Identification of Underground River Flow in Karst Area of Sumber Bening-Malang, Indonesia Based on Geoelectrical Self-Potential and Resistivity Data

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Abstract

Research has been conducted on karst area in Sumber Bening Malang, Indonesia. The research objective is to find out the underground river flow. Data acquisition was carried out using two types of geophysics method, namely the self-potential method and the resistivity method of dipole-dipole configuration. In the self-potential method, data acquisition is carried out as many as 176 points where each point is measured five times with the distance between points is 10 m. In the resistivity method of dipole-dipole configuration, data acquisition was carried out as much as 6 lines. Based on the results of measurement and data processing, the electrical potential value detected in the study location was around 0-14 mV and low potential values (0-1.5 mV) indicated as underground river flow. The resistivity value in the research location is in the range of 1-22800 Ωm, which value 1-221 Ωm interpreted as sandy marl and 222-22800 Ωm as carbonate. The results of self-potential and resistivity interpretations show underground river flow found beneath carbonate rock layers and from there it can be suspected that fluid flows from the northeast to the southwest of the study site.

Keywords: *Karst area, Underground river flow, Self-potential, Resistivity.*

I. INTRODUCTION

Indonesia has a very diverse natural resource potential, one of the landscapes which have the potential and strategic value is the karst region. Karst is the result of the rock dissolution which contains $CaCO_3$. Higher the content of $CaCO_3$ in the rock, the development of karst is more blooming. The dissolving process results in brittle rock structures, rock cavities, and irregular distribution. Karst areas generally experience dryness, thus very difficult to find water in this area [1,2].

The South Malang region, especially the Sumber Bening village, belongs to karst geomorphology. The natural landscapes seen from the surface in the study area consists of limestone and caves so that in the dry season the region experiences dryness and the lake in this area also dries out. In the dry season, people in this area experience difficulty getting water to meet their daily needs.

Geoelectricity is one of the methods in geophysics that studies the nature of electrical flow inside the earth by means of subsurface detection including measurement of potential, current, and electromagnetic fields that occur both naturally and due to injection of current into the earth. This method generally used for natural resource exploration. Natural electrical properties caused by ions differences in the subsurface, leading to oxidation and reduction reaction bound by the water table. This phenomenon can be found too in sulfide mineral. The geoelectrical method based on this property was called self-potential [3].

The resistivity method of dipole-dipole configuration is one option that can be used to identify the depth of underground river flow in the karst region. Identification of underground river flow in the study area using resistivity method dipole-dipole configuration still requires supporting data to determine the direction and flow the underground river in the study area, therefore the self-potential (SP) method is considered very appropriate in providing distribution about the direction and flow of subsurface water. Both of these methods have been widely used and show good correlation in various regions including [2,4,5,6]. It is expected that the correlation between these two methods can provide a good understanding of the study area.

II. MATERIALS METHODS

The acquisition was carried out in Sumber Bening, Bantur District, Malang Regency, Indonesia, which located at 8.3-8.41 South Latitude and between 112.5 degrees-112.57 degrees East Longitude geographically. Based on the geological map of the Turen sheet [7] as in figure 1, the location of the study belongs to the Wonosari formation and Nampol formation. The Wonosari Formation is composed of limestone, sandy marl, and claystone insertions while the Nampol formation is composed of tuffaceous, black claystone, sandy marl, and sandstone.

In this study, two methods are used that is geoelectricity resistivity and self-potential, which are carried out in accordance with the survey design shown in figure 2. The area of the study is 500 m^2.

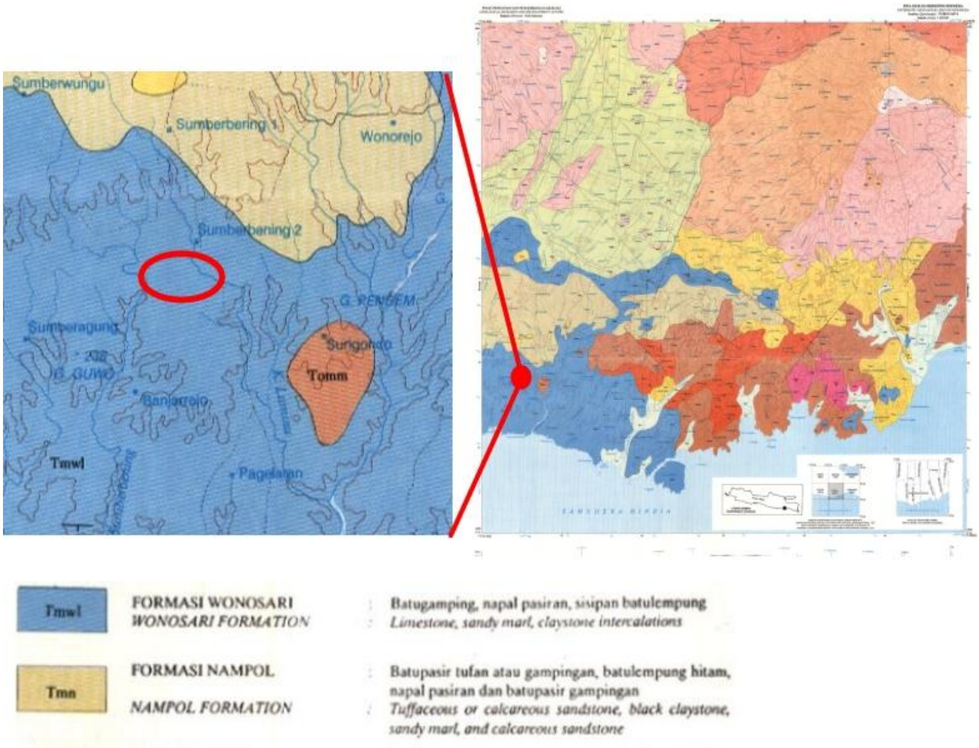

Fig 1: Turen Geological map sheet [7]

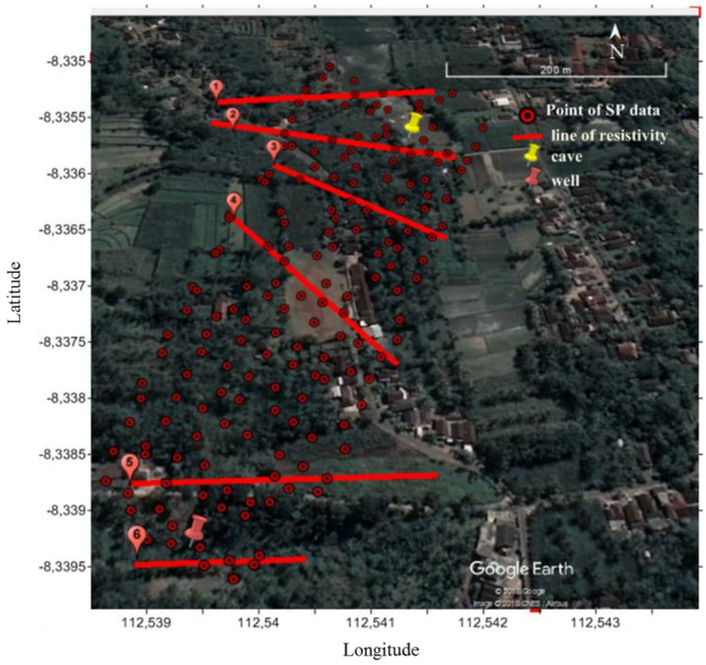

Fig 2: Geoelectrical resistivity and self-potential research survey design

A. *Data Acquisition Self-potential*

Self-potential measurement conducted with the distance between the porous pot is 10 m. Measurements were performed using electrodes that consist of copper wire dipped in the CuSO4 solution in 2 porous pots with the same solution concentration. Measured potential data then was corrected using calibration correction. The correction results are plotted in the Surfer 10 software [13] to get an isopotential contour map. Afterward, based on the isopotential map, it can be used to interpret the direction of underground river flow at the study site [8].

B. *Resistivity Geoelectric Data Acquisition*

In geoelectrical resistivity measurements, 6 lines dipole-dipole configuration [11] was used with each line consisting of 100-200 m with spaces "a" between 5 and 10 m. Line 1 has a length of 200 m with an electrode spacing of 10 m, line 2 has a line length of 200 m with an electrode spacing of 10 m, line 3 has a line length of 160 m with an electrode spacing of 10 m, line 4 has a line length of 200 m with an electrode spacing of 10 m, line 5 has a line length of 200 m with an electrode spacing of 10 m, line 6 has a line length of 100 m and an electrode spacing of 5 m. Measurements were made using the McOHM-EL resistivity meter.

Data measurement in the field was obtained in the form of the current and potential electrode positions, potential (V) data, and current (I) data. These parameters are prepared for the data processing stage. Data processing steps aim to determine the apparent resistivity value. After apparent resistivity value was obtained, then the inversion process was done using the RES2DINV software [12]. This 2D method inversion process was carried out with the least squares method to eliminate restricted geometric effects. The final result of this inversion was 2D cross-sectional model with actual resistivity value and depth variation [2].

III. RESULTS AND DISCUSSION

Measurement of self-potential and resistivity methods has been carried out in the karst area of Sumber Bening village, Malang, Indonesia. Corrected potential data is then processed to get an isopotential contour map which contains self-potential value distribution pattern in the measurement area (figure 3). Potential values that exist in the study area scales from 0 mV-14 mV which made three potential values that are low (0 mV-5 mV), moderate (6 mV-10 mV) and high (11 mV-14 mV). Based on research conducted by [2] low potential values can be indicated as water. Moreover, on the interpretation of the isopotential contour map, the potential value of 0 mV to 1.5 mV marked in black and blue as an indication of groundwater flow.

The results of the interpretation of the actual resistivity value for all measurement line extend from 1-22800 Ωm. Furthermore, the correlation of the corresponding geological map sheet [7] with the resistivity value obtained, it was assumed that the type of rock layer in the study area is listed in table 1.

TABLE I
Classification of rock types from measurements

Number	Resistivity value (Ωm)	Type of Rock
1	1-221	Sandy marl
2	222-22800	The carbonate rock /limestone

Contour map self-potential value distribution pattern in the measurement area at all points of measurement in the study area was shown in the following pictures.

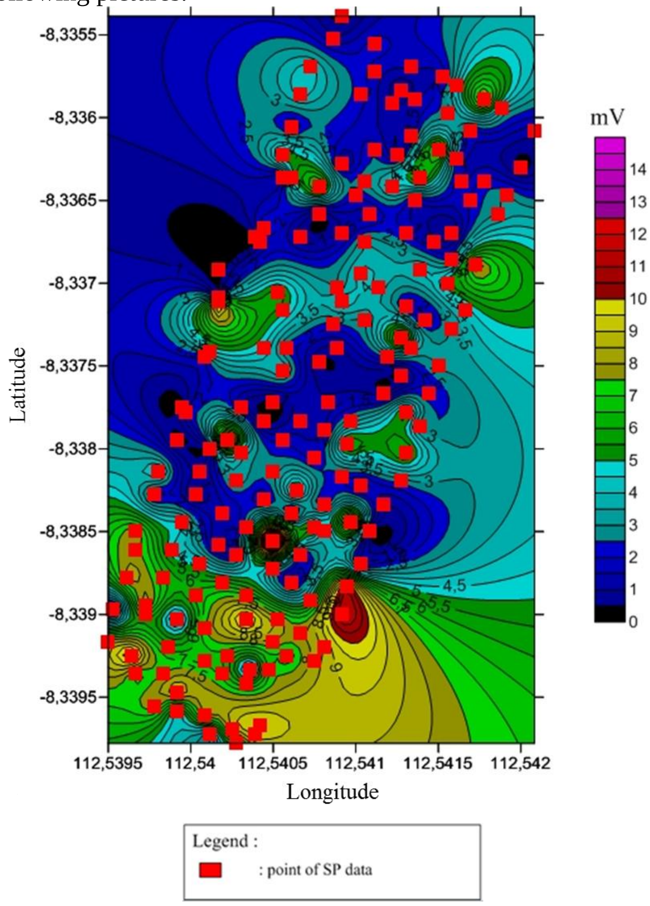

Fig 3: Map contour of potential value

2D cross-sectional resistivity values at all measurement points in the study area are shown in the following pictures (figure 4, figure 5, figure 6, figure 7, figure 8, and figure 9).

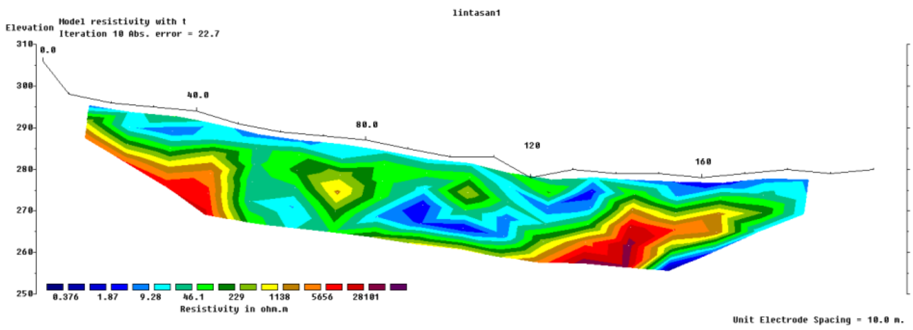

Fig 4: Subsurface resistivity 2D cross-section of line 1

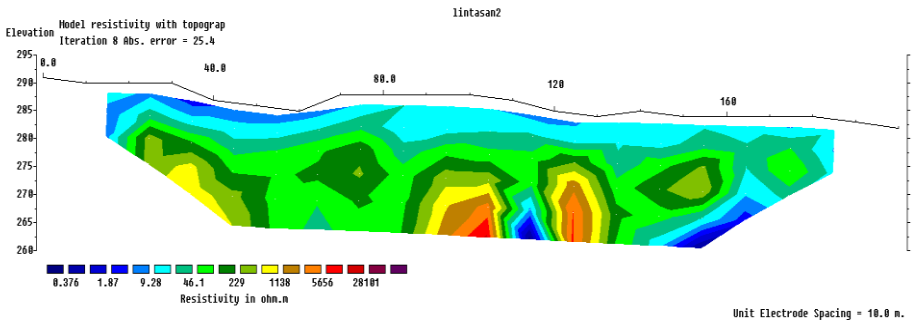

Fig 5: Subsurface resistivity 2D cross-section of line 2

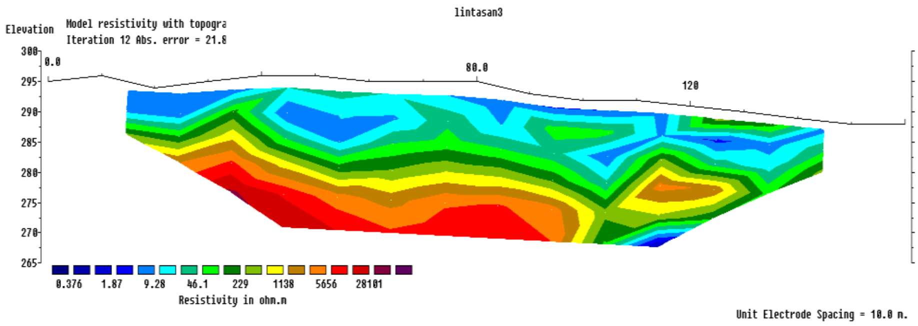

Figure 6: Subsurface resistivity 2D cross-section of line 3

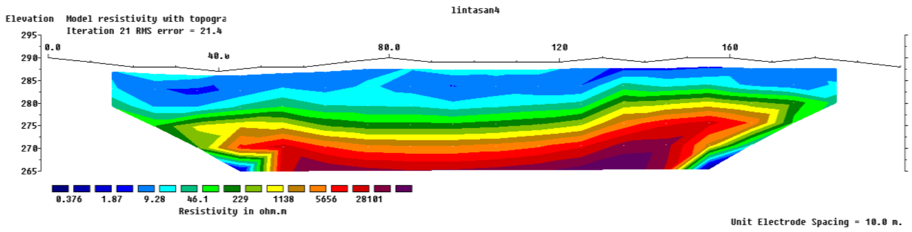

Figure 7: Subsurface resistivity 2D cross-section of line 4

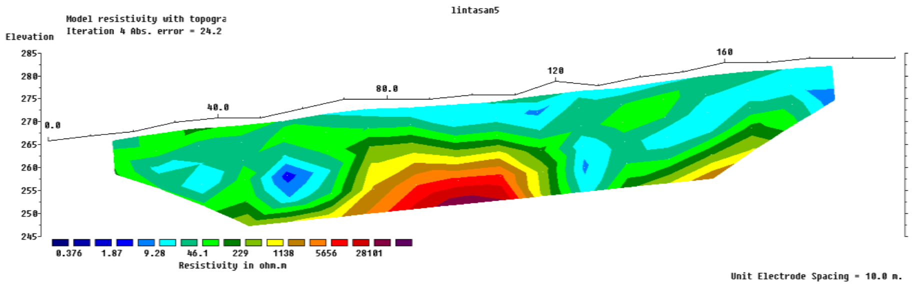

Figure 8: Subsurface resistivity 2D cross-section of line 5

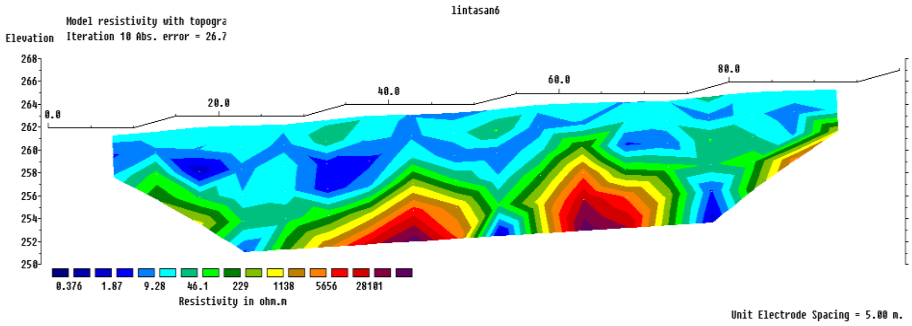

Figure 9: Subsurface resistivity 2D cross-section of line 6

Based on figure 4 (line 1) top layer with resistivity values ranging from 1-137 Ωm was a layer of sandy marl with a depth of ± 6 m.

At the certain measurement point, this layer has a varying thickness in the stretch of 50-70 m sandy marl rock which has a depth of ± 23.6 m. The carbonate rocks in this line are in the beneath of sandy marl layer with resistivity values varying from 539-8300 Ωm. This layer begins to be found at a depth of ± 7 m, on a stretch of 20-50 m and 90-170 m and in some points, the carbonate rock layer is shaped like pockets, in the of 70-80 m and 100-110 m point.

Based on figure 5 (line 2), it shows that top soil is sandy marl rock with resistivity values ranging from 1-221 Ωm. Sandy marl at a measurement point of 110 m was found at a depth of 20 m and almost dominated on this line. The Carbonate rock with resistivity values of 793-2840 Ωm are only found at some points that look like pockets, ie at a stretch of 30-50 m, with a depth of 14-23 m and a stretch of 90-100 m with a depth of 13.26-23.6 m and on a 120-130 m stretch with a depth of 10-23.6 m.

Based on figure 6 (line 3), top soil layer is sandy marl with a range of resistivity values of 1-135 Ωm which also dominates this line. The carbonate rock with resistivity values of 488-6405 Ωm are found along a stretch of 20-100 with a depth of 9.25-23.6 m and then establish a structure that is mixed with sandy marl rock and looks like pockets on a stretch of 100-130 m.

Based on figure 7 (line4), the top soil layer is sandy marl rock with a resistivity value of 1-213 Ωm. The carbonate rock with a resistivity value of 1013-22810 Ωm in this line is seen at a depth of 13.6-23.6 m in the 30-170 m stretch. The Carbonate rock on the trajectory forms a structure that is homogeneous and not filled or mixed with other rocks.

Based on figure 8 (line 5), the top soil layer is sandy marl with a resistivity value of 3.66-119 Ωm and at some case reaching a depth of 23.6 m. The carbonate rock with a resistivity value of 378-12257 Ωm is seen in a extent of 40-110 m and 140-160 m.

Based on figure 9 (line 6), top soil layer is sandy marl rock with resistivity values of 1-78 Ωm and almost dominates on this trajectory. The Carbonate rock in this line is found at several points with a resistivity value of 222-17680 Ωm and form like pockets.

Based on the 2D cross-sectional results, the top layer or cap layer on all measuring line is a rock of sandy marl layer while the second layer is the carbonate rock layer. In general, layers or rock structures in the study area constitute one unit or a continuous structure, as seen in line 3 and 4. However, in another line, the carbonate rock and sandy marl rock are found to mix or form pockets at certain depths. The phenomenon of differences in the depth of carbonate rocks is caused by the erosion and dissolution of carbonate rocks by water so that it forms a cavity below the surface which is then occupied by rocks of sandy marl and some are passed through underground river flows. To show an indication of fluid flow (underground river flow) is interrelated between line and another then it is necessary to do 3D cross-section correlation using Rockwork software [14] as in figure 10.

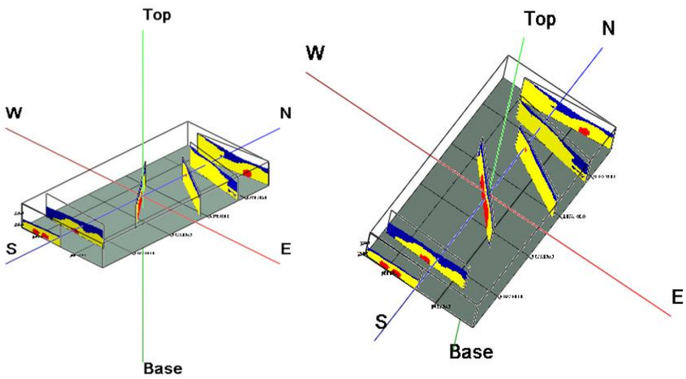

Fig 10: Correlation of 6 cross-sectional line 3D Resistivity

According to research conducted by [5], it shows that carbonate rock layers form an impermeable rock anomaly that is shaped like a hallway and this rock is thought to be cap rock of underground river flow structures so that in this study the spread of the carbonate rock considered as cap rock. Underground river flow with a very high resistivity value is marked in red, which is the cavity of the path where the fluid flows (underground river flow), and it can be concluded that the water model (underground river flow) is interrelated between line 1 and the other.

Based on figure 10 it is suspected that the direction of fluid (underground river) flow from track 1 to line 6 or from northeast to southwest. On line 2 there is no sign of fluid flow because this line is just behind the cave which at the time of acquisition it was filled with water so that the resistivity value reading was relatively low. The result of a combination of self-potential contour maps with 2D geoelectrical resistivity cross-section shows the area that has low resistivity values also have low potential values. This can be seen in figure 11 which the self-potential contour overlay on the resistivity measurement line.

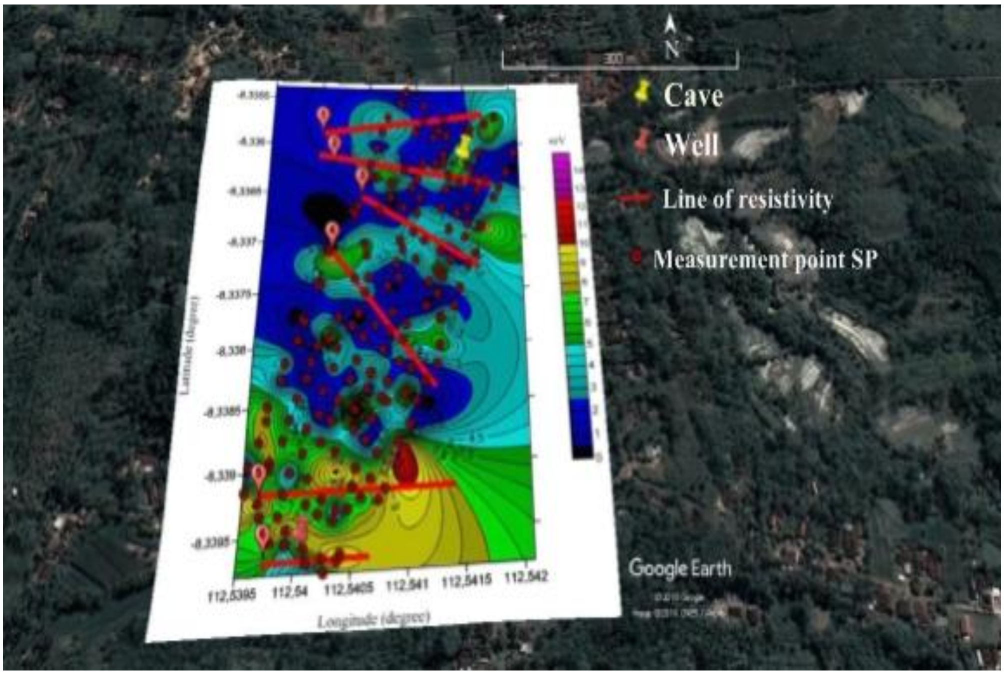

Figure 11: Overlay of the self-potential contour, resistivity line and google earth map

Based on figure 11, it can be concluded that there is a fluid (underground river) flowing from the northeast (cave or conduit) to the southwest (well) where the research is conducted and this evidence proves the existence of the flow from the cave to the well which is the source of springs for local residents.

IV. CONCLUSION

Based on the identification of groundwater flow in the karst area based on geoelectrical resistivity and self-potential data in Sumber Bening village, Malang, Indonesia which has been done, the following conclusions were obtained:

Electricity potential value in the research location was extended around 0-14 mV, assuming low potential value (0-1.5 mV) indicated as underground river flow.

Resistivity values in the study area are in the range 1-22800 Ωm with rock interpretation in the study location was sandy marl (1-221 Ωm) and carbonate rock (222-22800 Ωm).

Underground river flow is found after carbonate rock layers and it can be a suspected that the fluid flows from the northeast (cave or conduit) to the southwest (well) of the study site.

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