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Landslide investigation using self potential method and electrical resistivity tomography (Pasanggrahan, South Sumedang, Indonesia)

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Abstract. Landslide is a geological event that occurs because the movement of slope-forming material in the form of soil, rock or combination of material type to a lower place due to the influence of gravity. The trigger factor of landslide in Pasanggrahan, South Sumedang, Indonesia is the increase of water content in the slope and the slip plane. The slip plane began to actively to turn on when the rainy season arrives. The infiltration of rainwater into slopes as an avalanche trigger can be detected by Self Potential (SP) method. SP measurements were performed to determine changes in subsurface water flow. SP data acquisition using fixed base technique and leap frog technique. The rocks in the research area that serve as the slip plane are clays associated with Volcanic Breccia. One of the geophysical methods that can identify the slip plane is the Electrical Resistivity Tomography Method. The ERT method can detect slip plane based on rock resistivity. Based on the local geology that has been correlated with the value of Self Potential and Electrical Resistivity Tomography, the following results are obtained: water table : (1 - 13) Ohm.m and SP value : (16 - 50) mV, clay : (72 - 100) Ohm.m and volcanic breccia: (171 - 550) Ohm.m.

1. Introduction

Pasanggrahan area, South Sumedang Subdistrict, Indonesia is included in Cadas Pangeran Lane is an area prone to landslides. In September 2016 there was occured landslide in this area and until now the movement of the land is still active. Based on Geological Map of Bandung [1], the rocks of the study area consist of: volcanic breccias and lava flows arranged andesite - basalt (old volcanic breccia, Qvb), volcanic lava showing tectonic joint structure and columnar joint structure from old volcano (Qvl), tuffs sand, breccia, lava and agglomerates that are partly derived from Mt.Tangkubanparahu and Mt.Tampomas (Qyu).

Movement of land that occurred in the form of landslide of material on the cliff above the body of the road with a very steep slope. The horseshoe-shaped landslide crown extends from north-south and west-east. This ground movement began to actively move triggered by rain water. Water-saturated soil will reduce the soil bond strength, so that the soil becomes unstable and eventually landslides. Landslide is a geological phenomenon that occurs because the movement of slope-forming material

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such as soil, rock or combination of material type to a lower place due to the influence of gravity force [2], and to obtain a new equilibrium due to the influence of outside interference resulting in a reduction in shear strength and increase in soil shear stress [3,4].

Factors triggering the occurrence of landslides or movement of the land that is high rainfall, slope angle, soil moisture change, land cover [5], and rock that serves as the slip plane. Water that seeps into the soil if below there are impermeable underlying rocks, the layer will experience water saturation and soil binding becomes reduced, so the soil becomes unstable and there is movement of the soil / landslide. The slip plane is a stable plane found in impermeable rocks, if there is a solid material above the plane such as rocks or infrastructure, then the material will be derailed and move in the direction of the slope.

The landslide investigation has been carried out by applying various study methods. Several methods in study landslide problems such as : electrical resistivity tomography method to identify the slip plane [6,7,8], geotechnical methods for predicting slope stability [9,10,11], and self potential method to determine the flow of groundwater of landslides [12] as well as obtaining its hydrological pattern [13]. Several landslide studies have been conducted with several data combinations, such as : a combination of geotechnical data and electrical resistivity tomography [14], a combination of self potential and microtremor data [15].

A landslide investigation with a combination of unified data self potential (SP) and electrical resistivity tomography (ERT) has never been done. SP method is one of the Geoelectric Method very cheap and fast measurement. The SP method is used to determine water table zone associated with the slip plane and determine the landslide plane. The ERT method is used to identify lateraly-verticaly rock move, determining the water table and determining the slip plane.

2. Methods

The landslide investigation in the study area using Self Potential Method (fixed base and leap-frog method) and Electrical Resistivity Tomography (ERT) Method. Selection of ERT and SP Methods in this study, based on the consideration that rocks on the slip plane have contrast of a resistivity and self potential to surrounding rocks, such as sand, breccias, clay and other rock types.

2.1 Self Potential (SP)

The Self potential (SP) method is a passive method, because the measurements are performed without injecting the electric current to the soil surface, the natural potential difference of the soil is measured through two points on the ground surface. Measurable potentials range from several millivolts (mV) to 1 volt. Self potential is triggered by the flow of water in a porous medium called electrokinetic potential.

Groundwater flow is normally formulated by Darcy's Law, as follows:

$$\frac{Q}{A} - \frac{k}{\zeta}\nabla \mathrm{P} = -\frac{k\rho g}{\eta}\nabla H = -K\nabla H \quad (1)$$

where Q: flow discharge (volume / time), A: cross-sectional area, k: intrinsic permeability, and K: hydraulic conductivity. $\frac{Q}{A}$ = v is the speed of darcy in cm / s.

SP Anomaly if associated with Darcy's law (equation 1), we will obtain the following equation :

$$v = K\nabla H = \frac{K}{C}\nabla V \quad (2)$$

where v is the flow velocity of the water (LT^{-1}), k : intrinsic permeability, (L^2), K : hydraulic conductive (cm/det), η : viscosity of fluid ($ML^{-1}T^{-1}$), C : coefficient of electrohydraulic potential (mV/cm), ∇V : electrokinetic potential gradient ($MLI^{-1}T^{-3}$).

Equation (2) explain the relation of fluid flow velocity with an electrokinetic potential or SP anomaly in the medium. Based on these relations, the flow velocity is directly proportional to the magnitude of SP. If the velocity of penetration of water in the soil is higher then the potential response on the surface will be higher also.

Acquisition of self potential data using leap frog method and fixed base. In the Leap-Frog Method, the two electrodes move for each measurement. The measurement scheme with the Leap-Frog Method is shown in Figure 1.a. Other methods used in SP data acquisition are Fixed Base Method. In this method one of the electrodes is at a fixed point (reference point), while the other electrode moves away from the reference point for each measurement. Self potential measurement scheme using Fixed Base Method is shown in Figure 1.b. The length of the SP measurement line is 234 m, while the distance between the electrodes is 6 m.

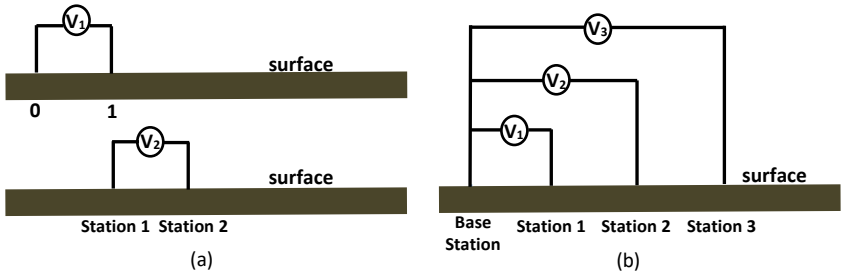

Figure 1. SP Configuration : a. Leap-Frog Method, b. Fixed-Base Method

The equipment used in self potential measurement consists of: one digital Multimeter Fluxegate, two pouros pots, two cable rollers and one global positioning system. Porous pots are copper electrodes installed in a saturated (copper sulfate / CuSO4) solution in a porous place.

2.2 Electrical Resistivity Tomography (ERT)

The ERT method is a method of measuring ground surface resistivity using many electrodes, in order to obtain variations of resistivity distribution in the sub-surface [16]. In this study the length of the measurement line of ERT is 234 m, the distance between electrode 6 m and the number of electrode 41. The measurement scheme of Electrical Resistivity Tomography (ERT) is shown in Figure 2.

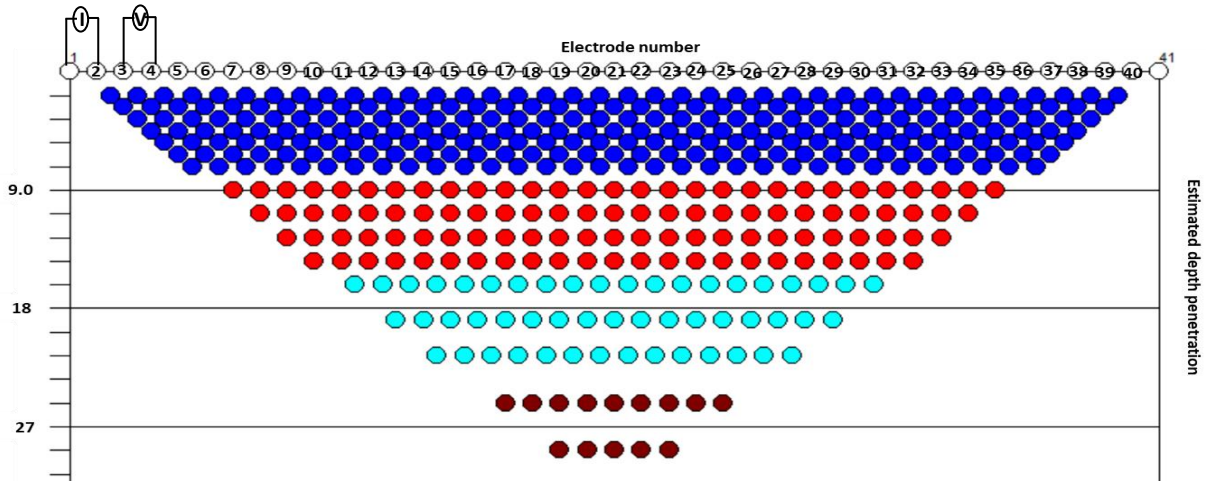

Figure 2. Resistivity measurement scheme with Electrical Resistivity Tomography (ERT) method, Dipole-Dipole configuration, I : current electrode, V : potential electrode

The resistivity value obtained in the ERT Method is calculated by the equation below :

$$\rho_s = K\frac{\Delta V}{I} \tag{3}$$

Geometric factor used in ERT measurement using dipole-dipole configuration, the equation as follows:

$$K = n(n+1)(n+2)\pi a \tag{4}$$

Substituting equation (4) into equation (3), obtained the apparent resistivity equation as follows :

$$\rho_s = n(n+1)(n+2)\pi a \frac{\Delta V}{I} \tag{5}$$

ρ_s is apparent resistivity in Ohm.m, ΔV is potential difference in V, I is injected current in A, and a is distance between current and potential pairs of electrode in m.

Equipment used in ERT measurement consist of : Resistivity Meter of Naniura Multielectrodes NRD 300 Hf, switchbox, electrodes, global positioning system, total station, handy talky, and laptop. The raw data obtained in the ERT measurement is stored in the *.dat format, this raw data is still a apparent resistivity value. To obtain the actual resistivity value is done resistivity modeling with Inversion Method.

3. Results and Discussion

Figure 3 shows the geomorphology of the study area. Geomorphologically this area of research is a ridge with a slope of slope > 50° and altitude (550 - 700) m above sea level. Landslide occurred in hilly areas [17], and affected landforms and caused infrastructure damage [18,19].

The results obtained in this study consisted of : SP section with Fixed Base method (1 section), ERT section (1 section) and one SP map with Leap-Frog Method (0 - 6) m. The position of the SP and ERT measurement line is shown in Figure 4.

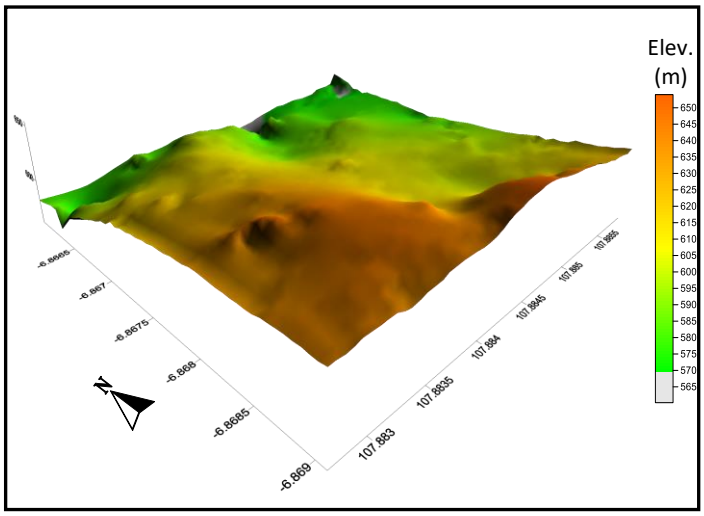

Figure 3. Geomorphology of Pasanggrahan region, South Sumedang, West Java, Indonesia

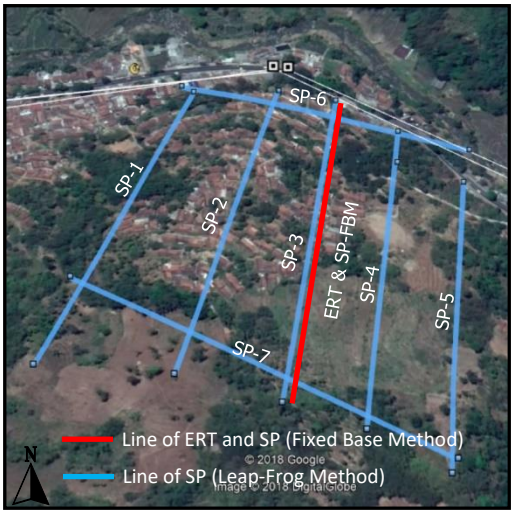

Figure 4. Map of SP and ERT measurement line

Based on ERT data modeling and SP data, SP and ERT values obtained for the slip plane, landslide and groundwater fields are shown in Table 1.

Table 1. Value of resistivity and self-potential of the study area

Lithology	Resistivity ERT (*Ohm.m*)	Self Potential (*mV*)	Hidrology
Rough sands	1 – 13	> 16	Water table
Tuffs sand	72 – 170	14 – 16	Water table
Clay	72 – 100	15	-
Breccia	171 – 550	1 – 12	-

The Electrical Resistivity Tomography (ERT) section with depths up to 34 m is shown in Figure 5. The indication of the slip plane in this section is very clear, this can be seen from the contrast of its rock resistivity. At the bottom layer there is a high resistivity with a value of : (170 - 400) Ohm.m which is indicated Breccia, while above there is a thin layer with value : (72 - 100) Ohm.m which indicated as Claystone. The clay associated with Breccia is indicated as the plane of Slip because it is impermeable.

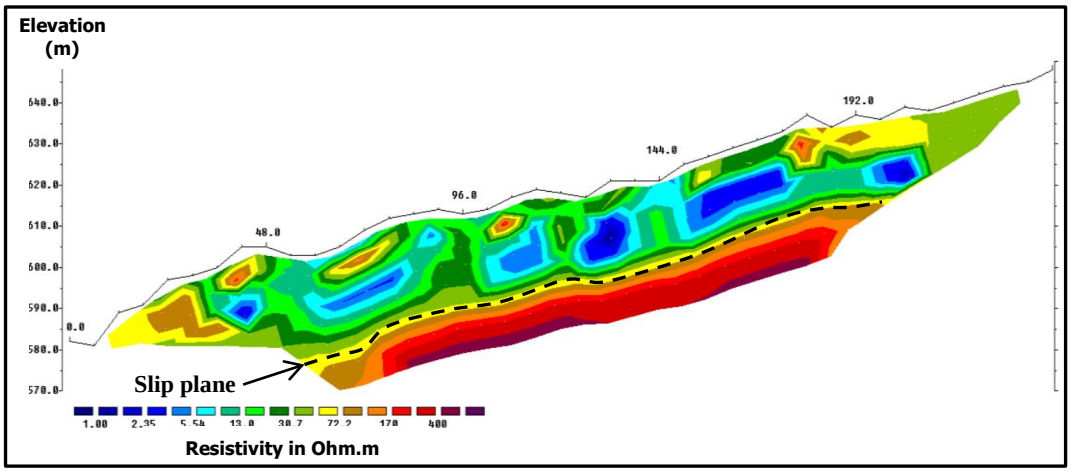

Figure 5. The higher resolution ERT section (depth: 34m), with the same line position as the SP line (Fixed Base Method)

In the top layer of the slip plane there is a low resistivity of < 13 Ohm.m indicated as the water table that flows in the direction of the slope. The existence of Claystone that serves as a plane of slip causes this rainwater can not seep into the layer below again, so the water will rise to the surface and reduce the strength of the soil, consequently there was movement of soil / landslide. Lens patterns with values: (72 - 170) Ohm.m indicates loose rock material or indicates rocks that are shifting / slides.

In Figure 6a. displayed SP Section with Fixed Base Method. At distances : 15 m, 70 m, 100 m, 165 m, 190 m, 210 m and 230 m there is a lens pattern near the surface with a value of < 12 mV, which indicates a solid layer consisting of tuff sand and shifting breccia . This rock shift occurs because the soil / rock is reduced due to the influence of the water saturated layer. Self potential is high with the value: (16 - 44) mV is indicated as a water table coming from rainwater seeping into the soil through a rock fracture structure on the surface and flowing from the top of the cliff to the slope.

In Figure 6b. Displayed The ERT section with the same measurement line position as the ERT section in Figure 5, but the resolution is lower (depth: $\pm$ 20 m). At a distance of : 18 m, 48 m, 72 m, 118 m, 156 m and 192 m there is a lens pattern with values: (72 - 170) Ohm.m which is indicated as tuff sand and breccia with values: (171 - 400) Ohm.m. Lens pattern is indicated as a rock that has shifted because the material is loose (previously massive). Indication of the fracture structure is located at distances: 60 m, 102 m, and 144 m. The existence of this fracture structure facilitates the infiltration of rainwater into the soil. At the lowermost layer there is a water table with resistivity value: (1 - 13) Ohm.m.

In general, the pattern of SP anomaly and ERT anomaly have almost the same pattern, such as : lens pattern of the lens near the surface (SP < 16 mV and ERT : 171 - 400 Ohm.m) indicating the material of solid (rock) that is loose, indicating the soil movement, while in the bottom layer there is an almost massive pattern indicating water table and water infiltration (SP > 16 mV and ERT : 1 - 13 Ohm.m).

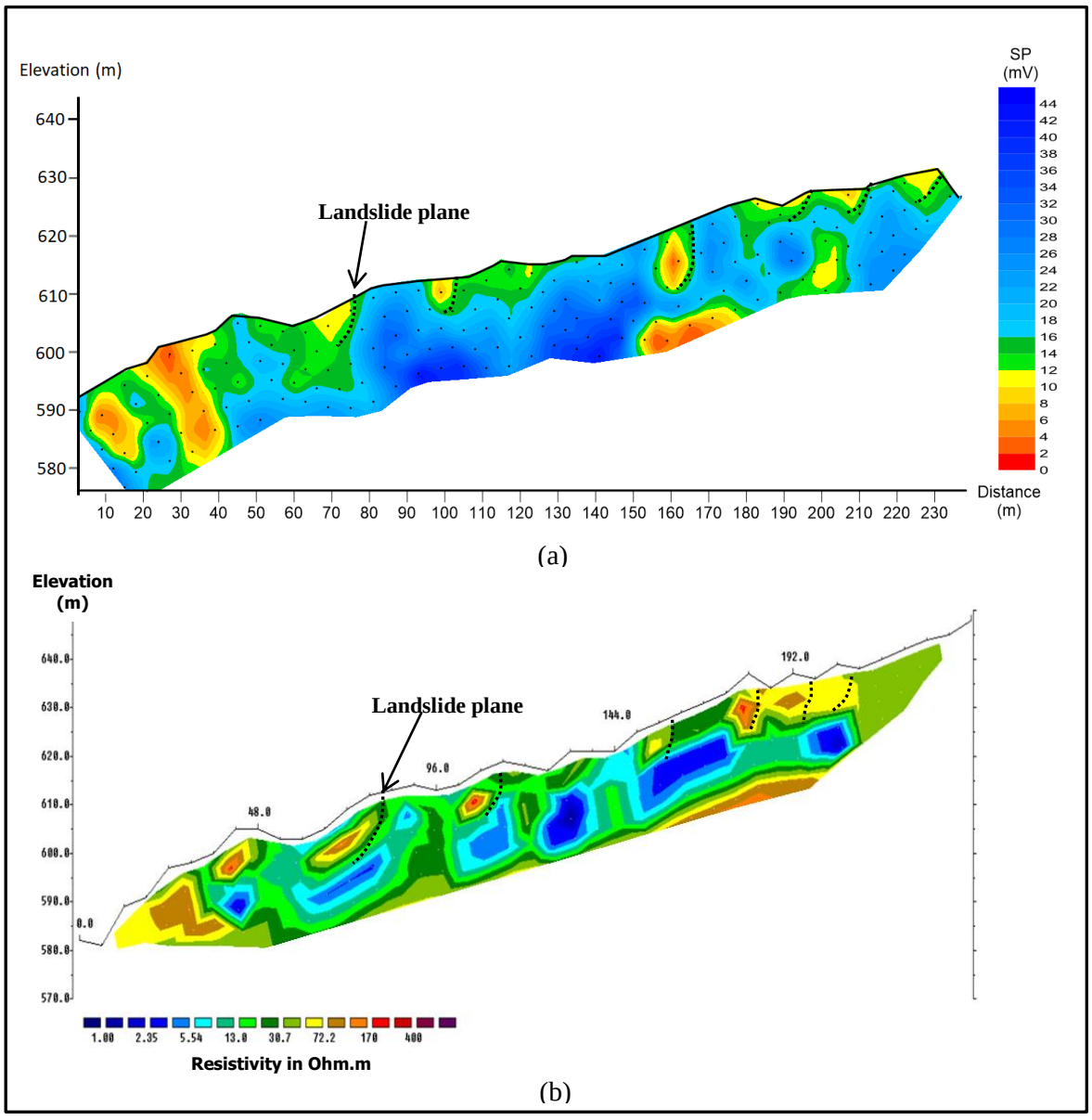

Figure 6. (**a)** Section SP (Fixed Base Method) with resolution almost the same to ERT Section, (**b)** Section of ERT with same line position and similar resolution (depth: 25m) with SP section (Fixed Base Method)

In Figure 7 displays a Self Potential Map (0 - 6 m). SP Anomaly with high value : (16 - 44) mV is located in the west in the South-North direction, which is indicated as weak zone because it is water table zone with high rainfall seepage rate so it has high SP value. The rain water seepage in the West occurs due to several factors, such as : the number of the fracture structure which is the entry of rain water into the soil and the existence of claystone that is impermeable, so that when the layer is saturated water then the water will rise to the surface and spread laterally and down the slope. Water table zone with high SP values > 16 mV indicate indirectly that the location is indicative of the slip

plane because there is an impermeable so that the layer becomes water saturated and has a high landslide risk.

A low SP value < 16 mV in the east indicates that the area is more solid than in the west. Smaller SP values in the East can be attributed to several factors, such as : fewer fracture structures, so the infiltration process is slow, indicated by the water table and the slip plane rocks in the deeper location than in the West.

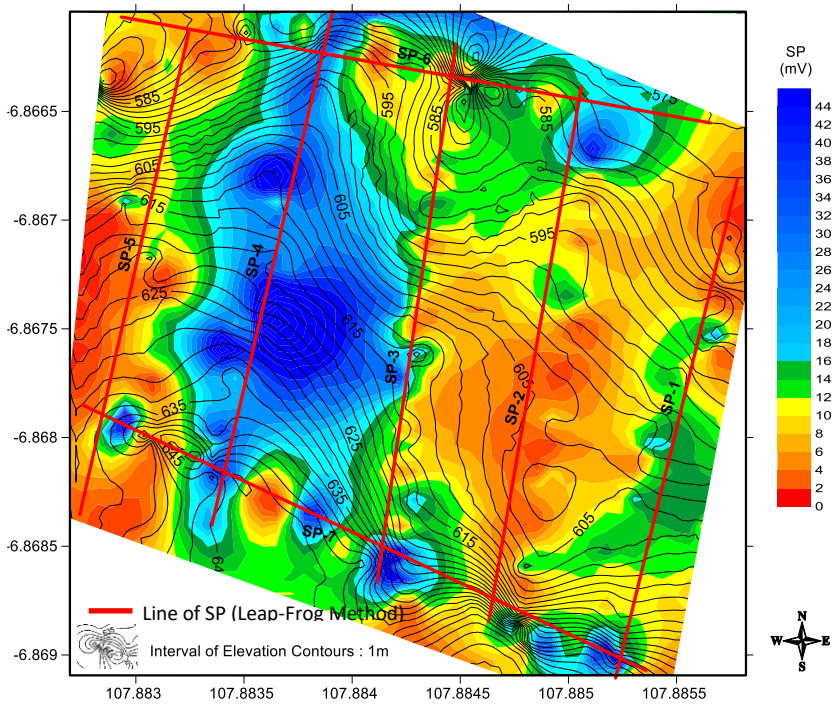

Figure 7. Self potential map (0 - 6 m), Pasanggrahan region, South Sumedang, Indonesia

4. Conclusion

If the ERT measurement has the same resolution as the SP (Leap-Frog Method) measurement, an almost identical pattern of anomalies will be obtained, such as the lens pattern near the surface with resistivity values : (72 – 550) Ohm.m and SP < 16 mV. The lens pattern indicates a rock shift. In the high resolution ERT section (depth : 34 m) indication of slip plane at a depth of $\pm$ 20 m with lithology is clay (resistivity: 72 - 100 Ohm.m) associated with Volcanic Breccia (resistivity : 171 - 550 Ohm). In the SP Map (0 - 6m), Anomaly with high value: (16 - 44) mV is in the West, with North-South pattern indicated as water table distribution. The distribution of the water table implies that there is an indication of the slip plane.

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References

[1] P H Silitonga 1973 *Geological Map of Sheet of Bandung Java* Geological Research and Development Center
[2] Chowdhury R N 1978 *Slope Analysis* Elsevier Amsterdam
[3] Sassa K and Canuti P 2009 *Landslides Disaster Risk Reduction* Springer-Verlag Berlin Heidelberg
[4] Malamud B D, Turcotte D L, Guzzetti F and Reichenbach P 2004 Landslide Inventories and Their Statistical Properties *Journal of Earth Surface Processes and Landforms* **29** (6) 687–711
[5] Varnes D J 1978 *Slope Movement Types and Processes In : Special Report 176: Landslides: Analysis and Control* Transportation and Road Research Board National Academy of Science Washington D C.
[6] Stefan Carpentier, Markus Konz, Ria Fischer, Grigorios Anagnostopoulos, Katrin Meusburger and Konrad Schoeck 2012 Geophysical imaging of shallow subsurface topography and its implication for shallow landslide susceptibility in the Urseren Valley Switzerland *Journal of Applied Geophysics* **83** p46-56
[7] J Gance, J P Malet, R Supper, P Sailhac, D Ottowitz and B Jochum 2016 Permanent electrical resistivity measurements for monitoring water circulation in clayey landslides *Journal of Applied Geophysics* **126** p98-115
[8] Sebastian Uhlemann, Paul B Wilkinson, Jonathan E Chambers, Hansruedi Maurer, Andrew J Merritt, David A Gunn and Philip I Meldrum 2015 *Journal of Applied Geophysics* **121** p93-105
[9] Takashi Tsucida, A.M.R.G. Athapaththu, Shouichi Kawabata, Seiji Kano, Takashi Hanaoka and Atsuki Yuri 2014 Individual landslide hazard assessment of natural valleys and slopes base on geotechnical investigation and analysis 2014 *J. Soil and Foundation* **54** (4) p806-819
[10] Yueping Yin, Bin Li, Wenpei Wang, Liangtong Zhan, Qiang Xue, Yang Gao, Nan Zhang, Hongqi Chen, Tiankui Liu and Aiguo Li 2016 Mechanism of the December 2015 Catastrophic Landslide at the Shenzhen Landfill and Controlling Geotechnical Risks of Urbanization *J. Engineering* **2** p230-249
[11] Giovanni Gulla, Luigi Aceto, Loredana Antronico, Luigi Borrelli, Roberto Coscarelli and Francesco Perri 2018 A smart geotechnical model in emergency conditions : A case study of a medium-deep landslide in Southern Italy *J. Engineering Geology* **234** p138-152
[12] G Colangelo, V Lapenna, A Perrone, S Piscitelli and L Telesca 2D Self-Potential tomographies for studying groundwater flows in the Varco d;Izzo landslide (Basilicata, southern Italy) *J.Engineering Geology* **88** p274-286
[13] M Bordoni, C Meisina, R Valentino, N Lu, M Bittelli and S Chersich 2015 Hydrological factors affecting rainfall-induced shallow landslides : From the field monitoring to a simplified slope stability analysis *J.Engineering Geology* **193** p19-37
[14] Inger-Lise Solberg, Michael Long, Vikas Chand Baranwal, Anders Samstad Gylland and Jan Steinar Ronning 2016 Geophysical and geotechnical studies of geology and sediment properties at a quick-clay landslide site at Esp, Trondheim, Norway *J.Engineering Geology* **208** p214-230
[15] Fawu Wang, Austin Chukwueloka-Udechukwu Okeke, Tetsuya Kogure, Tetsuya Sakai, Hisao Hayashi 2018 Assessing the internal structure of landslide dams subject to possible piping erosion by means of microtremor chain array and self-potential surveys *J.Engineering Geology* **234** 11-26
[16] William Daily, Abelardo Ramirez, Andrew Binley and Douglas LeBrecque 2004 Electrical resistance tomography *J.The Leading Edge* **23** 5
[17] Bell R, Petschko, H Röhrs M and Dix A 2012 Assessment of Landslide Age, Landslide Persistence and Human Impact Using Airborne 4. Laser Scanning Digital Terrain Models. *Geografiska Annaler: Series A Physical Geography* **94** (1), 135-156.
[18] Crozier M J 2010 Landslide Geomorphology: An Argument for Recognition, With Examples from New Zealand. *J.Geomorphology* **120** (1-2) p3–15
[19] Korup O, Densmore A L and Schlunegger F 2010 The Role of Landslides in Mountain Range Evolution *J.Geomorphology* **120** (1-2) p77–90