundaries.

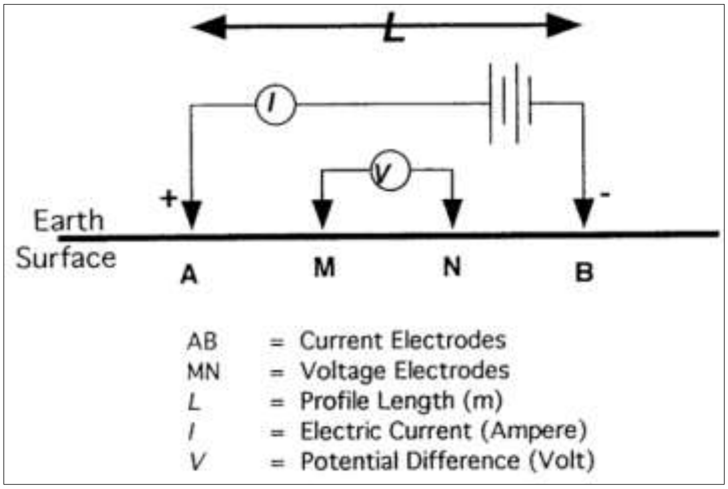

Figure 1. VES using Schlumberger configuration

The characteristics of subsurface can be known and analyzed by compare the resistivity value from inversion result to table reference that describe resistivity value of some material of the earth and data logging of research location. The reference table (Table 1) can be seen in the following table:

Tabel 1. Material resistivity value [25]

Material	**Resistivity (Ωm)**
Soil Clay, Moist	1,5 – 3
Soil Silt-clay & Moist	3 – 15
Soil Silt	15 – 50
Soil Clay	2 – 20
Shale	100 – 300
Shaly Sandstone	50 – 300
Sandstone	500 – 3000
Basement rock fractured & filled moist soil	150 – 300
Gravel sand mixed with silt	300
Gravel sand has a silt layer	300 – 2400
Basement rock fractured & filled dry soil	300 – 2400

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2.1 Area of Study

The study in Prambanan, Sleman, Yogyakarta (Fig 2) area. The most of Prambanan area is covered with mountains. Data retrieval is carried out by taking 7 data sounding that spread perpendicular the direction of avalanches. There are 7 measurement points with an average distance between 130 m. The research area has a settlement shown in Fig 3. Landslides can endanger residents in the Gayamsari region.

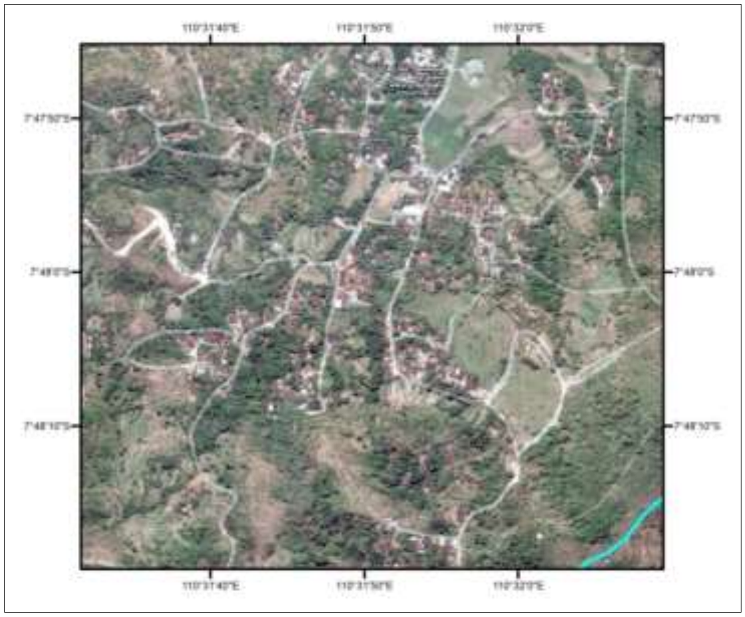

Figure 2. Overview map showing location of study area Prambanan using Google Maps,2018

III RESULT AND DISCUSSION

3.1 The Condition & Lithology

Conditions at the study site were influenced by two seasons. The season is the dry season and the rainy season. Data collection was carried out in July - August where the period was the dry season. Factors affecting resistivity value, soil homogeneity, metal mineral content, aquifer content, porosity, permiability, temperature and soil age (Muallifah, 2009). Water content is closely related to permiability and porosity, which will affect the water content in Soil. Soil has an average porosity between 0.43 - 0.36 for sandy soil and an average of 0.58 - 0.51 for clay soil. (1) (2). Nevertheless the Soil porosity is complex. Traditional models regard porosity as continuous. This fails to account for anomalous features and produces only approximate results. (3) In this study a general model is used which is divided into four parts. Starting from the top ; topsoil, subsoil, parent material and bedrock.

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 10, 2020
ISSN: 1475-7192

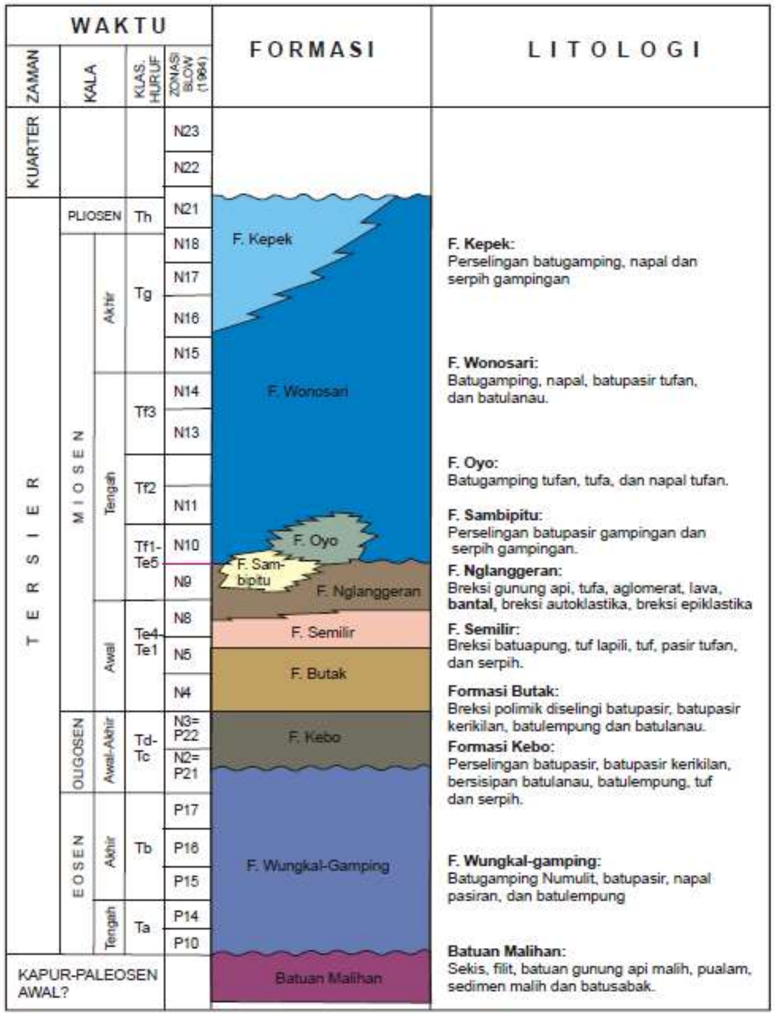

Figure 3. Stratighraphy Baturagung dan Jiwo Hills (modified from Sudarno, 1997)

Rock lithology references in the area use literature sources from geological map sheets (Surono, 1992). In addition, field observations were also conducted. The Kebo Formation is between sandstones and gravel sandstones, with inserts of siltstone, claystone, tuff and shale. While the Butak formation consists of polymic breccia with sand intervals, gravel sandstone, siltstone / shale (Surono, 2008). Based on observations in the field it is known that rocks. The lithology found at the study site was Sandstone with intercalation of tuff. Strike-Dip observations of rock outcrops in the field have N85E / 31. Above the rock piled up the Soil layer covering most of the research area.

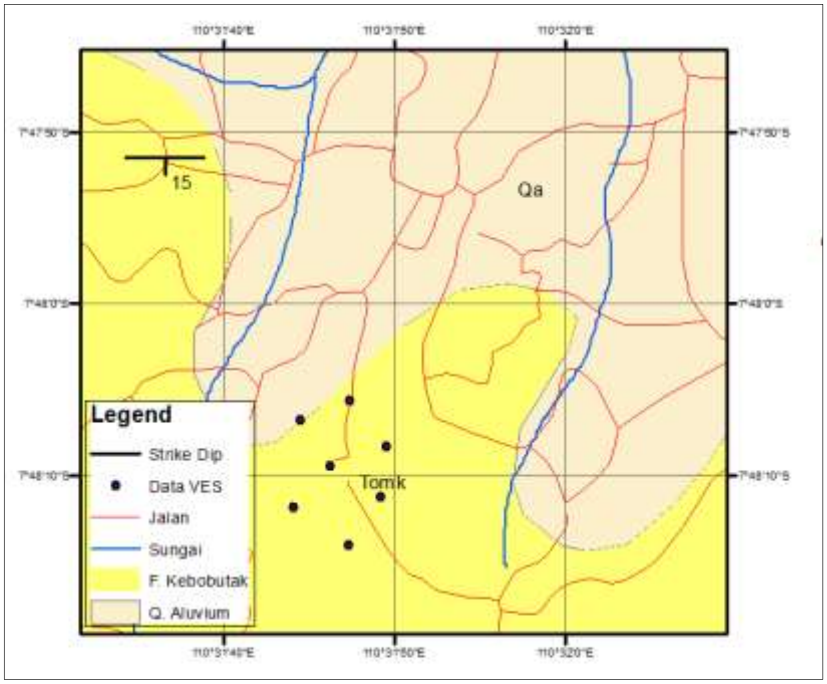

Figure 4 Geological map of research location (Surono, 1992)

3.2 Morphologi Condition

Figure 5 and 6 shows the location and description of the state of the research location consisting of residents and agriculture fields. In Figure 5 and 6 shows the distribution of residential locations. This area of the valley is located by 3 slopes. The slopes are in the southeast, southwest and northwest of the research location. Based on measurements in the field it is known that the southeast slope has a slope 16.2 ° (29.05%), southwest slope = 9.2 ° (16.19%), and northwest slope = 7.4 ° (12.987%). Slope also causes slope instability. Based on the slope and the morphology of the slope of the Gayamharjo area, it has a landslide potential. The source of landslides can come from the three slope directions that lead to the village of Gayamharjo.

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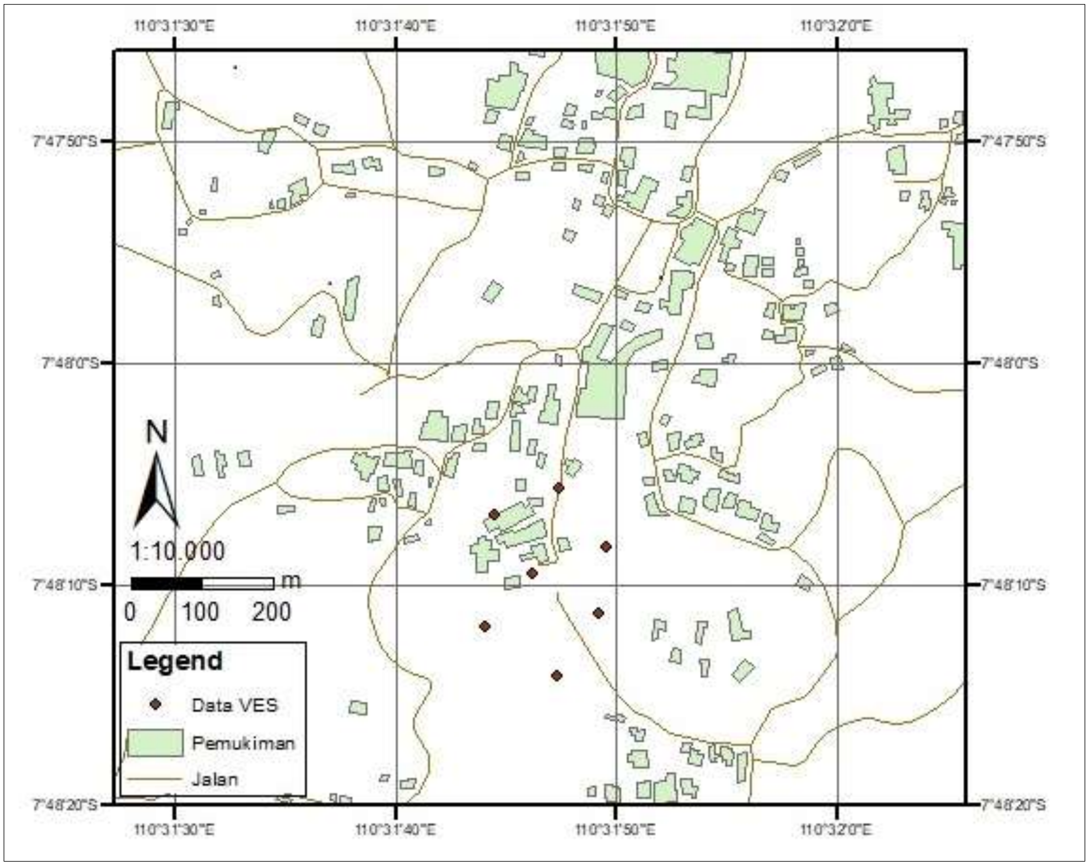

Figure. 5 Map of the distribution of residential areas

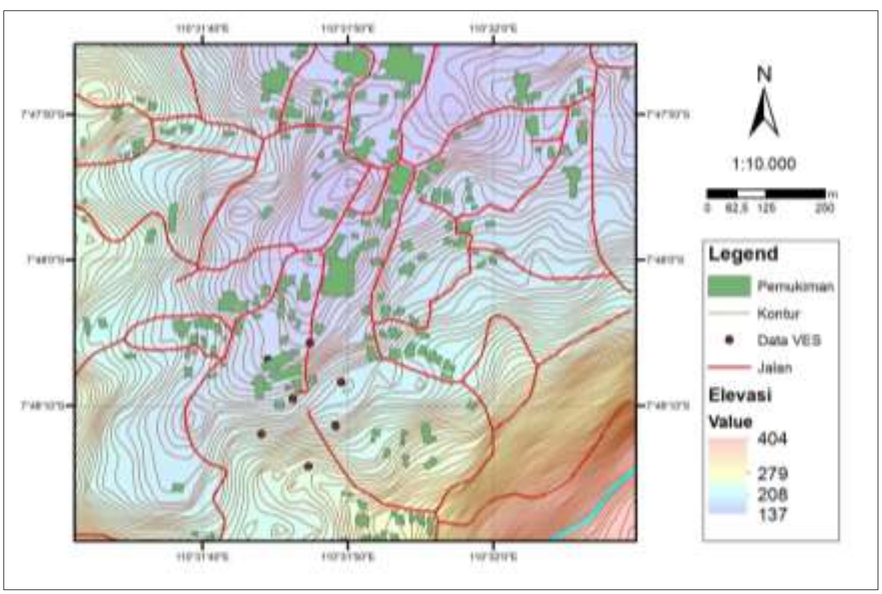

Figure 6. Map of settlement distribution and morphology in the study area by topography maps using ASTER GDEM v.2 data.

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 10, 2020
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3.3 Data Processing Results

VES (Vertical Electrical Sounding) measurements at Prambanan are carried out with a total of 7 points (Fig 7). The electrode configuration used in this study is Schlumberger with a maximum stretch length of AB / 2 is 40 m. The results are then processed using two layers of qualitative VES interpretation.

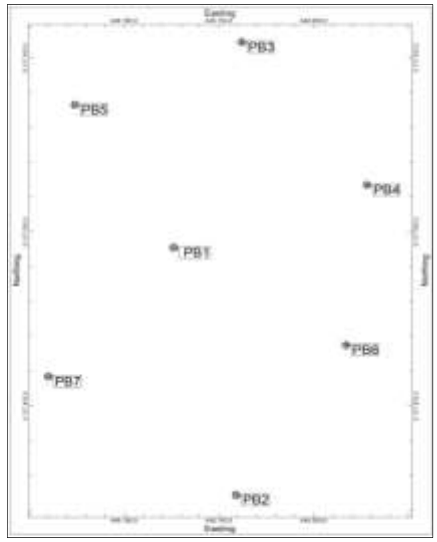

Figure 7. Acquisition data Location

The data then plotted in a log in the form of a matching curve with interpretation of depth (x) and interpretation of type resistivity (y). Processing and interpretation using IPI2win software with processing results are reistivity (N) contrast, medium resistivity (ρ), medium layer thickness (h) and depth (d). The interpretation approach uses in this study is a two layer and three layer model (PB 6) . From the Fig 8, it shown that there are two medium contrasts between the upper and lower layers. At the top layer is interpreted to have a resistivity value of 36.8 Ωm. The upper layer thickness is 2.51 m. Its depth is from 0 m - 2.51 m. At the lower layer it is interpreted to have a resistivity value of 7.23 Ωm. Layer depth of 2.51 m - infinite. The upper layer has a relatively larger type of resistivity than the bottom layer.

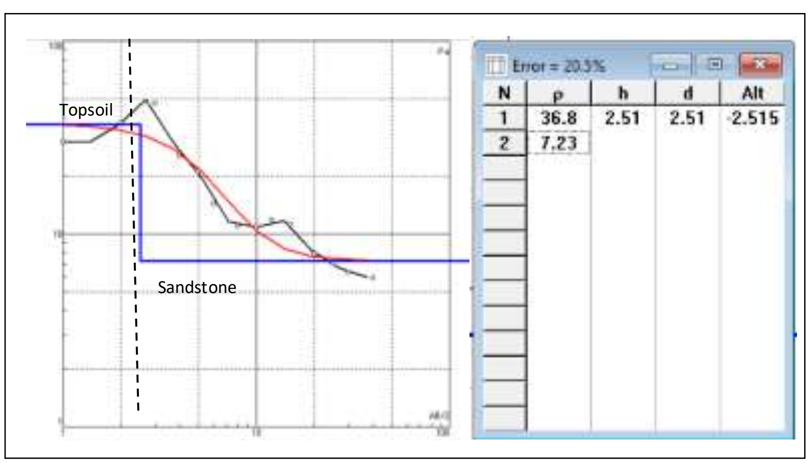

Figure. 8. Profil of PB 1

There are two medium contrasts between the upper and lower layers withh resistivity value 25.9 Ωm and 9.28 Ωm, respectively (Fig. 9). Upper layer thickness has depth 0 m - 3.69 m while the bottom layer is 3.69 m - infinite. The upper layer has a relatively larger type of resistivity than the bottom layer.

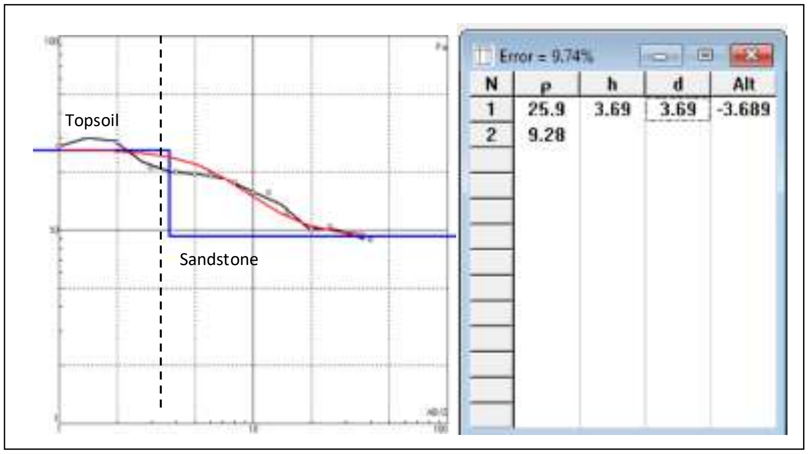

Figure. 9. Profil of PB 2

From Fig. 10 the top layer is interpreted to have a resistivity value of type 158 Ωm with depth is from 0 m - 3.71 m. At the second layer it is interpreted to have a value of 2.87 Ωm, depth of layer 3.71 m - infinite. The upper layer has a relatively larger type of resistivity than the bottom layer.

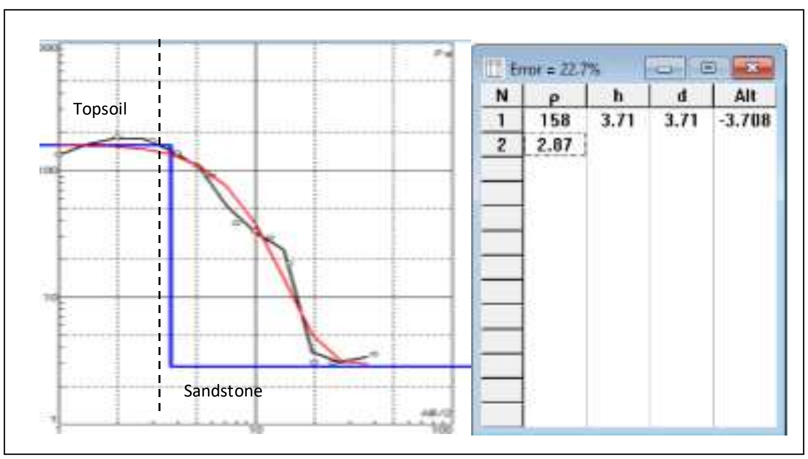

Figure. 10. Profil PB 3

There are two medium contrasts between the upper and lower layers withh resistivity value 2.81 Ωm and 715 Ωm, respectively(Fig. 11) Upper layer thickness has depth 0 m – 7.19 m while the bottom layer is 7.19 m - infinite. At this PB 4 point there is an anomaly, that is, this point the upper layer resistivity value is smaller compared to the lower layer.

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 10, 2020
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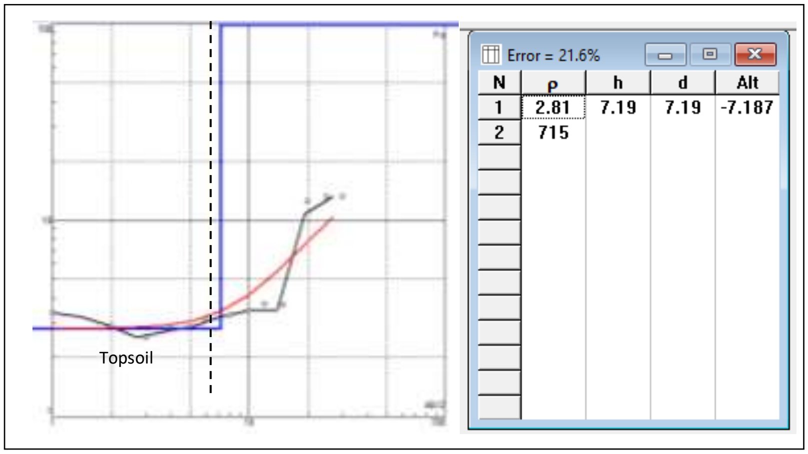

Figure 11. PB 4

From Fig. 12 the top layer is interpreted to have a resistivity value of type 15.7 Ωm with depth is from 0 m - 3.32 m. At the second layer it is interpreted to have a value of 7.43 Ωm, depth of layer 3.32 m - infinite. The upper layer has a relatively larger type of resistivity than the bottom layer.

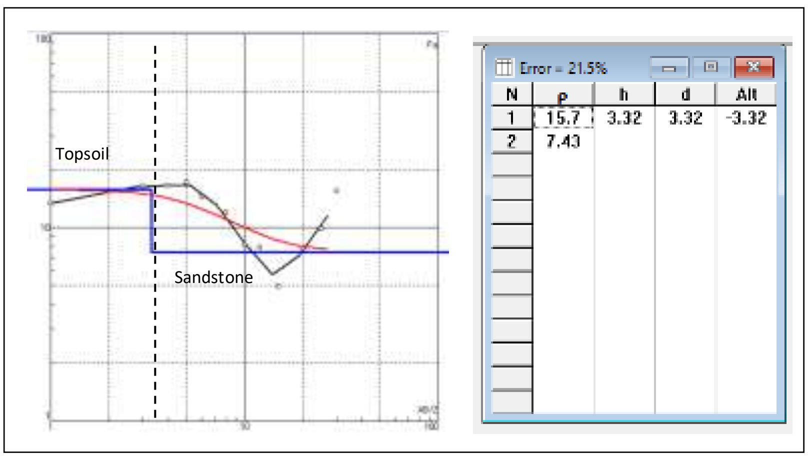

Figure 12. PB 5

From the Fig. 13 the top layer is interpreted to have a resistivity value 25.6 Ωm with depth is from 0 m – 1.02 m. At the second layer it is interpreted to have a value of 4.16 Ωm, depth of layer 1.02 m – 9.47 infinite. Third layer it is interpreted to have a value of 7.68 Ωm, depth of layer 9.47 - infinite. The first layer has a larger type of resistivity than the second layer. Dan third layer has a larger resistivitas larger than second layer.

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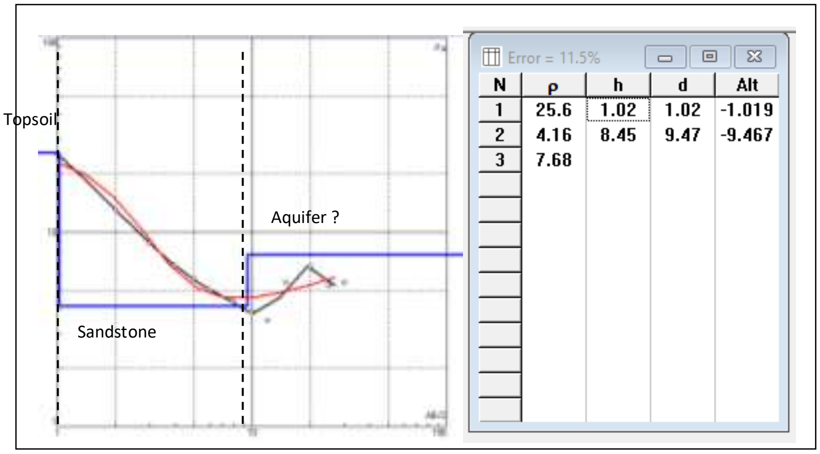

Figure 13. PB 6

From Fig. 14 the top layer is interpreted to have a resistivity value of type 47.6 Ωm with depth is from 0 m – 1.43 m. At the second layer it is interpreted to have a value of 16.5 Ωm, depth of layer 1.43 m - infinite. The upper layer has a relatively larger type of resistivity than the bottom layer.

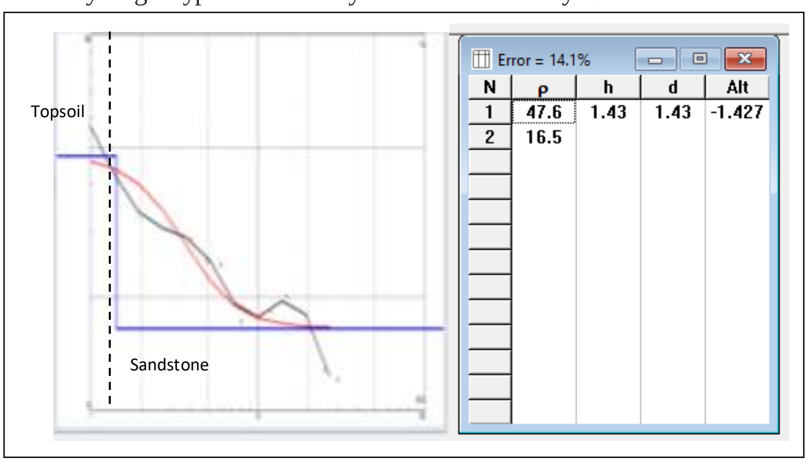

Figure 14. PB 7

Data from sounding profiles are then correlated with each other in the form of the fence diagram shown in (Fig. 15 and 16). Shows the relationship between topsoil layer thickness and slope from sounding profile interpretation data. Dark brown is interpreted as Soil layer thickness. The yellow color in the second layer is interpreted as Tuffaceus Sandstone.

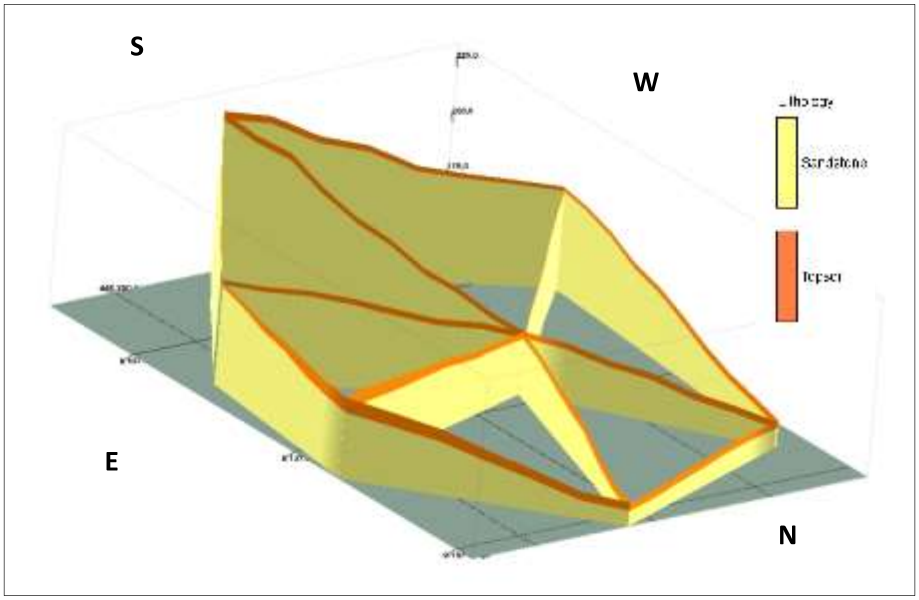

Figure 15. Fences Diagram shows correlation between profil sounding point.

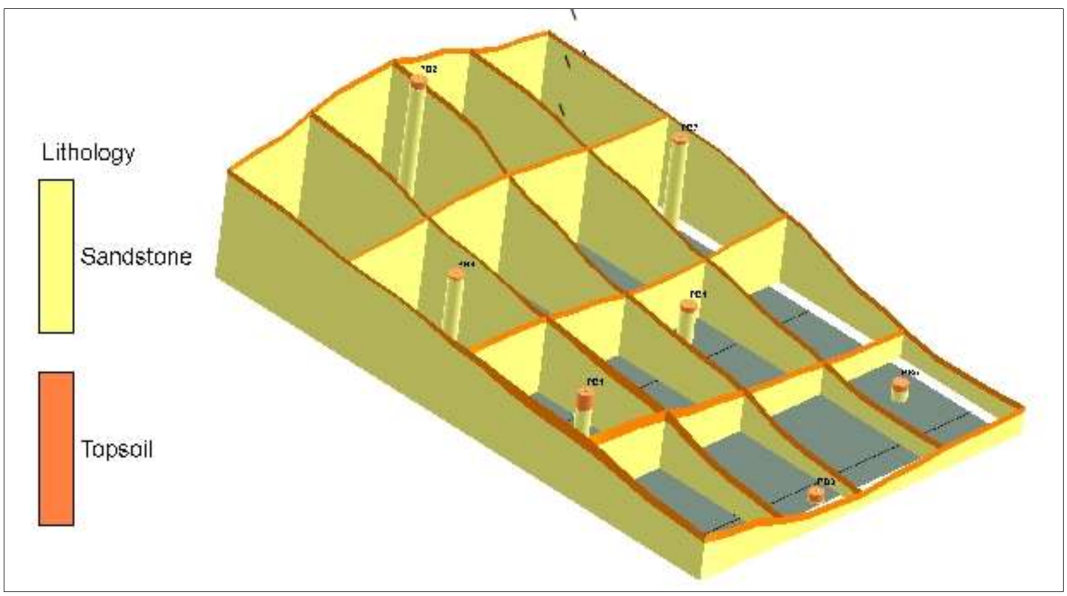

Figure 16. fences Diagram in grid section and sounding profil

Based on the results of the thickness of the Soil layer, number of Soil layer volumes is estimated. Volume calculation is limited to the surrounding area with sounding points. The formula used is the formula of the volume of the cube with the limit of length x width x height. The lenght value = 300 m, width = 220 m and the thickness is obtained through the sounding profile interpretation value (Table 2). The estimation result is that the Soil volume is 243,206 m3 shown in Fig. 17.

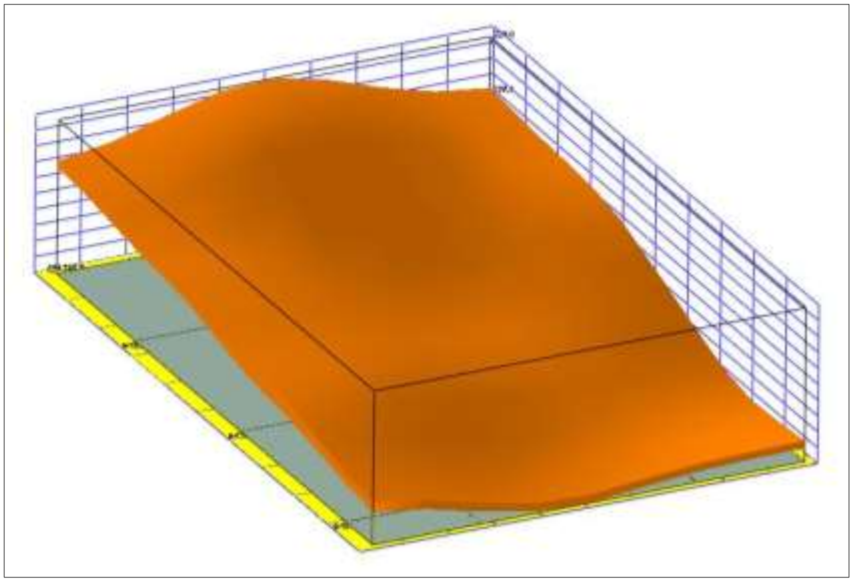

Figure 17. PB 6

Table 2: Interpretation Results

Station	Layer	Resistivity (Ω.m)	Contrast ratio of layer (0 = good ; 1 = poor)	Depth (m) from	to	Thickness	Geological Implication
PB 1	1	36,8	0,196	0	2,51	2,51	Soil
	2	7,23	ρ1>>ρ2	2,51	~	~	Tuffaceus sandstone
PB 2	1	25,9	0,358	0	3,69	3,69	Soil
	2	9,28	ρ1>>ρ2	3,69	~	~	Tuffaceus sandstone
PB 3	1	158	0,018	0	3,71	3,71	Soil
	2	2,87	ρ1>>ρ2	3,71	~	~	Tuffaceus sandstone
PB 4	1	2,81	0,004	0	7,19	7,19	Soil
	2	715	ρ1<<ρ2	7,19	~	~	Gravel sandstone
PB 5	1	15,7	0,473	0	3,32	3,32	Soil
	2	7,43	ρ1>>ρ2	3,32	~	~	Tuffaceus sandstone
PB 6	1	25,6	0,163	0	1,02	1,02	Soil
	2	4,16	ρ1>>ρ2	1,02	~	~	Tuffaceus sandstone
Pb 7	1	47,6	0,347	0	1,43	1,43	Soil
	2	16,5	ρ1>>ρ2	1,43	~	~	Tuffaceus sandstone

In addition to using the table value, the interpretation also takes into account the conditions and field conditions. Using resistivity table data and geological data is interpreted that the first layer is the soil layer. Seasonal measurements cause dry soil layers which cause the resistivity value in the first layer to be relatively larger compared to the second layer. This is because pores in soil are not filled with water. At the second slice it is interpreted as a compact rock as a layer of tuffaceus sandstone and gravel sandstone.

Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

In the second layer, the relative resistivity value is smaller because there is a tuff content in the sandstone, the tuff resistivity value has a small value as in shale [32]. In PB 4 there is a relatively smaller first layer value anomaly than in the second layer. Based on the PB 4 morphological analysis located on a hill. It is interpreted that the area is more resistant than other measurement points located in the morphology of the valley. Based on geological data and the second layer resistivity table on PB 4 is interpreted as Gravel sandstone

IV CONCLUSION

Interpretation created by using resistivity table and real conditions in the field. Based on interpretation from resistivity and geology value the first layer is soil. Measurements on dry season caused soil layers will be dried it make the resistivity value in the top layer to be relatively larger compared to the second layer. It caused pores in soil are not filled with water. At the second level it interpreted as a compact rock as a layer of tuffaceus sandstone and gravel sandstone.

The second layer, the resistivity value relative is smaller because there is a tuff content in the sandstone, the tuff resistivity value has a smaller value than in shale [32]. In PB 4 there is anomaly, first layer has smaller value resistivity than in the second layer. Based on the PB 4 morphological analysis located on a hill. It is interpreted that the area is more resistant than other measurement points that located in valley. Based on geological data and the second layer resistivity table on PB 4 is interpreted as Gravel sandstone. Based on result of Vertical Electrical Sounding measurement at the Prambanan area the minimum depth of the top layer is 1.02 and the maximum depth is 7.19 m. Average first layer depth at Prambanan location is 3.26 m.

Based on result of Vertical Electrical Sounding measurement at the Prambanan area the minimum depth of the top layer is 1.02 and the maximum depth is 7.19 m. Average first layer depth at Prambanan location is 3.26 m. The slip plane lies in the fresh rock as sandstone and gravel sandstone layer, at a average depth of 3.26 meters. This layer is a compact layer that can act as a slip field. Unlike the soil layers of the depth at 0 – 3.26 meters depth It is a weak layer during the rainy season so that it can become material and material carrier that will move to lower area.

V Acknowledgment

The authors would like to thanks Ministry Reseach and Higher Education, Universitas Pembangunan Nasional “Veteran” Yogyakarta for providing facilities and financial support under Competence Research Gran (PBK) No. 114/UN62.21/LT/IV/2018.

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