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Research Article

The Estimation of Resistivity of Poka Alluvial Plain Material by Geoelectric Method with Wenner-Schlumberger Configuration

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ABSTRACT

This study was conducted to determine the lateral and vertical distribution of material resistivity values on Poka alluvial plain using electrodes with Wenner-Schlumberger configuration. Mapping is carried out on 2 lines each 120 m long with the smallest space of 10 m. The results showed that the resistivity of the material ranged from 48.8 Ωm to 2.247 Ωm spread laterally with a depth of up to 26.2 m. Loose Sand material occupies the upper layer, followed by the Alluvium and Sand layers in the middle, and Sand and Water which are unconfined aquifers in the lower layer.

Keywords: *Alluvium, Geoelectricity, Resistivity*

Introduction

Rocks are composed of various types of minerals that can conduct electric current. Electric current through rock and mineral matrices can occur due to 1) electronic conduction through free electrons, 2) electrolyte conduction through ions in solution, and 3) dielectric conduction due to electron polarization (Telford, et al., 1990). The flow of electricity (I) through the matrix of rocks and minerals is proportional to the magnitude of the electric voltage (V) and the electrical resistance (R). Resistivity is the amount of resistance to the flow of electric current between two surfaces expressed in units of Ωm (Milsom, 2003).

In soil, resistivity values vary depending on the type of constituent material (Septiyansah, et al. 2020). The soil layer formed from sand, andesite, breccia, and tuff has resistivities ranging from 185 Ωm to 4,128 Ωm (Latupapua, et al. 2023). In reef limestone lithology, it ranges from 8.82 Ωm to 1,561 Ωm (Latupapua, 2022a; 2022b), while in alluvial plains it is 11.44 Ωm to 849.29 Ωm (Sihaloho, et al. 2023). Gravel, sand and clay materials have a resistivity of 50 Ωm to 100 Ωm (Pratama, et al. 2019). The clay-sand layer is a layer containing groundwater (Rahayu, et al., 2019). Aquifer layers can also be in sand and shale layers with a range of resistance values of 4.2 Ωm to 50.6 Ωm (Putra, et al., 2021). The thickness of fresh water in coastal alluvial plain landforms is between 15 m to less than 20 m with resistivity values between 30 Ωm to 109 Ωm (Salam, et al., 2018). Research on limestone lithology shows low resistivity values as an indication of saltwater intrusion

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(Sultan 2018; Latupapua, 2022a; 2022b). The resistivity value of salt water entering the rock ranges from 0.734 Ωm to 6.31 Ωm (Wardhana, et al., 2017).

The resistivity value and type of material below the ground surface can be known through geoelectric measurements, both by *Vertical Electrical Sounding* (VES) and laterally (Mapping). The VES measurement technique is used to study the vertical distribution of resistivity values below the surface. This technique is particularly suitable for determining resistivity values for flat-layered rock structures such as sedimentary layers, or depth to the water surface with *Schlumberger electrode configurations* (Milsom, 2003). While *the Mapping* measurement technique is used to study the distribution of resistivity values laterally and vertically. Generally, this technique uses *the Wenner-Schlumberger* electrode configuration (Jefriyanto, et al., 2015; Farhati and Rosid, 2022; Latupapua, et al., 2023).

Research with the VES technique to obtain the value of subsurface resistivity of the Poka alluvial plain has proven that free aquifers exist at depths of 6.69 m to 22.92 m (Sihaloho, et al., 2023). The distribution of free aquifers laterally is unknown, although the use of groundwater is very important because in this location, there are educational activities, offices, public housing, and agricultural businesses. Aquifers at this location are aquifers with widespread flows and groundwater close to the ground surface based on the Indonesian Hydrogeological map scale 1:250,000 issued by the Directorate of Environmental Management Geology (1993). Meanwhile, based on the Groundwater Basin Map (CAT) of the Maluku Islands Sheet IV scale 1:250,000 (Ucu Takhmat Akus, 2004), the alluvial plain of Poka is included in the Ambon CAT with the number of free groundwater affixes (Q1) = 303 million m3 / year and the number of depressed groundwater flows (Q2) = 65 million m3 / year. The geological formation of the alluvial plain of Poka is in the form of alluvium surface deposits with cobble, pebble, silt, sand, clay, and plant remains (Tjokrosaputro, et al., 1993) or alluvium (Verbeek and Koperberg, 1898).

In accordance with the hydrogeology, CAT, and geological maps, the alluvial plain of Poka has materials with resistivity that varies horizontally and vertically. Resistivity values will vary for gravel 1,400 Ωm (Reynolds, 1998), loose sand 500 – 5,000 Ωm (Milsom, 2003), alluvium and sand 10-800 Ωm (Reynolds, 1998), wet sand 50-100 Ωm (Reynolds, 1998), clay 1-100 Ωm (Telford, et al., 1990; Milsom, 2003; Reynolds, 1998), and groundwater 10–100 Ωm (Telford, et al., 1990).

To determine the distribution of resistivity of the Poka alluvial plain material vertically and laterally, it is necessary to measure it with *Mapping techniques* using the Wenner-Schlumberger electrode configuration.

Methods

The research was conducted in the Poka Alluvial plain, Teluk Ambon District, Ambon City. Resistivity data acquisition by mapping technique using Wenner-Schlumberger electrode configuration on two paths each 120 m long with the smallest electrode distance is 10 m. The measurement of V and I values on Line-1 starts from point A with coordinates 410,137.48 mE and 9,596,269.5 mS to point B with coordinates 410,566.9 mE and 9,596,686.83 mS. Furthermore, measurements on Line-2 start from point A at coordinates 410,657.8 mE and 9,596,359.46 mS to point B at coordinates 410,655.24 mE and 9,596,306.25 mS. The study site is at an altitude of 5 m above sea level with a flat slope.

Measurements using the Wenner-Schlumberger configuration in both passes are in lithology of alluvium or alluvial deposits (Figure 2). With this configuration, the geometry factor (K) is:

$$K = n(n + 1)\pi a$$

The value of n is the ratio between electrode distances that determine the *datum point*. For a track length of 120 m with a closest distance of 10 m, the values of n are n=1, n=2, n=3, n=4, and n=5 with 30 *datum points, a is the* distance between potential electrodes P1-P2 which is 10 m. From the values of K, V and I, the resistivity value (ρ) is obtained from the following equation:

$$\rho = k\left(\frac{\Delta V}{I}\right)$$

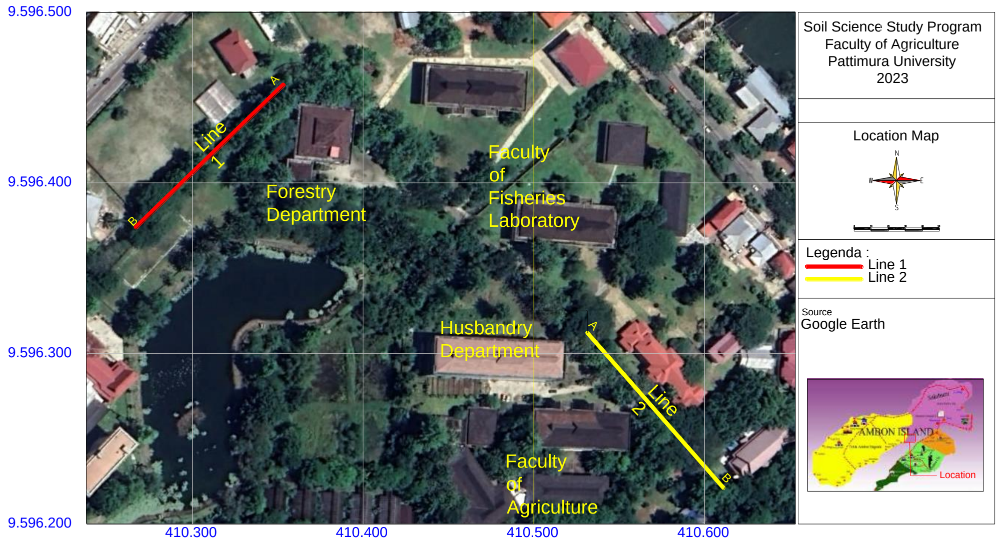

Figure 1. Research Location

Figure 2. Geologic Map

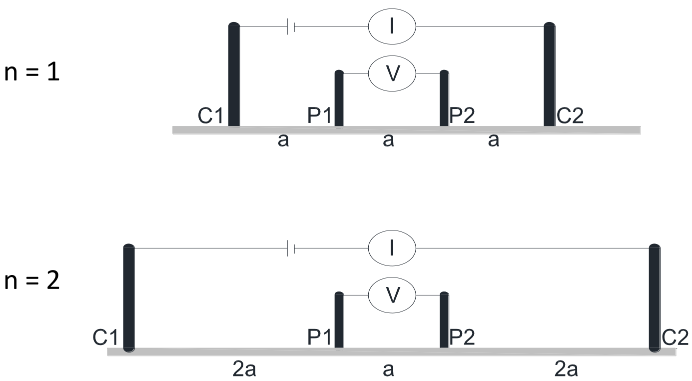

Figure 3. Wenner-Schlumberger electrode configuration

Data that has been tabulated and considered to have better quality is then processed through an inversion process using Res2Dinv. The inversion process uses the least squares method which produces real resistivity values from field data, calculation results, and *pseudosection* inversion results. The resistivity value of the calculation results is compared with the resistivity value of alluvial materials according to Telford, et al., (1990), Milsom, (2003), and Reynold, (1998).

Table 1. Material Resistivity Value as a reference

No	Material	Resistivity (Ωm)	Source
1	Gravel	1.400	Reynold (1998)
2	Loose sand	500-5.000	Milsom (2003)
3.	Sand & Groundwater	50-100	Reynold (1998)
4	Aluvium & Sand	10-800	Reynold (1998)
5	Groundwater	10-100	Telford, *et. al*. (1990)

Result and Discussion

Line-1

The measurement data on Line-1 after processing shows a picture of the horizontal and vertical distribution of Measured Apparent Resistivity Pseudosection, Calculated Apparent Resistivity Pseudosection, and Apparent Resistivity resulting from inversion with RMS error of 17.2% (Figure 4).

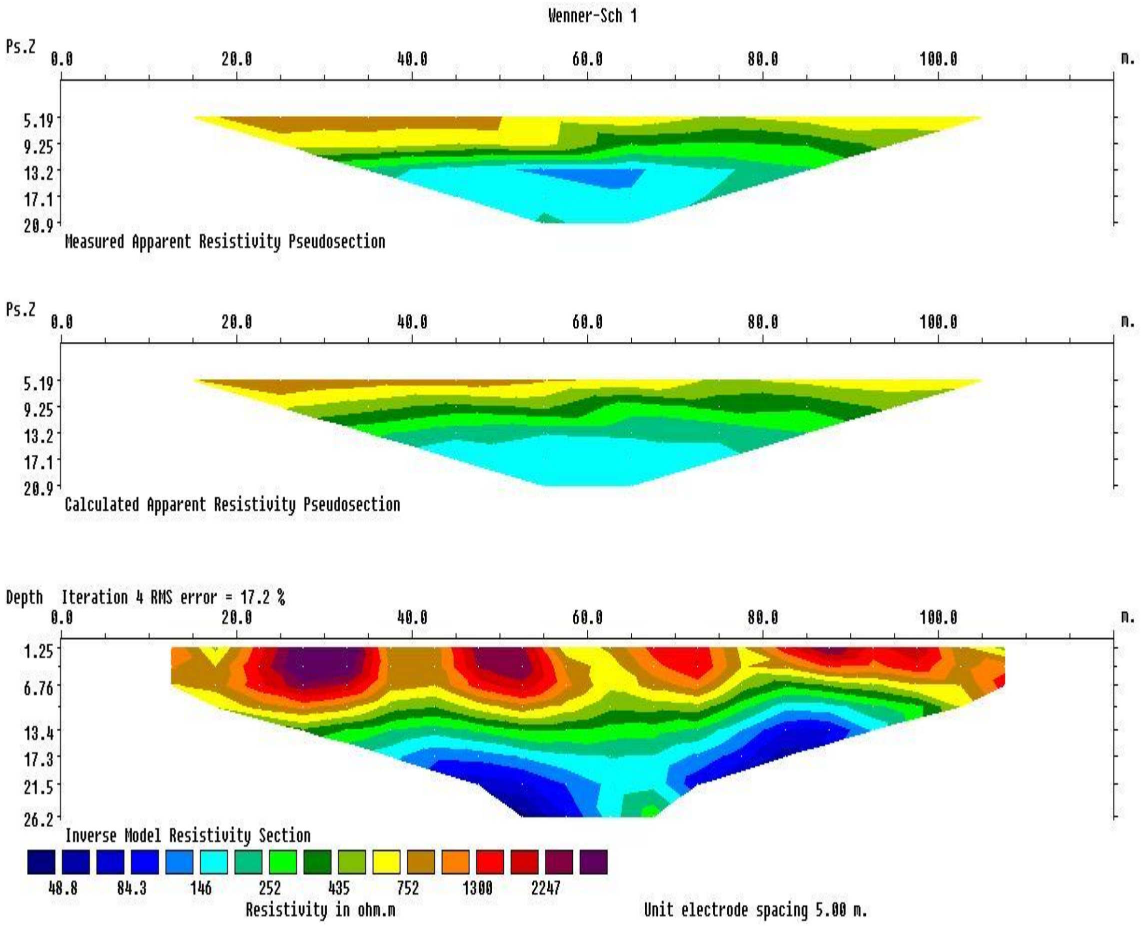

Figure 4. Resistivity Cross-section on Line-1

Table 2. Material Type based on the correlation of geological data on Line-1

No	Depth (m)	Space (m)	Resistivity Ωm	Material Type
1	0 – 6.76	25-35; 50 m	2,247	Loose sand
2	0 -10	20-35; 45-55; 60-100	1,300	Gravel
3	10 – 17.3	20 – 100 m	752-252	Aluvium & Sand
4	17.3 – 26.2	40-90	146 – 48.8	Sand & Groundwater

On Line-1 Loose Sand is spread laterally at a distance of 25-35 m and at a distance of 50 m from the starting point of measurement with a depth of 6.76 m. This is in accordance with the resistivity value according to Milsom (20023), namely Loose Sand has a resistivity of 500 – 5,000 Ωm. Gravel with a resistivity of 1,300 Ωm at a distance of 20-35 m, 45-55 m and 60-100 m with a depth of 10 m, followed by alluvium and sand material at a distance of 20-100 m with a depth of 17.3 m. The resistivity value of gravel is 1.400 Ωm (Reynolds, 1998). At a distance of 40-90 m there is sand and groundwater with a resistivity of 48.8-146 Ωm which is also a free aquifer found at a depth of 17.3-26.2 m. The presence of aquifers like this was also discovered by Sihaloho, et al. (2023). According to Reynolds, (1998) the resistivity value of sand and groundwater is 50-100 Ωm.

The data in Table 2 show that the arrangement of material layers varies vertically, namely Loose Sand in the upper layer followed by Gravel, Alluvium-Sand, and Sand and Ground Water in the lower layer, respectively. With the presence of coarse material, rainwater infiltration will be easy into the ground so that the groundwater level will rise in the rainy season but will fall back in the summer. Groundwater level fluctuations like this cause groundwater on Line-1 is not good for use as a source of clean water. The Sand layer that functions as an aquifer was also discovered by Rahayu, et al. (2019), Putra, et al. (2021), Salam, et al. (2018), and Sihaloho, et al. (2023).

Line-2

Measurement data on Line-2 after processing produced a picture of the horizontal and vertical distribution of Measured Apparent Resistivity Pseudosection, Calculated Apparent Resistivity Pseudosection, and Apparent Resistivity resulting from inversion with RMS error of 14% (Figure 5).

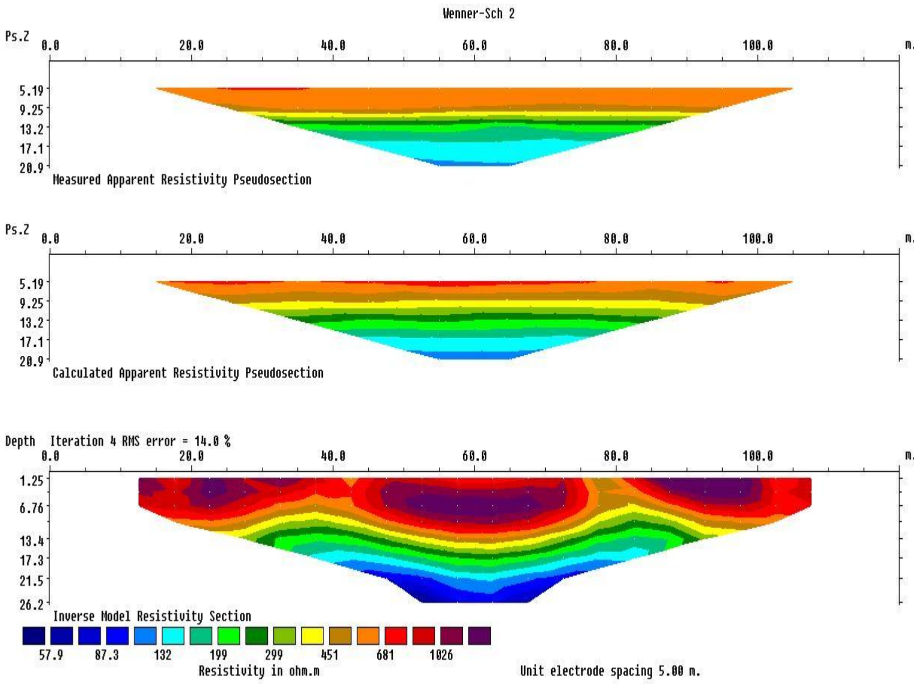

Figure 5. Resistivity Cross-section on Line-2

Table 3. Material Type based on the correlation results of geological data on Line-2

No	Depth (m)	Space (m)	Resistivity Ωm	Material Type
1	0 – 6.76	20-35; 45-75;85-100	1,026	Loose sand
2	6.76 – 17.3	20-100	681-199	Aluvium & Sand
3	17.3 – 26.2	40-85	132 – 57.9	Sand & Groundwater

On Line-2 resistivity values of 1,026 Ωm are spread laterally at distances of 20-35 m, 45-75 m and 85-100 m with a depth of 6.76 m. This layer is a Loose Sand because its resistivity falls into the range of 500-5,000 (Milsom, 2003). At a distance of 20-100 m with a depth of 6.76-17.3 m there are Alluvium and Sand materials with a resistivity of 199-681 Ωm. This resistivity value is included in the resistivity range of Alluvium and Sand according to Reynolds (1998), which is in the range of 10-800 Ωm. Furthermore, at a depth of 17.3-26.2 m along a distance of 40-85 m there is Sand and Groundwater material with a resistivity of 57.9-132 Ωm which is an unconfined aquifer. This range of resistivity values corresponds to the range of values according to Reynolds (1998) for sand and groundwater, which is 50-100 Ωm. Sihaloho, et al. (2023) found an unconfined aquifer at this location with a depth of 4.4 m.

The presence of Sand material from the surface layer to the bottom layer shows that the soil constituent material is easy to seep water. In the rainy season, infiltration water will easily enter the soil along Line-2 so that the groundwater level will rise close to the ground surface. Conversely, in the dry season, groundwater levels will fall. Groundwater with fluctuations like this is not good for use as a source of clean water.The presence of Sand material from the surface layer to the bottom layer shows that rainwater infiltration is easy into the soil. In the rainy season, infiltration water will easily enter the soil along Line-2 so that the groundwater level will rise close to the ground surface. Conversely, in the dry season, groundwater levels will fall. Groundwater with fluctuations like this is not good for use as a source of clean water

Conclusion

The resistivity value of the Poka alluvial plain material ranges from 48.8 Ωm to 2.247 Ωm spread laterally with a depth of up to 26.2 m. The soil constituent materials from the top layer to the lower layers are respectively Loose Sand, Alluvium and Sand, and Sand and Water. The aquifer layer is free with sand and water material at a depth of 26.2 m and cannot be used properly as a source of clean water.

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