Identification of Groundwater Presence Using ERT (Electrical Resistivity Tomography) in Berkas Village, Teluk Segara Sub-district, Bengkulu City

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Abstract *- Kelurahan Berkas is a coastal area in Teluk Segara Sub-district, Bengkulu Regency, Bengkulu Province. The purpose of this research is to identify the presence of groundwater in Kelurahan Berkas. The method used was resistivity geoelectric method with Wenner-Schlumberger configuration. This research applied three lines, the first in the Southwest-Northeast direction and the second in the East-West direction, with a length of 240 metres each. The results show that the free aquifer layer in the first pass has a resistivity value of 1.61 Ω.m to 3.98 Ω.m at a depth of 7 metres to 24 metres. While the second pass has a resistivity value of 3.17 Ω.m to 9.23 Ω.m at a depth of 8 metres to 36.9 metres and the third pass has a resistivity value of 1.62 Ω.m to 7.05 Ω.m at a depth of 2 metres to 20 metres. The results also show that the lithology of the aquifer layer in the study area is interpreted as clay, sandy clay, and sand. This layer contains groundwater that has been affected by seawater intrusion. The influence of this intrusion causes the groundwater to have a relatively low percentage of salinity so that the groundwater at the research location feels brackish. The existence of seawater intrusion is caused by the kelurahan berkas right on the coast so that the kelurahan berkas community lacks clean water, so the well water becomes brackish, therefore with this research the community can find out the location or point where there is groundwater.*

Keywords: *Geoelectric, Brackish Water, Groundwater, Resistivity, and Bengkulu*

INTRODUCTION

Water is very important in life because living things, especially humans, cannot live without water. The increasing population requires a sufficient amount of water. An area that has limited water is difficult to meet the needs of a high population especially during the dry season. Groundwater is one of the sources of water for the life of creatures on earth (Abdillah & Malik, 2021). Groundwater is stored in a container (aquifer), which is a water-saturated geological formation that has the ability to store and release water in sufficient quantities (Manrulu et al., 2018).

Groundwater is freshwater that covers approximately 24 per cent of the total amount of freshwater on earth (10.5 million km^3). Groundwater is in a layer of soil/rock that lies beneath the surface known as an aquifer. This aquifer layer can function to store and drain groundwater. The aquifer layer consists of a relatively shallow unconfined aquifer, and a relatively deep confined aquifer (Multi et al., 2023).

Bengkulu City is part of the west coast (coastal) area, partly consisting of peaty swampland and the water is coloured, smelly, tasteless and partly brackish. The brackish water does not meet the quality requirements for use as clean water for daily and industrial needs. To identify the presence of a water-bearing layer at a certain depth, geophysical methods can be used, namely the type resistance geoelectric method. The geoelectric method is intended to obtain an overview of the subsurface soil layer and the possibility of groundwater and minerals at a certain depth (Sedana et al., 2015). Aims to estimate the electrical properties and subsurface rock formations, especially their ability to conduct or inhibit electricity (Agustina et al., 2019). In Teluk Segara Sub-district, more precisely in Berkas Village, Bengkulu Province, it is located near the coast. One of the problems of the coastal area is the availability of clean water that will be utilised by the surrounding population. People in the Kelurahan Berkas area are very dependent on the existence of groundwater as clean water to be used in their daily lives. There are also dug wells and boreholes owned by the community with relatively shallow depths that are still not optimal in obtaining clean water because the groundwater obtained still tastes brackish and salty. This condition is caused by the position of settlements right on the coast to the influence of intrastate water (Wardhana et al., 2017). Seawater intrusion is the movement of seawater into freshwater aquifers that can contaminate groundwater sources (Asri, 2024). As an area that is only about two kilometres from the coast, Teluk Segara Sub-district's groundwater is highly vulnerable to seawater intrusion. This chance of intrusion is even greater because groundwater is exploited almost all year round. The groundwater table will decline if exploited continuously due to the loss of water that fills the voids in the soil grains. This can cause seawater to seep into the land because of the empty space in the aquifer (Wijaya et al., 2019). Some aspects of life that can be affected by seawater intrusion are health problems of people and ecosystems, decreased soil fertility, building damage and many more. Therefore, it is necessary to conduct research to determine the presence of clean water in Teluk Segara District (Septiardi et al., 2019).

The phenomenon of seawater intrusion into groundwater is common in coastal cities in Indonesia. Abdul's research (2020) identified that groundwater in the Kandang Limun Campus area of UNIB contains very high chloride and total dissolved solid (TDS) values that do not meet groundwater quality standards, TDS values in UNIB groundwater are significantly higher in the rainy season, and are significantly positively correlated with pH values; and there is no correlation between chloride values with TDS and pH in UNIB groundwater.

The geoelectric method used is the Wenner-Schlumberger configuration geoelectric method. This research is processed using Res2DInv software, to see information on subsurface structures (Djereng et al., 2017). Taking data by injecting current into underground materials that have varying resistivity will provide information about the structure of the material passed by the current (Saranga et al., 2016). In an effort to carry out activities to find out the composition of the subsurface layer of the earth, conducting investigation activities through the ground surface or underground must be carried out, in order to determine the presence or absence of a water-bearing layer (aquifer) (Nugroho & Farida A, 2016). Although groundwater cannot be directly observed from above the earth's surface, investigation of the ground surface is a fairly important start of the investigation, at least it can provide an overview of the location of the groundwater. This research is expected to provide information to the community around Teluk Segara Sub-district, especially the Berkas area, regarding the depth and distribution of potential clean water that can be used by the community for daily needs.

Electrical Resistivity Tomography (ERT) has been used extensively over the years for groundwater exploration. The technique is used in conjunction with drilling to determine the resistivity value of alluvium and the influence of groundwater. This study was conducted in an area with a thick geological record of alluvium. The results show that groundwater will lower the resistivity value and mud will also lower the resistivity value which is lower than the effect of groundwater. Groundwater reservoirs were found in saturated sand, saturated sandy loam and saturated silt, clay and sand. Electrical Resistivity Tomography (ERT) data, on the other hand, provides a continuous profile of the subsurface resistivity distribution along a survey line or grid. These data offer relatively high spatial coverage, capturing information between measurement locations.

RESEARCH METHODS

Geology Regional

Bengkulu City is located at the coordinates of 30°45‘ - 30°59’ South latitude and 102°14‘ - 102°22’ East longitude. This geographical position is located on the western coast of Sumatra Island, directly facing the Indian Ocean. The area of Bengkulu City consists of 8 (eight) sub-districts namely Selebar sub-district, Kampung Melayu sub-district, Gading Cempaka sub-district, Ratu Agung sub-district, Ratu Samban sub-district, Teluk Segara sub-district, Sungai Serut sub-district, Muara Bangkahulu sub-district (Nofirman, 2016).

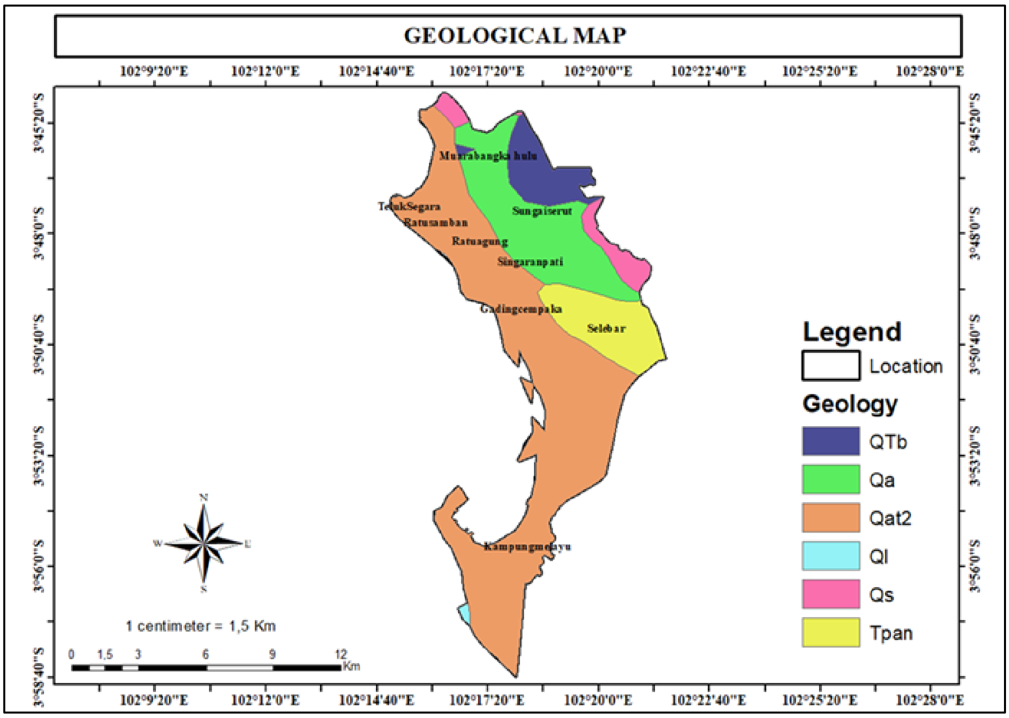


Figure 1. Regional Geological Map of Bengkulu City

Based on the geological sheet map (Gafoer, S., Amin, T.C., 2012) Bengkulu City has six geological formations, namely,

1. Undak Aluvium (Qat)

A geological unit that occurs in the form of the youngest group of surface deposits, dated Holocene Quaternary with materials composed of sand, silt, clay and gravel accumulated due to river, beach and swamp deposits. This geological unit is spread throughout Bengkulu City, from the north to the south, but does not reach the eastern part of the city.

2. Alluvium (Qa)

This geological unit formed during the Holocene period is composed of boulders, pebbles, sand, clay, silt and mud. This geological unit is scattered in Singaran Pati sub-district, Sungai Serut sub-district, and Muara Bangkahulu sub-district.

3. Swamp Deposits (Qs)

Geological unit in the form of Holocene aged surface deposits in the form of sand, silt and mud containing plant remains. Scattered in Singaran Pati sub-district, and the northern part of Muara Bangkahulu sub-district.

4. Coral Reef Limestone (Ql)

The geological unit in the form of reef limestone of Plistocene age is spread in the coastal area in several sub-districts, namely Kampung Melayu sub-district, Ratu Samban sub-district and Ratu Agung sub-district.

5. Bintunan Formation (QTb)

A geological unit composed of conglomerate of various materials, breccia, reef limestone, tuffaceous claystone, mudstone, eroded wood. The bintunan formation is found in the southern part of Selebar sub-district and the eastern part of Muara Bangkahulu sub-district.

6. Andesite (Tpan)

The geological unit with andesite material that occurs as a breakthrough rock is found only in Selebar Sub-district.

The research area, Teluk Segara Sub-district, has Undak Aluvium (Qat) formation which is composed of sand, silt, clay and gravel.

Acquisition data

This research used resistivity geoelectric equipment in Teluk Segara Sub-district, Berkas Village, Bengkulu Province. Field measurements were conducted in August 2024 with three lines spread along Berkas Village, with a track length of 240 metres (Figure 2). The track length of 240 metres was used to see the variation of resistivity values and the potential depth charge of groundwater penetration of deeper currents to determine the zone of change in the research area. This research field is located at latitude-longitude coordinates (3°47'50.7‘’LS and 102°15'13.7‘’BT). The software used in this research is Res2DInv to produce a 2D resistivity cross section model to determine the dominating rock lithology in the research area.

The software used in this research is Res2DInv. **Res2DInv** is a technique for processing and inversion of soil resistivity data in two dimensions. This technique is often used in geophysical exploration, especially to determine the resistivity distribution profile of soil or rock below the earth's surface. Resistivity itself is a measure of the ability of a material to conduct electric current, which can be influenced by many factors such as water content, minerals, or rock types.

The data collected from these geoelectric measurements is then used to create a 2D model of the subsurface resistivity distribution. This model depicts changes in soil resistivity based on depth and horizontal position.

Data inversion (Res2DInversion) is the process of calculating a soil resistivity distribution that fits the collected measurement data.

This research also uses the Wenner-Schlumberger configuration. The Wenner-Schlumberger configuration is one of the configurations used in geoelectric methods with a combined method between the Wenner and Schlumberger configurations. This configuration has good sensitivity to see a vertical cross-section of the subsurface model. The configuration for depth surveys is well used for geotechnical surveys, one of which is to find hard layers below the surface for building foundations.

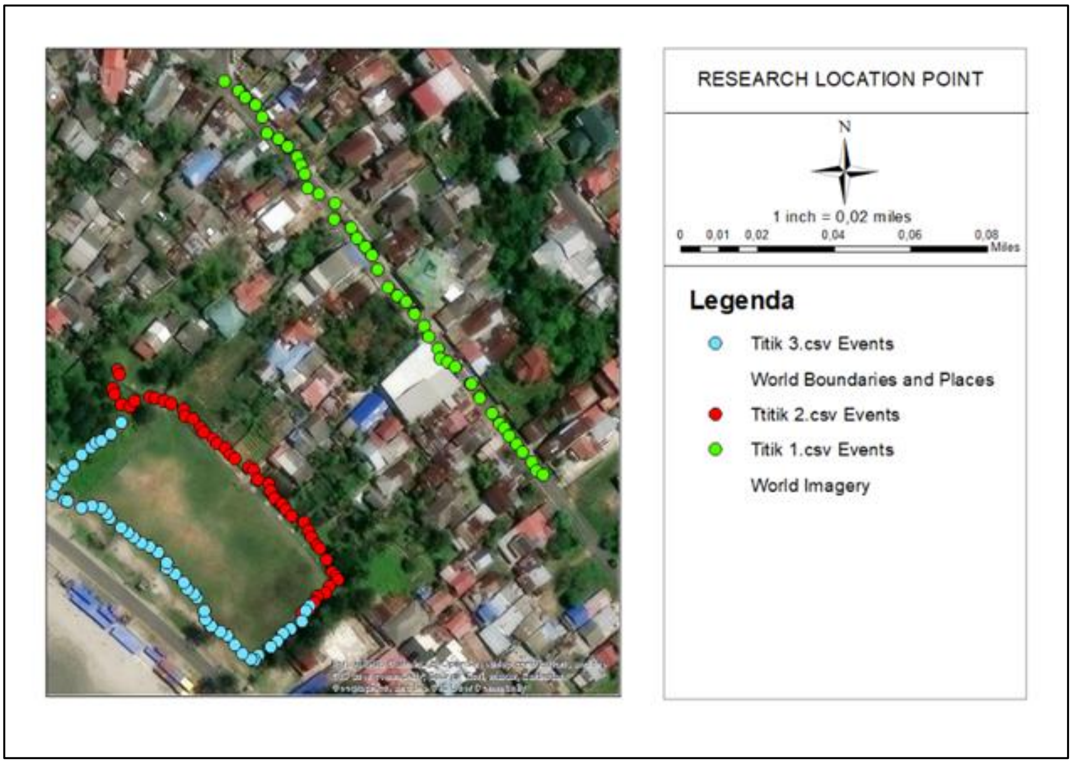
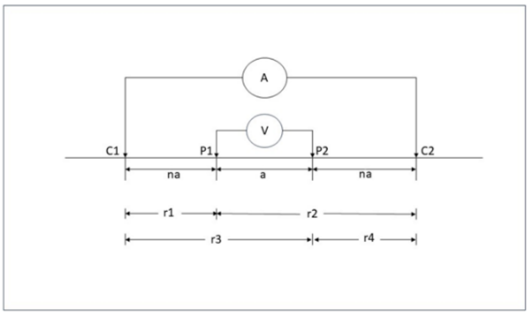


Figure 2. Research Maps

The electrode arrangement in the Wenner-Schlumberger configuration can be seen in:



$$R = \frac{\Delta V}{I}$$

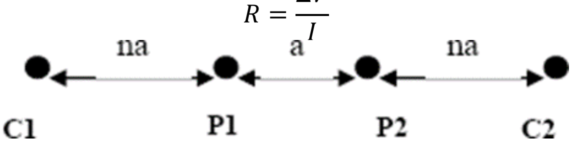


Figure 3. Wenner-Schlumberger configuration

This configuration is sensitive for both horizontal and vertical structures, where R is the electrical resistance in ohms. ΔV is the potential difference in Volts. And I is the amount of electric current in Amperes.

$$K=\rho \frac{L}{A}$$

$$\rho = \frac{VA}{IL}$$

$$\sigma = \frac{I}{\rho} \qquad (1)$$

In each configuration in the geoelectric method there is a geometry factor (K) which is the sum of the corrections from the location of the two potential electrodes to the area of the two current electrodes. The geometry factor is defined in Equation 2. From Equation 1, the geometry factor of the Wenner configuration will be obtained (Hana Raihana, Khairun Nazli, Suhendra,Refrizon, 2023), namely:

$$K = 2\pi\{\left(\frac{1}{\alpha} - \frac{1}{2\alpha}\right) - \left(\frac{1}{2\alpha} - \frac{1}{3\alpha}\right)\} - 1$$

$$K = 2\pi\{(\tfrac{2}{6\alpha})\text{-}1\text{=}2\{(\tfrac{1}{3\alpha})\}\} - 1 = 2\pi\{3\alpha\}$$

$$K = 6\pi\alpha \qquad (2)$$

Use International Units (MKS) or CGS as the units of dimension (SI units are recommended). The British system of quantities can be used as secondary quantities written in brackets. Avoid using SI and CGS together, for example current magnitude in amperes and magnetic field magnitude in oersted. This will cause errors because the dimensions do not match. Clearly state the units used in each quantity, either SI or CGS units.

RESULTS AND DISCUSSION

The Groundwater Hydrological System refers to the flow and distribution of water below the earth's surface, known as groundwater. This system is an important part of the larger hydrological cycle, which includes the movement of water through the atmosphere, the Earth's surface and into the soil. Groundwater plays a major role in supporting a variety of human activities, such as clean water supply, agriculture, and industry, as well as influencing soil and ecosystem stability. Seawater intrusion occurs due to phenomena caused by various natural factors and human activities, including overexploitation of groundwater, sea level rise, changes in aquifer pressure, and geological activities. This phenomenon is further exacerbated by climate change and urbanisation in coastal areas. To prevent or mitigate their impacts, wise management of groundwater resources, reduction of overexploitation, and the use of technologies for efficient water management are essential.

The results of research conducted with the Wenner-Schlumberger configuration geoelectric method in Berkas Village, Teluk Segara District, Bengkulu City, were carried out as many as three passes. The results of the 2D model illustrate several ranges of resistivity values which at certain depths show changes in the form of a decrease in resistivity value so that seawater intrusion is suspected in the research area. According to Sastrawan (2021) groundwater polluted by seawater will experience a decrease in resistivity value. This causes the visible difference in the resistivity value of groundwater polluted by seawater and unpolluted The measurement distance from the coastline affects the size of the resistivity value, the closer to the coastline the smaller the resistivity value and vice versa. Measurements on the first track are directed from east to northwest, while on the second track are directed from east to west, and on the third track are directed from east to northwest.

The research area experienced seawater intrusion which occurs due to seawater seeping into underground water, this depends on the permeability and porosity values. The smaller the permeability value of a rock, the more difficult it is for seawater to pass through. Because the cavities in the rock will be smaller. Likewise, if the porosity of the rock is greater, the possibility of water escaping is more difficult. This is seen from the ability of the rock to hold water. If the porosity is small, the sea water will easily pass through it.

This research applied a track with a length of 240 metres, spacing between electrodes 5 metres. The results obtained on the first track identified the distribution of resistivity with a value of 0.65 Ω.m - 371 Ω.m, while on the second track identified the distribution of resistivity with a value of 3.17 Ω.m - 5580 Ω.m, and on the third track identified the distribution of resistivity with a value of 1.65 Ω.m - 277 Ω.m, each track reached varying depths including the first track has a depth of 33.8 metres, on the second track 43.1 metres and on the third track 33.8 metres.

In this first pass, it can be seen that the layer is thought to be a shallow aquifer containing groundwater. This first pass has a relatively small resistivity value of around 1.61 Ω.m to 3.98 Ω.m, and is at a depth of 8 metres to 24 metres, while the second pass has a relatively small resistivity value of 3.17 Ω.m to 26.8 Ω.m, and the third pass has a relatively small resistivity value of around 1.62 Ω.m to 7.05 Ω.m.

Arliska's research (2022), said that rocks that have good permeability and porosity such as sandstone and gravel in coastal areas have a high probability of being easily infiltrated by seawater. Shallow aquifers containing groundwater are thought to be in layers with sand, sandy clay and sand lithologies. The relatively low resistivity value in the first pass is due to the shallow aquifer containing groundwater that has salinity, due to seawater intrusion so that the groundwater becomes brackish. In the first pass in the western direction there is a deeper distribution of seawater intrusion compared to the eastern direction, because in the western direction it leads directly to the sea.

The study area is dominated by a layer of pasiran clay which is an impermeable layer, therefore although there may be groundwater flowing in this layer, it is still in small quantities. Sand allows the presence of groundwater, because sand has a large porosity and permeability and groundwater is between the pores of the sand, so that the layer is very potential for groundwater.

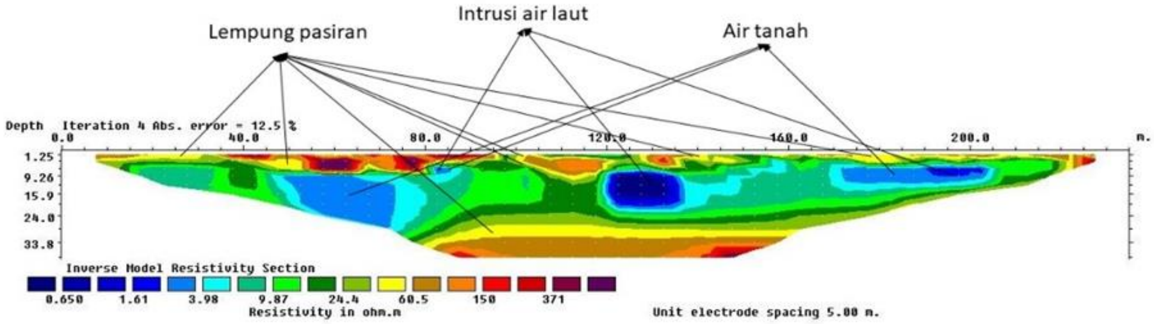


Figure 4. 2D cross section of line 1

The figure below the second traverse shows the distribution of seawater intrusion in the shallow aquifer layer (unconfined aquifer) in the study area shown by the solid blue coloured area. The results of the second pass show that the shallow aquifer containing groundwater has been affected by seawater intrusion with a resistivity value of 3.17 Ω.m to 9.23 Ω.m, and is at a depth of 9 metres to 30 metres. The influence of this intrusion causes the groundwater to have salt content, but with a relatively low percentage so that the groundwater at the study site feels brackish.

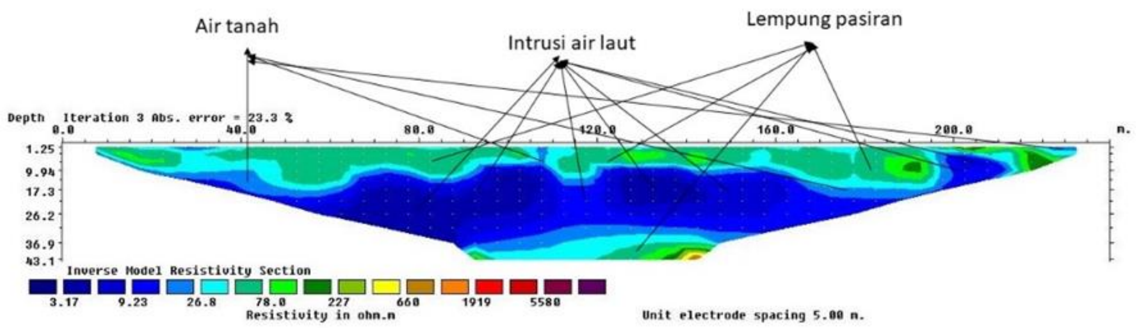


Figure 5. 2D cross section of line 2

The picture below is the third track that has a shallow aquifer on the third track there is also groundwater at a relatively low resistivity of around 1.62 Ω.m to 7.05 Ω.m, a small resistivity value caused by a shallow aquifer containing groundwater that has salinity due to the intrusion of sea water so that groundwater to the east of the research point the water feels brackish. This is because the eastern side of the track leads directly to the sea. So that the groundwater in the east has a brackish taste.

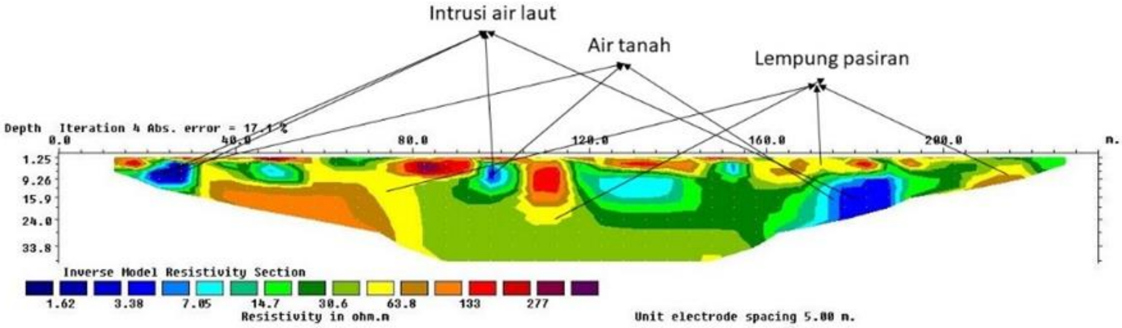


Figure 6. 2D cross section of line 3

Seawater intrusion is due to the fact that the study site is a coastal area approximately 200 metres from the sea. The lithology of the aquifer layer is interpreted as clay, pasiran clay, and clay under the overburden. Sand is a lithology that has relatively high porosity and permeability so that it easily passes fluids. Seawater can seep through the sand layer, contaminating groundwater in the shallow aquifer.

Table 1. Interpretation of 2D Geoelectric Line

No	Site	Depth	Resistivity	Lithology
1	Line 1	7m – 20m	0,65 Ω.m – 1,61 Ω.m	Seawater intrusion
		8m – 24m	3,98 Ω.m	Groundwater
		7m – 29m	9,87 Ω.m – 24,4 Ω.m	Clay
		1m – 33,8m	60,5 Ω.m	Passive clay
		1m – 40m	150 Ω.m – 371 Ω.m	Sand
2	Line 2	8m – 36,9m	3,17 Ω.m – 9,23 Ω.m	Seawater intrusion
		1,25m – 20m	26,8 Ω.m	Groundwater
		1,25m – 43,1m	78,0 Ω.m – 227 Ω.m	Clay
		9,94m – 41m	660 Ω.m	Passive clay
		1m – 43,1m	1919 Ω.m – 5580 Ω.m	Sand
3	Line 3	2m – 20m	1,62 Ω.m – 3,38 Ω.m	Seawater intrusion
		5m – 24m	7,05 Ω.m	Groundwater
		3m – 30m	14,7 Ω.m – 30,6 Ω.m	Clay
		1m – 40m	63,8 Ω.m	Passive clay
		1m – 39m	133 Ω.m – 277 Ω.m	Sand

CONCLUSION

Based on the research conducted in Berkas Village, Teluk Segara Subdistrict, Bengkulu City, it is concluded that in each track there is a layer of shallow aquifer (unconfined aquifer). On the first track (East - West) which has a resistivity value of 7.05 Ωm, and is at a depth of 8 metres to 24 metres. In the second pass the aquifer layer is at a depth of 1.25 metres to 20 metres with a resistivity value of 26.8 Ω.m, then in the third pass the aquifer layer is at a depth of 5 metres to 24 metres with a resistivity value of 7.05 Ω.m. Shallow aquifers containing groundwater are thought to be in layers with lithologies of clay, passive clay, and sand dominated by passive clay. the presence of groundwater on average is found at a depth of 1.25 metres to 24 metres but is intruded by seawater, this is because the research location is close to the coastal area and is approximately 200 metres away. The community is already aware of seawater intrusion and the impacts caused and has been able to adapt to existing conditions. Recommendations given in this study The community can dig or drill wells at a depth of more than 5 metres. It contains conclusions and some recommendations. It is not recommended in bullet points but in the form of paragraphs structured according to the order of the problems discussed in the article. In this study, it can inform the community of Segara Bay, especially residents of Brkas Village, where there is groundwater. Because the Brkas Village area is located on the coast, it is prone to seawater intrusion and lack of clean water, with this research it can appeal to residents in Brkas Village by finding existing clean water.

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