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IDENTIFICATION OF SALTWATER DISTRIBUTION USING ELECTRICAL RESISTIVITY TOMOGRAPHY IN BANJARSARI, GROBOGAN REGENCY, INDONESIA

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Abstract

Banjarsari village is located to the south of the Bledug Kuwu, the famous of mud volcano in Central Java province. In this location there are surface manifestations such as the mudflow and the saltwater explosion. In this village there are traditional salt mines, therefore a study of the potential source of salt mines is necessary. The aims of this research are detecting and mapping subsurface area of the saltwater intrusion. The direct measurement was conducted using OYO model 2119C resistivitymeter by using Wenner-Schlumberger array configuration and an *electrode spacing is 30 meters. The direction of line one (A-A') and three (C-C') are from the south to the north and line two (B-B') is the from east to the west. Based on the distribution of resistivity, the saltwater with highest salinity indicated have the lowest resistivity (0.020 – 0.190 ohm.m). The presence of saltwater with highest salinity is expected to be at 30 until 93.8 meters depth. The final result shows that the saltwater every line has a similar correlation, it means that the saltwater is very wide.*

Keywords

Mudflow, Manifestation, Saltwater, Wenner-Schlumberger, Resistivity

1. Introduction

The salt mines in Banjarsari Village is a series of the saltwater of Kuwu Village and Grabagan Village. The all of saltwater in there is known as the saltwater triangle of Kradenan because its location in Kradenan Sub-district. The geological of Kradenan based on the Geological Map of Ngawi sheet is an alluvium deposit consists of clay, silt, sand, and gravel (Datun et al., 1996). The production of the salt at Banjarsari was done traditionally by drying in bamboo blades so that it is not effective, efficient and economical. The salt mines are called **Klakah** which has long been abandoned by farmers. The low production is the main reason for the farmers of this region to switch professions.

Potential of the salt mines can still be seen from surface manifestations. The wells are filled with saltwater shown by the appearance of salt that dries up around the well. The saline water occur due the interaction between groundwater and rocks so that can change the chemical composition of groundwater into high salinity water (Najib et al., 2017). The presence of geothermal resources potential and mudflow manifestations of the research area also provides an overview of subsurface activities. The presence of mudflow on the surface indicates the existence of mud volcano activity in it. Mud volcano activity is the process of sediment material pushing from subsurface to surface.

(a) (b) (c)

Figure 1: (a) *The saltwater triangle of Kradenan*, (b) *the mudflow, and* (c) *wells of saltwater*

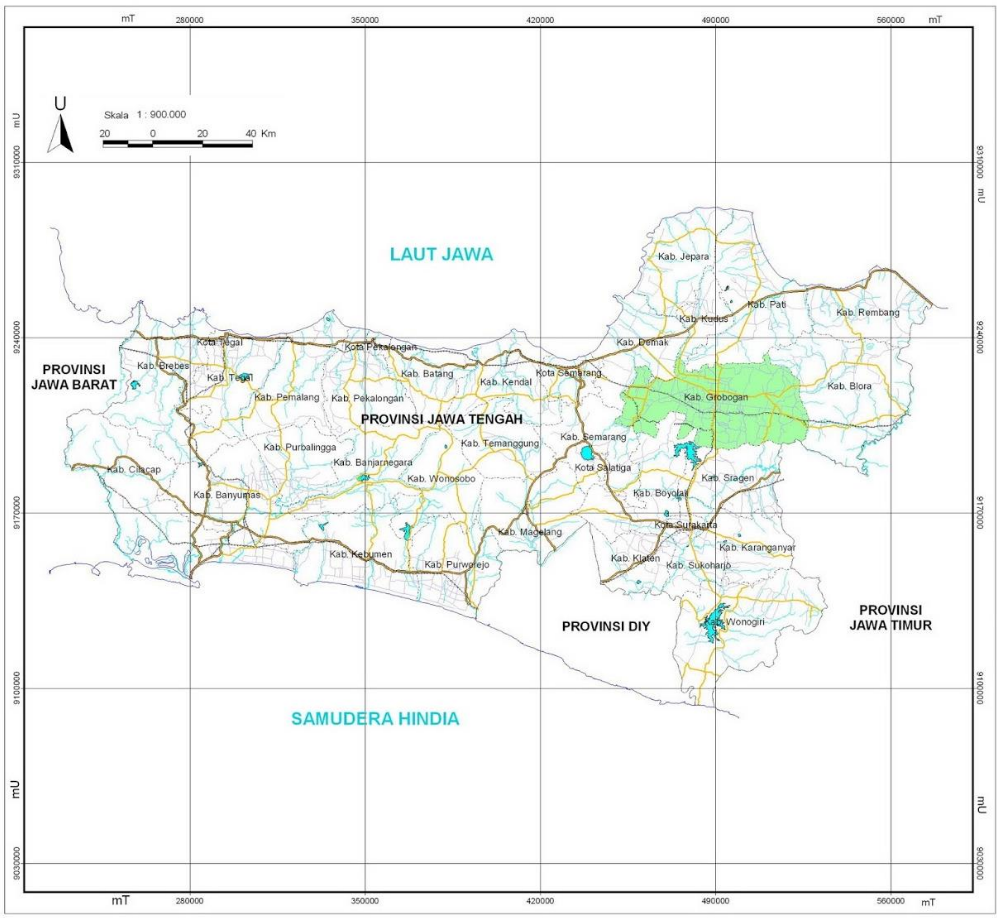

Figure 2: *Map of Grobogan Regency located in northeastern part of the Central Java province in Indonesia*

In addition, the sedimentary material carried away like mud there is also saline water and gas which is dominated by methane gas. Given the condition is also associated with the existence of hydrocarbon traps (Bonini, 2012). Until now the potential of the saltwater triangle of Kradenan has not been fully known. The Electrical Resistivity Tomography (ERT) is a method has been extensively used for structural, geothermal investigations, and hydrogeological such as to detecting of saltwater in the subsurface (Majumdar et al., 2014; Hermans et al., 2012). The research for determining saltwater zonation especially in Bledug Kuwu has been done using vertical electrical sounding (VES) of the Schlumberger configuration. The saltwater zone of this area is detected between 2 - 80 meters with the resistivity interval of 0.05 - 0.46 ohm.m (Darman et al., 2012). Investigation of subsurface anomalous saltwater using the Self Potential method in the Bledug Kuwu area also gained depths of more than 40 meters (Indriana et al., 2007). The aims of this research to identification of saltwater in Banjarsari and identify distribution saltwater the surrounding Banjarsari based on the resistivity in the subsurface.

2. Experimental Method

The geoelectrical measurement were carried out in Banjarsari is located in the south of Bledug Kuwu where is famous mud volcano in Central Java, Indonesia. The surveys performed using OYO model 2119C resistivitymeter. Three lines were conducted of the Wenner – Schlumberger configuration with an electrode spacing of 30 meters so the total length is 600 meters and "**n**" factor values of 1-8, therefore a maximum penetration depth is 93.8 meters. The resistivity from field measurement is referred to as the apparent resistivity, this is based on the assumption that the homogeneous subsurface (Telford et al., 1990). The Wenner – Schlumberger array is a better resolution for horizontal structure (Loke et al., 2010) and is appropriate to investigate saltwater distribution (Kazakis et al., 2016).

The data processing uses a RES2DINV software to obtain 2D resistivity models by least squares inversion scheme (proposed by Loke) from apparent resistivity to get true resistivity distribution in the subsurface. In the resistivity section, the horizontal axis is the electrodes spacing and the vertical axis is the depth (Loke, 2012). Figure 2 shown the line of geoelectric surveys.

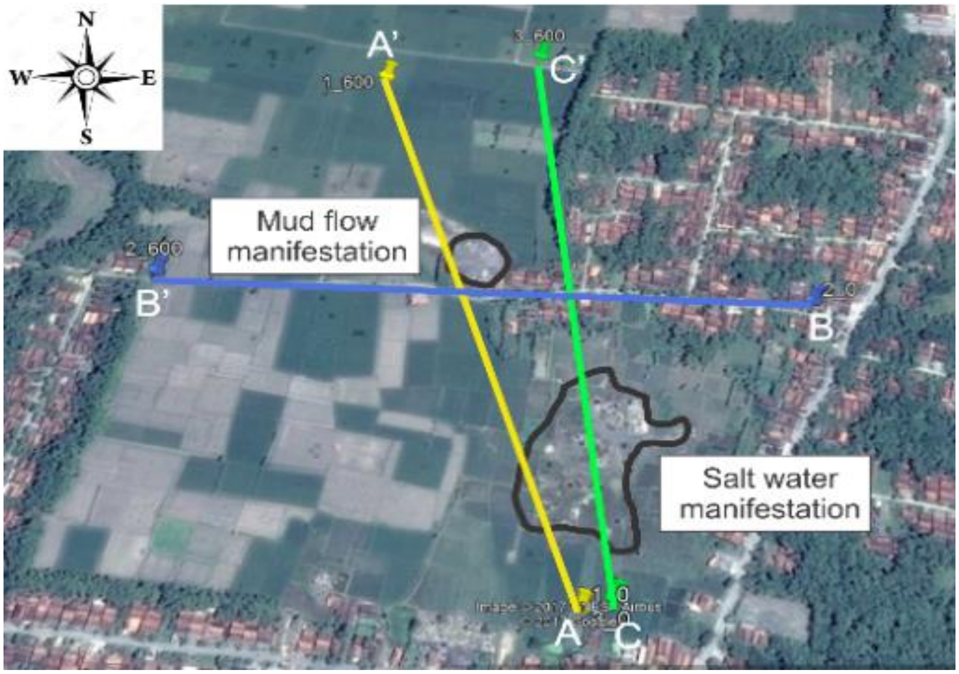

Figure 3: *The location of geoelectric measurement*

3. Result and Discussion

The Electrical Resistivity Tomography (ERT) were performed to identification of saltwater in Banjarsari and identify distribution saltwater the surrounding Banjarsari based on the resistivity in the subsurface. Water has a resistivity between 1 to 1000 ohm.m depend on the ion concentration and the amount of dissolved solids. Average saline water has a resistivity of 0.05 – 0.1 ohm.m (Telford et al., 1990).

Tabel 1: *Resistivity of water and sediments* (Nowroozi, et al., 1999)

Resistivity	Sediments	Interpretation
0.5 – 2.0	Very porous sand or saturated clay	Seawater; very saline water
2.0 – 4.5	Porous sand or saturated clay	Saline water
4.5 – 10.0	Sandy saturated, or sandy clay	Salty brackish water
10.0 – 15.0	Sandy clay, sandy gravel	Brackish water
15.0 – 30.0	Sand, gravel, some clay	Poor quality fresh water
30.0 – 70.0	Sand, gravel, minor clay	Intermediate quality fresh water
70.0 – 100.0	Sand, gravel, no clay	Good quality fresh water
> 100.0	Coarse sand, gravel, no clay clay	Very good quality fresh water

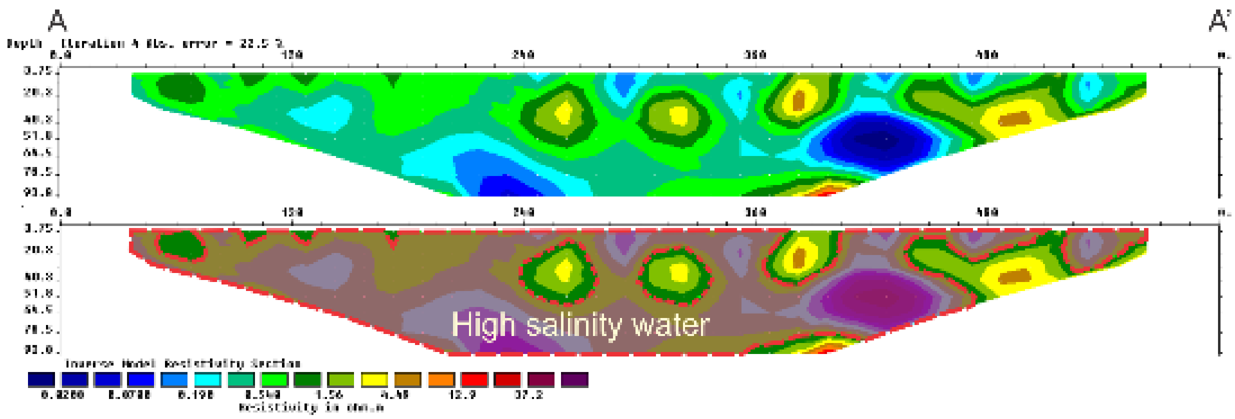

Figure 4: *Electrical resistivity tomography section of A–A'*

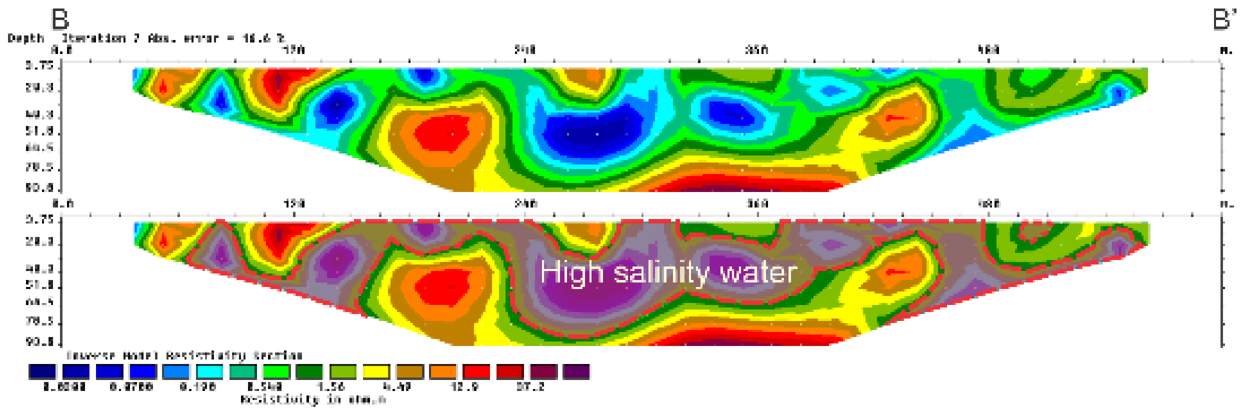

Figure 5: *Electrical resistivity tomography section of B–B'*

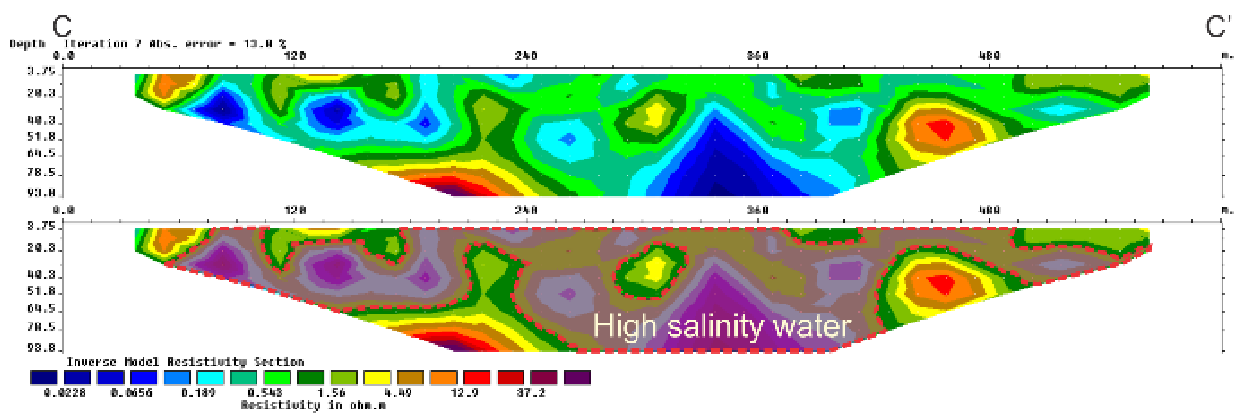

Figure 6: *Electrical resistivity tomography section of C–C'*

Three ERT section shown the difference resistivity, the resistivity below 1,00 ohm.m are described as the high salinity water. The distribution which is the saltwater flow from the source (water with the highest salinity), whereas the lowest resistivity value is 0.02 – 0.10 ohm.m (blue color) interpreted as a material with the highest salinity (saltwater saturation zone).

The first ERT profile (Figure 4) performed from south to north and the ERT section shows that the line A–A' with the interval of resistivity is 0.02 – 10.00 ohm.m this it means that almost all off survey area are affected by saltwater. This evidenced is shown by the presence of surface manifestations of saltwater explosion (points 65 – 185 meters) and mudflow (point 330 – 390 meter). Based on the ERT section of line A–A', the indication of saltwater saturation zone in the north part (points 390 – 450 meters) at the depth of 30 meters and in the south part (points 210 – 255 meters) at the depth of 60 meters.

The second ERT profile (Figure 5) performed from east to west and the ERT section shows that the line B–B' with the interval of resistivity is 0.02 – 37.20 ohm.m. Further north part of point 270 – 330 meters (line B–B') there is a flow of mud (same mudflow at line A–A'). Based on ERT section of line B–B', the saltwater saturation zone indicated at point 250 – 290 meters at the depth of 30 meters and at the surface at point 190 meters find a well with salty water where proved by the lowest resistivity value at 190 meters in ERT profile.

The third ERT profile (Figure 6) performed from south to north and the ERT section shows the line C–C' with the interval of resistivity is 0.02 – 37.20 ohm.m. Points 60 – 200 on the surface is a manifestation of the saltwater explosion, its correspond to an ERT section that at point 60 – 210 meters has a very low resistivity value (0.02 -s 0.3 ohm.m). To the west part of the point 320 - 360 meters there is a mudflow (same mudflow on line A-A') is seen at ERT section at 300 – 390 meters has the lowest resistivity value (30 meters depth) an indication of saltwater saturation zone.

Overall the saltwater presence is correlated to each line, on lines A–A' and C–C' shows that the distribution of saltwater (saltwater explosion) has considerable coverage. The presence salt water manifestation would be intrusion the surrounding area when fresh water needs is increased and the recharge rate shallow aquifer is low. While from the three lines there is a relations the existence of the saltwater of surface manifestation of mudflow is at depth of 30 meters with very low resistivity value.

4. Conclusion

The resistivity values corresponding to indentifying saltwater (water high salinity) distribution using Wenner – Schlumberger configurations in Banjarsari, Grobogan has been conducted. From the result we conclude that the distribution of saltwater is present in all lines with a resistivity interval of 0.02 - 0.1 ohm.m, meanwhile the highest salinity material (saltwater saturated zone) is at the depth of 30 meters. Saltwater intrusion in the surrounding areas could happen if freshwater in exploited uncontrollably and the low recharge rate of the shallow aquifer.

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