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Identification of subsurface layer with Wenner-Schlumberger arrays configuration geoelectrical method

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Abstract. One of measurement methods to investigate the condition of the subsurface is by using geoelectric method. This research uses wenner-Schlumberger arrays configuration geoelectrical method which is mapping resistivity that is commonly known as profiling (2D) in order to identify the lateral and vertical anomaly of material resistivity. 2D resistivity cross section is obtained from the result of data- processing on software Res2Dinv. The data were obtained along 70 m using Wenner-Schlumberger configuration with 5 m spaced electrode. The approximated value of resistivity obtained from the data processing ranged from 1000-1548 Ωm and with the iteration error 87.9%. Based on the geological map of Ujung Pandang sheet, the location of the research is an alluvium and coastal precipitation area with grain in forms of gravel, sand, clay, mud, and coral limestone. Thus, by observing and analyzing the variety of the resistivity cross-section from the inversion data, there are areas (a) showing resistivity values ranged from 0.1-0.2 Ωm which is estimated to be salt water intrusion based on the resistivity table of Earth materials, and region (b) which is a mixture of sand and clay material with the range of resistivity values between 1-1000 μm.

1. Introduction

The geoelectrical method is a method that uses the principle of electric current flow in investigating the subsurface structure of the earth. The flow of electric current in the soil is through the rocks and is strongly influenced by the presence of groundwater and salt contained in the rock, high metal, and heat minerals. Therefore, geoelectrical methods can be used in hydro geological investigations such as an aquifer, determination contamination mineral investigations, archaeological surveys and hot rocks detection in geothermal investigations. Identification to know the presence of water carrier layer at a certain depth can use a geophysical method, which is geoelectrical type resistance method. The geoelectric method is intended to obtain an overview of subsoil and the presence of groundwater and minerals at a certain depth [1]. The goal is to predict the electrical properties of medium or subsurface rock formations, especially its ability to conduct or inhibit electricity [2]. This research uses the Wenner-Schlumberger configuration by injecting the current into the earth. The material with varying resistivity will provide information about the material structure passed by the current.

2. Geoelectrical methods

Geoelectrical methods are used extensively in groundwater mapping for investigation of the vulnerability of aquifers and shallow aquifers themselves. The vulnerability of aquifers is closely related to the heterogeneity of the clay cap. The clay content of the formation shows low resistivity, and sandy permeable formation shows high resistivity. The geoelectrical method is capable of mapping both low and high resistive formations, and therefore it is a valuable tool for vulnerability studies [3,4].

A geoelectrical measurement is carried out by recording the electrical potential arising from current input into the ground with the purpose of achieving information on the resistivity structure on the ground. In a homogeneous ground (half space) the current flow radially out from the current source and the arising equipotential surfaces run perpendicular to the current flow lines and form half spheres. In the common situation with both a current source and a current sink, the current flow lines and the equipotential surfaces become more complex. In reality, the current flow lines and the equipotential lines will form an even more complex pattern as the current flow lines will bend at boundaries, where the resistivity changes.

The potential difference between MN caused by current injection at AB is:

$$\Delta V = V_M - V_N \quad (1)$$

$$\Delta V = \frac{I\rho}{2\pi}\left[\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right] \quad (2)$$

$$\rho = 2\pi \quad \left[\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right]^{-1} \quad (3)$$

Geoelectrical data are commonly expressed as apparent resistivities

$$\rho = \frac{\Delta V}{I} k \quad (4)$$

i.e. ΔV is the measured potential, I the transmitted current, and k the geometrical factor expressed as:

$$k = 2\pi\left[\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right]^{-1} \quad (5)$$

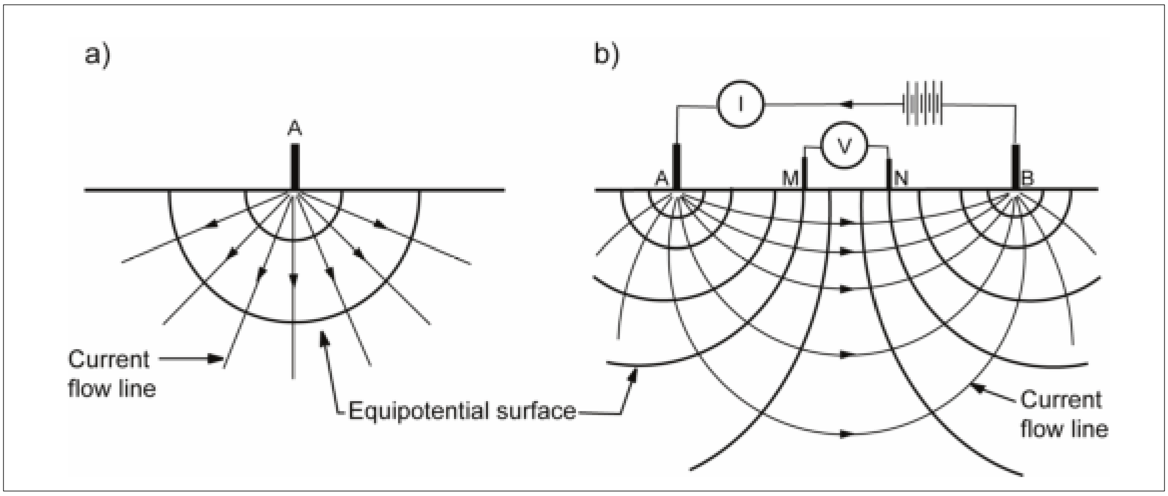

Figure 1. Simplified current flow lines and equipotential surfaces arising from (a) a single current source and from (b) a set of current electrodes (a current source and sink).

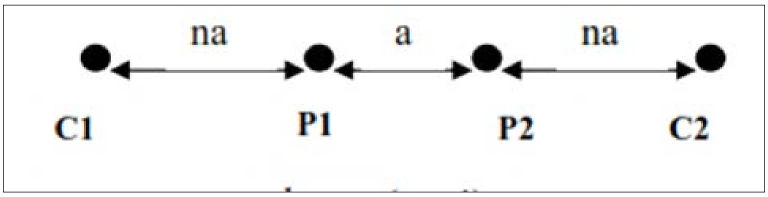

Figure 2. Configuration form Wenner-Schlumberger and geometry factor k.

2.1 Resistivitymeter
Resistivitymeter gives resistance value R = V / I so resistivity value can be calculated by

$$k=\pi n\ (n+1\ )\ a \tag{6}$$

Earth is composed of layers whose resistivity value of a particular soil layer or rock differs from the resistivity value of the soil layer or other rocks. This resistivity value can be determined by connecting the battery with an Ammeter and a current electrode to measure the amount of current flowing into the ground, then placing two potential electrodes with a distance to measure the potential difference between two locations.

2.2 Wenner-Schlumberger configuration
Wenner-Schlumberger configuration is a configuration with a constant system of spacing rules with a note of factor "n" as this configuration is the comparison of the distance between C1-P1 (or C2-P2) electrodes with spaces between P1-P2 as in figure 3. If the distance between electrodes The potentials (P1 and P2) are a than the distance between the current electrode (C1 and C2) is 2na + a. The resistivity determination process uses 4 electrodes placed in a straight line.

This configuration is a combination of the Wenner configuration and Schlumberger configuration. In the measurement by the spacing factor (n) = 1, the Wenner-Schlumberger configuration is similar to the measurement in the Wenner configuration (distance between electrode = a), but on the measurement with n = 2 and so on, the Wenner-Schlumberger configuration is the same as the Schlumberger configuration. The current electrode and the potential electrode are greater than the distance between the potential electrode).

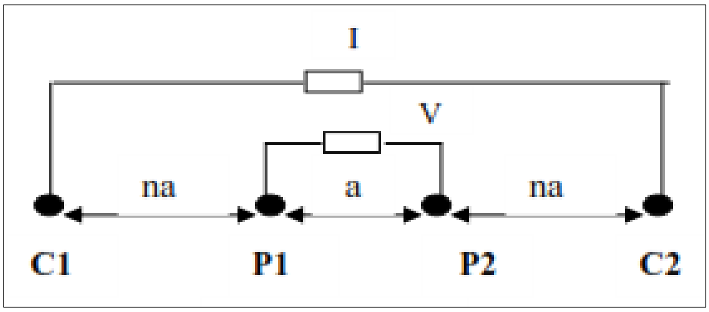

Figure 3. The setting of Wenner - Schlumberger configuration electrode.

3. Results and Discussion

3.1. Calculates the values of R, ρ, and k
Before calculations, R, ρ, and k, determine the value of AB / 2, ie half the distance between the C1 - C2 electrode and the MN/2 value, ie the distance of the P1-P2 electrode, calculate the geometry constant value (k) for the configuration of the Wenner-Schlumberger electrode using the equation (6).

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Next, calculate the value of R by dividing the measured voltage value with the measured current value and calculating the resistivity (ρ). From the resistivity value, we can determine the type of material at that point based on the table (1).

Table 1. Resistivities of some common rock and minerals.

Material	Resistivity (Ωm)
Air	
Pyrite	0,01 - 100
Quartz	500 – 800.000
Calcite	1 x 10^{12}- 1 x 10^{13}
Rock Salt	30 - 1 x10^{13}
Granite	200 – 100.000
Andesite	1,7 x10^{2} – 45 x 10^{4}
Basalt	200- 100.000
Limestones	500 – 10.000
Sandstones	200 – 8.000
Shales	20 – 2.000
Sand	1 – 1.000
Clay	1 – 100
Ground Water	0,5 – 300
Sea Water	0,2
Magnetite	0,01 – 1.000
Dry Gravel	600 – 10.000
Alluvium	10 – 800
Gravel	100 – 600

3.2. Inversion of resistivity measurements

The measured sounding curves represent multi-layered models with three to four layers. The apparent resistivity of the measured soundings was inverted using IPI2WIN software. This program is based on fitting 1D field resistivity measurements to forward modeling (using a Newton algorithm) of the least number of layers to solve the inverse problem.

Based on the inversion of sounding data on the IPI2WIN program, it was obtained a 1D resistivity cross section and the comparison of resistivity value with depth. From 1D section, the obtained 4 layers are:

- The first layer is sand associated with gravel with a depth of 0-0.261 m with a resistivity value of 981 Ωm.
- The second layer is clay with a depth of 0,261-2,68 m with a resistivity value of 653 Ωm.
- The third layer with a depth of 2,68 – 6,43 m with a resistivity value of 9.05 Ωm.

- The fourth layer is groundwater with a depth ranging from 6,43 m with a resistivity value of 152,98 Ωm.

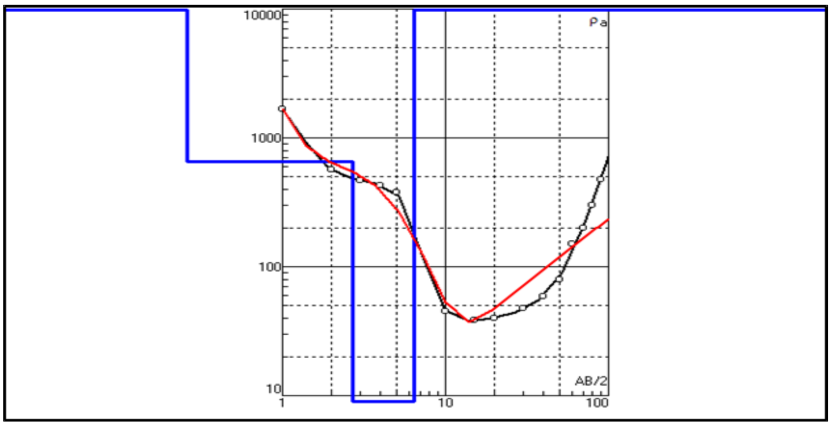

Figure 4. 1D resistivity models.

Two-dimensional resistivity data were processed by using an iterative smoothness-constrained least-squares inversion algorithm (deGroot-Hedin & Constable 1990) to create a model of subsurface resistivity by inverting the apparent resistivity measurements. In this inversion method, the subsurface along the measured profile is divided into a number of rectangular blocks equal in number to the measured apparent resistivity points. During the inversion procedures, the apparent resistivities of the sub surface blocks are estimated and the difference between the observed and calculated data is minimized [5]. Commercially available Res2dinv software was used for all inversion procedures. The inversion parameters were set based on expected subsurface geology, quality of measured data, type of electrode array and expected resolution of the inverse models.

Figure 5 shows a 2D resistivity cross section with the direction of the perpendicular trajectory of the coastline with a 75-meter long track, resulting in 49 datum points. The readable depth is 9 meters. The measured resistivity value is in the range of 0.082 Ωm to 304 Ωm.

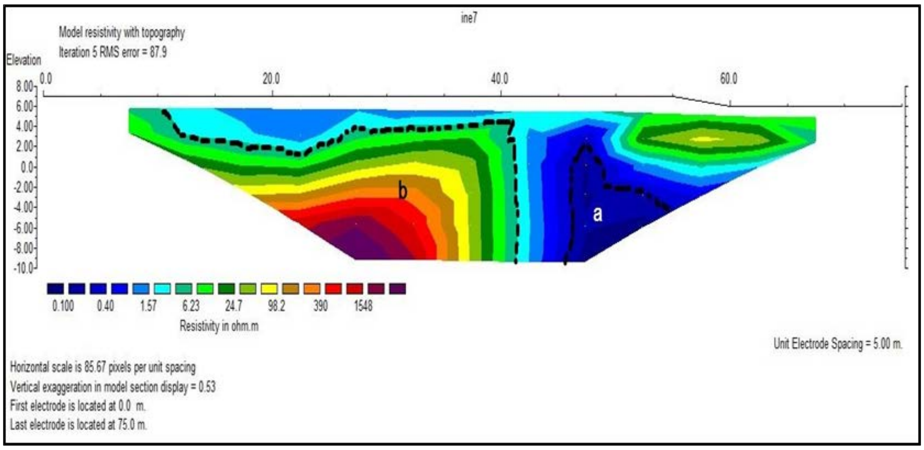

Figure 5. Two-dimensional visualization resistivity model showing the distribution of resistivity with depth.

2D resistivity cross section was obtained from the result of data processing on software Res2Dinv. Data were obtained along 70 m using Wenner-Schlumberger configuration with 5 m spaced electrode. The resistivity value from the data processing ranges from 0.100 - 1548 Ωm and iteration error is 87.9%.

Based on the geological map of Ujung Pandang sheet, the research location is an alluvium and coastal precipitation area with grain in the forms of gravel, sand, clay, mud, and coral limestone. Thus, by observing and analyzing the variation of the resistivity cross-section of the inversion data, there are areas (a) showing resistivity values ranging from 0.1 - 0.2 Ωm which is estimated to be salt water intrusion based on the resistivity table of earth materials and region (b) which is a mixture of sand and clay material with a range of resistivity values between 1 - 1000 μm.

4. Conclusions

This research used the resistivity geoelectric method i.e the Wenner–Schlumberger configuration which is a method with a constant spacing system with a notice that factor of ‘n‘ is a spacing comparison between electrode C1- P1 (or C2-P2) with P1-P2. The instrument used is a Resistivitymeter with four electrodes that is able to read the output of voltage response as the consequence current that has been injected into the sand surface through two potential electrodes and two current electrodes. This study used Res2Dinv software for processing the data obtained. The result of this research gets the range of the resistivity value that is 0,082 – 304 Ωm to a depth of 9 meters.

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