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Estimation of Groundwater Potential at Khalid Bin Walid Boarding School Using the Schlumberger Configuration Geoelectric Method

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Abstract: Khalid Bin Walid Islamic Boarding School is one of the Islamic boarding schools in Rokan Hulu Regency. This school is located in a water crisis area with complex groundwater sources. This study aims to determine the potential of groundwater as a reference for drilling wells and to determine the structure of the subsurface layer by using the geoelectrical method. The geoelectrical method is a method that is widely used, and the results are promising, namely, to obtain an overview of the subsurface soil layers and the possibility of groundwater presence. The configuration used in this study is the Schlumberger configuration using the basic principle of current propagating in the earth when injected in all directions and the assumption that the potential of the subsurface rock layer is the same. Data will be collected on four tracks, with a track length of 100-200 m. From the data processing results, it was found that potential sources of groundwater on track 3 with a depth of 13.7–30.3 m with alluvium rocks were suspected. Groundwater on this track can be used as a source of clean water using drilling.

Keywords: Geoelectric; Groundwater; Khalid Bin Walid; Schlumberger

Introduction

Khalid Bin Walid Islamic Boarding School is one of the Islamic Boarding Schools in Rokan Hulu Regency. The student population of ±1000 requires large amounts of water for bathing, washing, and cooking. This Islamic boarding school has three wells, but only two water sources are available. Of the two water sources available, one has turbid water and frequent droughts, making it unable to meet the needs of students. The Khalid Bin Walid Islamic boarding school is in a water crisis area with complex groundwater sources.

Water is an inexhaustible resource on earth. Therefore, water can be called a renewable energy source (Bisma et al., 2023). Water is divided into surface water and groundwater. Groundwater is water trapped in the ground from rainwater or surface water. Geologically, the area has no surface water but substantial groundwater reserves (Hiden et al., 2022; Krisnasiwi, 2021). Of course, knowing where water is below the surface is not easy, so more detailed investigation is needed to determine the presence of subsurface layers that may contain groundwater (Angglena et al., 2022; Bhatnagar et al., 2022; Karimah et al., 2022).

Groundwater is stored in layers of aquifer rock called aquifers. Efforts to locate aquifers should be conducted through surveying, surveying, and inferring subsurface rock formations and making the locations and depths of aquifers available to communities (Juandi et al., 2021; Prasetyo et al., 2022; Vasantrao et al., 2017).

Underground geological surveys have been completed to obtain information by conducting geophysical mapping surveys using geoelectric tools. Geoelectric measurements are intended to demonstrate the presence of aquifers in the study area by knowing the distribution, lithology type, depth, and thickness of the rock formations, including both horizontal and

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vertical aquifers (Rakhmanto et al., 2019; Ulfah et al., 2021). This method has been applied to identify aquifers around the Watershed (DAS) in Sungai Salak Village, Rokan Hulu Regency (Daruwati, 2019).

Groundwater is still the primary source of solutions to meet the world's clean water needs (Bharti et al., 2019; Fajana, 2020). According to Onawola et al. (2021) estimate that 70% of the population needs clean water met by groundwater. For clean water originating from groundwater, data and information are needed regarding the potential condition of groundwater in the area, including the aquifer configuration, depth, and groundwater potential (Bassey et al., 2019; Naryanto, 2020; Rahajoeningroem et al., 2020).

This study uses the Schlumberger configuration geoelectric method to determine the potential of groundwater and subsurface structures. The Schlumberger configuration geoelectric method is a method that is widely used to determine the characteristics of subsurface rock layers to look for the presence of aquifer layers. The benefits of this research can provide information on the location of groundwater sources at the Khalid Bin Walid Islamic Boarding School.

Theoretical Background

Geology of the Research Area

This research was conducted at the Khalid bin Walid Islamic Boarding School in Rokan Hulu Regency. Geology of the research area can be seen in Figure 1.

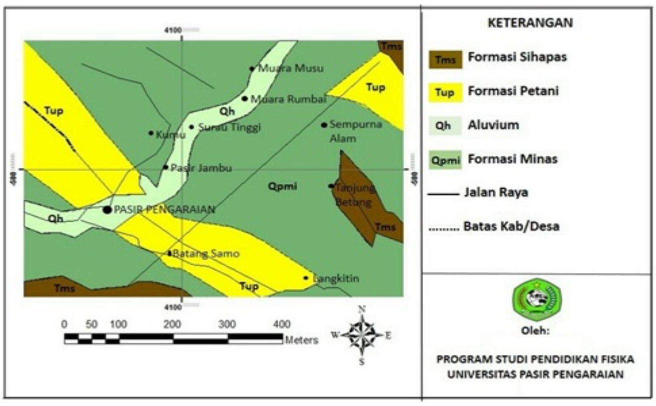


Figure 1. Geology of the research area

Based on the geological map in Figure 1, the study area consists of one rock formation, namely the Alluvium Formation (Qh), which consists of sand, gravel, conglomerate, carbonated silt and mudstone (Samodra, 1992).

Groundwater

Water is one of the primary human needs, so a special science deals with water, namely hydrology. Hydrology is the science of water in the atmosphere, on the earth's surface, and in the earth. About the occurrence of rotation and its influence on life (Shiddiqy, 2014).

In addition, another understanding of groundwater is water that moves in the soil, which is contained in the spaces between soil grains that seep into the soil and combine to form a layer of soil called an aquifer (Herlambang, 1996). Groundwater is stored in aquifers (Raymond Jr, 1988). Groundwater can be located tens or hundreds of meters below the earth's surface. The layers of rock that allow water to pass are called permeable, and those that do not pass are called impermeable. Groundwater is stored in geological formations called aquifers in the form of porous material or rock with conditions that it can store water and has good permeability (Daniswara et al., 2020). The absorbent layer consists of sand, gravel, pumice, also cracked rock, while the impermeable layer consists of marl and clay.

Groundwater resources have a vital role as an alternative source of raw water to supply water needs for various purposes (Windhari et al., 2022). Groundwater is a natural resource that can be renewed even though it has gone through a long formation process, tens or even thousands of years (Freeze et al., 1979).

The community's need for clean water continues to increase from year to year. The limited number and increasing surface water contamination have stimulated groundwater resource development. Consequently, research techniques on the study and movement of groundwater, extraction techniques, resource management concepts, and research have been developed to better understand groundwater (Tood, 1980).

Resistivity Geoelectrical Method

The geoelectric method is a method in geophysics that studies the nature of electric currents in the earth by detecting them above the earth's surface. The purpose of this method is to estimate the electrical properties of the medium or formation below the surface associated with conductivity alternatively, inhibit electric current (conductivity or resistivity) (Telford et al., 1990).

Each layer of the earth is a rock material with a different type of resistance. The basic principle used in the resistivity geoelectric method is Ohm's Law which is expressed in the equation (1).

$$V = I \, x \, R \tag{1}$$

Information: V is potential difference (Volt), I is electric current (Ampere), and R = Resistance (Ohm).

Schlumberger Configuration Geoelectrical Method

Measurement of resistivity in the vertical direction or Vertical Electrical Sounding (VES) is one of the resistivity geoelectrical methods to determine changes in soil resistivity with depth to study the vertical variations in the resistivity of rocks beneath the earth's surface (Telford, 1990).

Electrical resistivity techniques allow the determination of subsurface resistivity by sending an electric current into the ground and measuring the potential field generated by the current. The penetration depth is proportional to the Schlumberger arrangement using closely spaced potential and widely spaced current electrodes (Nejad, 2009).

The Schlumberger configuration geoelectric method is a method that is widely used to determine the characteristics of subsurface rock layers to look for the presence of aquifer layers. Generally, rock layers do not have perfectly homogeneous properties. The rock layers' position close to the surface will significantly affect the measurement results. The measured value is the apparent resistivity in Figure 2.

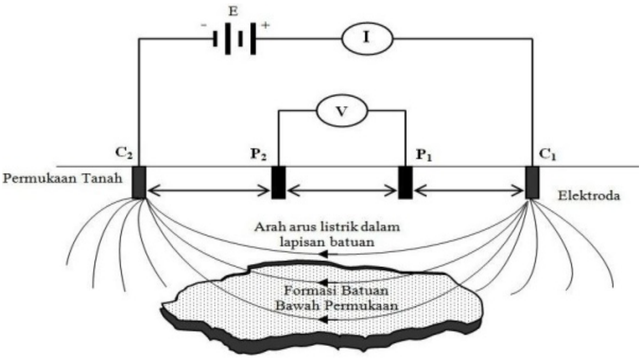


Figure 2. Scheme of resistivity geoelectrical method measurement equipment (Sehah et al., 2016)

Furthermore, after the current (I) and potential difference (ΔV) values are known, the apparent resistivity for each subsurface rock layer can be calculated using the equation (2).

$$\rho_a = K\frac{\Delta V}{I} \qquad (2)$$

Where, ρ_a is the apparent resistivity, ΔV is the potential, K is the geometry factor, and I is the electric current strength. To determine the value of the geometry factor can be seen in equation (3).

$$K_{sch} = \frac{2\pi}{\left(\frac{1}{AM}-\frac{1}{MB}\right)-\left(\frac{1}{AN}-\frac{1}{NB}\right)} = \pi\left(\frac{a^2-b^2}{2b}\right) \qquad (3)$$

Method

This research was conducted at the Khalid bin Walid Islamic Boarding School, Rambah District, Roka Hulu Regency, in September 2022.

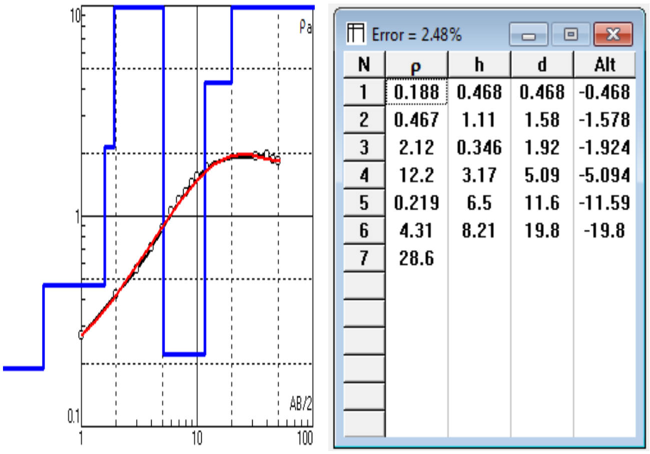
The tools and materials used in this study are the RS505 GeoResist type resistivity meter, the Global Positioning System (GPS) used to determine the position of the measurement point, four electrode rods used for injecting current and voltage from within the earth, four rolls of EIW-GR II type cable set for current and voltage conductors, two hammers to hit the electrodes when plugging into the earth, 2 meters to measure the length of the track and the spacing to be studied, a battery or battery (12 Volt) serves as a current source, a writing tool to record results manually, Laptops are used to process data from research and compile reports. The materials used are Microsoft Excel to record research calculations and IP2WIN Software to process data.

Result and Discussion

Result

This research was conducted at the Khalid Bin Walid Pasir Pengaraian Islamic Boarding School. In the research area, four paths were measured using the Schlumberger configuration geoelectric method. Based on field research data, it was obtained data as many as four tracks with track lengths of 1, 2 and 4 having a track length of 100 meters, and track 3 has a track length of 200 meters. The following are the results of the interpretation of each research trajectory.

Track 1



Error = 2.48%

N	ρ	h	d	Alt
1	0.188	0.468	0.468	-0.468
2	0.467	1.11	1.58	-1.578
3	2.12	0.346	1.92	-1.924
4	12.2	3.17	5.09	-5.094
5	0.219	6.5	11.6	-11.59
6	4.31	8.21	19.8	-19.8
7	28.6			

Figure 3. Results of track 1 data processing

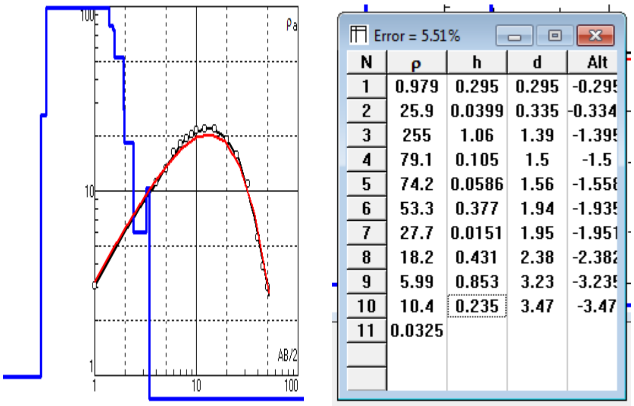
Based on Figure 3, the interpretation results on track 1 have different layer variations with an RMS error of 2.48%. Furthermore, the interpretation of the subsurface track 1 can be seen in Table 1.

Table 1. Interpretation of the Subsurface Track 1

Layer	Resistivity (Ωm)	Depth (m)	Interpretation
1	0.188	0 – 0.468	Pyrite
2	0.467	0.468 – 1.58	Pyrite
3	2.12	1.58 – 1.92	Sand
4	12.2	1.92 – 5.09	sand and silt
5	0.219	5.09 – 11.6	Pyrite
6	4.31	11.6 – 19.8	Sand and mudstone

Based on Table 1, the first layer with a depth of 0 – 0.468 meters, has a resistivity value of 0.188 Ωm. This resistivity value is interpreted as a layer of Pyrite. At a depth of 0.468 – 1.58 meters, it has a resistivity value of 0.467 Ωm. This resistivity value is greater than the previous resistivity value. In this layer, it is suspected that it is Pyrite. At a depth of 1.58 – 1.92 meters, it has a resistivity value of 2.12 Ωm, and this layer is interpreted as a sand layer. The depth of 1.92 – 5.09 m has a resistivity value of 12.2 Ωm, and this layer is interpreted as a layer of sand and silt. The next layer at a depth of 5.09 – 11.6 m has a resistivity value of 0.219 Ωm and is interpreted as a pyrite layer. And at a depth of 11.6 – 19.8 m, it has a resistivity value of 4.31 Ωm, interpreted as layers of sand and mudstone. On track 1, groundwater points were found at a depth of 2 – 19.8 meters.

Track 2



N	ρ	h	d	Alt
1	0.979	0.295	0.295	-0.29
2	25.9	0.0399	0.335	-0.334
3	255	1.06	1.39	-1.39
4	79.1	0.105	1.5	-1.5
5	74.2	0.0586	1.56	-1.55
6	53.3	0.377	1.94	-1.93
7	27.7	0.0151	1.95	-1.951
8	18.2	0.431	2.38	-2.38
9	5.99	0.853	3.23	-3.23
10	10.4	0.235	3.47	-3.47
11	0.0325			

Figure 4. Results of rack 2 data processing

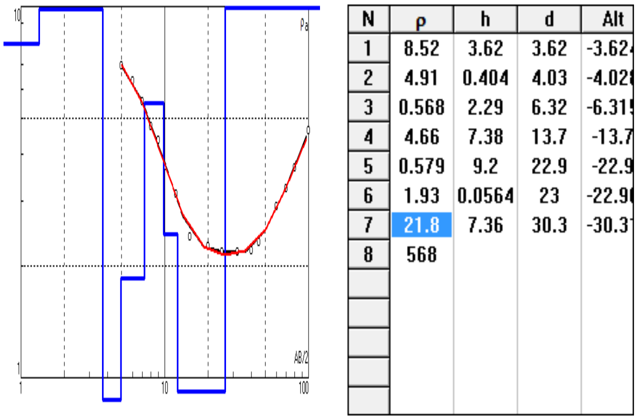
Interpretation results on track 2 in Figure 4 with an RMS error of 5.51% have different layer variations. This can be seen in Figure 4. In Table 2, the interpretation of the subsurface track 2 is explained.

In Table 2, the first layer with a depth of 0 – 0.295 m, has a resistivity value of 0.979 Ωm. This resistivity value is interpreted as a layer of pyrite. At a depth of 0.295 – 0.335 m, it has a resistivity value of 25.9 Ωm. This resistivity value is greater than the previous resistivity value in this layer. It is suspected that Alluvium (sand, silt, silt). At a depth of 0.335 – 1.39 m, it has a resistivity value of 255 Ωm, and this layer is interpreted as a gravelly sand layer. The depth of 1.39 – 1.56 m has a resistivity value of 74.2 Ωm, and this layer is interpreted as a layer of sand and silt. The next layer at a depth of 1.56 – 1.95 m has a resistivity value of 27.7 Ωm and is interpreted as an alluvium layer. At a depth of 1.95 – 2.38 m, it has a resistivity value of 18.2 Ωm which is interpreted as an alluvium layer. At a depth of 2.38 – 3.47 m, it has a resistivity value of 10.4 Ωm which is interpreted as an alluvium layer. On track 2, groundwater points were found at 0.335 – 3.47 meters.

Table 2. Interpretation of the subsurface track 2

Layer	Resistivity (Ωm)	Depth (m)	Interpretation
1	0.979	0 – 0.295	Pyrite
2	25.9	0.295 – 0.335	Alluvium (sand, silt, mudstone)
3	255	0.335 – 1.39	pebbled sand
4	74.2	1.39 – 1.56	sand and silt
5	27.7	1.56 – 1.95	alluvium
6	18.2	1.95 – 2.38	Alluvium
7	10.4	2.38 – 3.47	Alluvium

Track 3



N	ρ	h	d	Alt
1	8.52	3.62	3.62	-3.62
2	4.91	0.404	4.03	-4.02
3	0.568	2.29	6.32	-6.31
4	4.66	7.38	13.7	-13.7
5	0.579	9.2	22.9	-22.9
6	1.93	0.0564	23	-22.9
7	21.8	7.36	30.3	-30.3
8	568			

Figure 5. Results of track 3 data processing

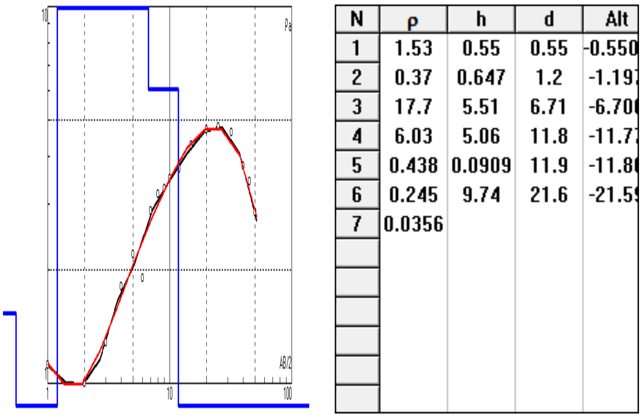
Interpretation results on track 3 in Figure 5, with an RMS error of 0.832%, have different layer variations. Can be seen in Figure 4. In Table 3, the interpretation of the subsurface track 3 is explained.

Table 3. Interpretation of the Subsurface Track 3

Layer	Resistivity (Ωm)	Depth (m)	Interpretation
1	8.52	0 – 3.62	sand and mudstone
2	4.91	3.62 – 4.03	sand and mudstone
3	0.568	4.03 – 6.32	Pyrite
4	4.66	6.32 – 13.7	sand and mudstone
5	0.579	13.7 – 22.9	Pyrite
6	1.93	22.9 – 23	Sand
7	21.8	23 – 30.3	Alluvium

The first layer in Table 3, with a depth of 0 – 3.62 m, has a resistivity value of 8.52 Ωm. This resistivity value is interpreted as a layer of sand and silt. At a depth of 3.62 – 4.03 m, it has a resistivity value of 4.91 Ωm. This resistivity value is smaller than the previous; in this layer, it is suspected that it is sand and silt. At a depth of 4.03 – 6.32 m, it has a resistivity value of 0.568 Ωm and this layer is interpreted as a pyrite layer. The depth of 6.32 – 13.7 m has a resistivity value of 4.66 Ωm, and this layer is interpreted as a layer of sand and silt. The next layer at a depth of 13.7 – 22.9 m has a resistivity value of 0.579 Ωm and is interpreted as a pyrite layer. At a depth of 22.9 – 23 m, it has a resistivity value of 1.93 Ωm, interpreted as a layer of sand. At a depth of 23 – 30.3 m, it has a resistivity value of 21.8 Ωm which is interpreted as an alluvium layer. On track 3, groundwater points were found at a depth of 13.7 – 30.3 m.

Track 4



N	ρ	h	d	Alt
1	1.53	0.55	0.55	-0.550
2	0.37	0.647	1.2	-1.19
3	17.7	5.51	6.71	-6.70
4	6.03	5.06	11.8	-11.7
5	0.438	0.0909	11.9	-11.8
6	0.245	9.74	21.6	-21.5
7	0.0356			

Figure 6. Results of track 4 data processing

Interpretation results on track 4 in Figure 6, with an RMS error of 4.81%, have different layer variations, as shown in Figure 6. Table 4 explains the interpretation of the subsurface track 4. Based on Table 4, the first layer with a depth of 0 – 0.55 m, has a resistivity value of 1.53 Ωm. This resistivity value is interpreted as a layer of sand. At a depth of 0.55–1.2 m, it has a resistivity value of 0.37 Ωm.

Table 4. Interpretation of the Subsurface Track 4

Layer	Resistivity (Ωm)	Depth (m)	Interpretation
1	1.53	0 – 0.55	Sand
2	0.37	0.55 – 1.2	pyrite
3	17.7	1.2 – 6.71	alluvium
4	6.03	6.71 – 11.8	sand and mudstone
5	0.245	11.8 – 21.6	pyrite

This resistivity value is smaller than the previous; in this layer, it is suspected that it is pyrite. At a depth of 1.2–6.71 m, it has a resistivity value of 17.7 Ωm, interpreted as an alluvium layer. The depth of 6.71–11.8 m has a resistivity value of 6.03 Ωm, and this layer is interpreted as a layer of sand and silt. The next layer at a depth of 11.8–21.6 m has a resistivity value of 0.245 Ωm and is interpreted as a pyrite layer. On track 4, groundwater points were found at a 6.71–11.8 meters depth.

Discussion

The geological conditions of the study area are composed of the Alluvium Formation consisting of sand, gravel, conglomerate, carbonaceous silt, and mud (Samodra, 1992).

Mudstone is a fine-grained sedimentary rock constituent whose main constituents are clay and silt. The grain size reaches 0.0625 mm, and each grain is too small to be distinguished without a microscope. Siltstone is a clastic sedimentary rock. As the name suggests, siltstone consists of (more than 2/3 of it) silt-sized particles, which are grains measuring 2-62 µm. Siltstone differs significantly from Sandstone because it has smaller pores and a higher tendency to contain a significant silt fraction. Sandstone is a clastic sedimentary rock that makes up about ¼ of the volume of sedimentary rock. In general, the composition of Sandstone consists of a matrix, cement, rock fragments (grain), quartz, feldspar, and other minerals. At the same time, gravel (gravel) is rock particles measuring 5 mm to 150 mm.

Other rock types found in the study area are Pyrite and Magnetite rocks. Pyrite or iron ore is fake gold, including sedimentary and metamorphic rocks. The distribution of Pyrite in rocks depends on the diagnosis. Pyrite contained in Sandstone comes from primary formation, where Pyrite has undergone sedimentation, including weathering, transportation, and deposition. Pyrite found in Sandstone will spread structurally, namely in its distribution. Pyrite has approximately the same size as sand grains. In formations or rocks containing Pyrite, the resistivity of the rocks will show a low value according to the percentage. This happens because the mineral Pyrite is a good conductor, so its presence will cause the resistivity value of the rock to be low. The alleged groundwater layer on line one can be found at a 2–19.8 m with a resistivity value of 2.12–4.31 Ωm. This layer is interpreted as groundwater, presumably rock in this layer, namely alluvium (sand, silt, and silt). On the second track, groundwater sources were found at a depth of 0.335 – 3.47 m with a resistivity value of 25.9 – 10.4 Ωm. This resistivity value is interpreted as the groundwater layer. Alleged rocks on this track are sand, gravel, silt, and mud. However, this track can also not be used because this layer has a thickness of only 1 m.

On the track 3, potential groundwater is found at a depth of 13.7–30.3 m. This layer is interpreted as a layer of groundwater and is a layer that can pass through groundwater. Groundwater on this track can be used as a source of clean water using drilling. Previously on this track was also a watershed. On track 4, it was found that there was groundwater at a depth of 6.71 – 11.8 m with a resistivity value of 17.7–6.71 Ωm and was interpreted as rock, namely sand, silt, and mud. Sandstone's presence can potentially store water (Sukarasa et al., 2020).

Based on a literature study of geological data and geoelectrical measurements, there are two aquifers in the study area: alluvial and quartz sand. Both are free aquifers, meaning they are not covered by an impermeable layer above (Cakrabuana et al., 2023). No aquifers were found for the identified rocks in the form of marl, tuff, tuffaceous marl, and clay because these rocks are classified as impermeable (Maemuna et al., 2017).

Conclusion

Based on the research results obtained, it can be concluded that the track 1 suggests groundwater at a depth of 2 – 19.8 m with a resistivity value of 2.12 – 4.31 Ωm. This layer is interpreted as groundwater, presumably rock in this layer, namely alluvium (sand, silt, and silt). The track 2 is the alleged groundwater point at a depth of 0.335 – 3.47 m with a resistivity value of 25.9 – 10.4 Ωm. This resistivity value is interpreted as the groundwater layer. Alleged rocks on this track are sand, gravel, silt, and mud. However, this track can also not be used because this layer has a thickness of only 1 m. The track 3 of groundwater potential is found at a depth of 13.7 – 30.3 m. This layer is interpreted as a layer of groundwater and is a layer that can pass through groundwater. Groundwater on this track can be used as a source of clean water using drilling. While on track 4, it was found that there was groundwater at a depth of 6.71 – 11.8 m with a resistivity value of 17.7 – 6.71 Ωm and was interpreted as rock, namely sand, silt, and mudstone.

Author Contributions
Ika Daruwati: Conceptualization, methodology, validation, writing—original draft preparation; Rindi Genesa Hatika: Formal analysis, data curation; Sohibun: Methodology, software; Hamid Syahropi: Software; Azmi Asra: Project administration, resources; Nurhikmah Sasna Junaidi: Writing—review and editing; Meilan Demulawa: Writing—review and editing.

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Conflicts of Interest
The authors declare no conflict of interest.

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