Identification of subsurface fluid flow using the 2D geoelectric method in Marunda, North Jakarta

M Farhan and M S Rosid

1Geophysics, FMIPA Universitas Indonesia, Depok 16424, Indonesia

Corresponding author: syamsu.rosid@ui.ac.id

Abstract. Jakarta is the most densely populated province in Indonesia and it will grow over time. This overwhelming population causes a decrease in the quality and supply of groundwater. Brines has been discovered in several areas in Jakarta. Several studies conducted by earth science researchers conclude that brine in Jakarta appears from either seawater intrusion or trapped connate water. This study focuses on the use of the geoelectric method to evaluate the groundwater quality problem in Kelurahan Marunda. Methods used in this study are resistivity, self-potential, and groundwater sampling. Conductivity, Salinity, pH and water table elevation are the parameters used in this study. These methods are done to observe subsurface groundwater quality, fluid flow and how far the seawater infiltrated. Based on the result of groundwater data of 40 wells, high conductivity and high salinity zones are found. High conductivity in this area affected mostly by the saline factor indicated by high salinity and neutral pH. The subsoil has low resistivity values showed by 2D resistivity data. Also, self-potential data displays a North-South groundwater subsurface fluid flow 1, 20 km from the coastline. Altogether, these data indicate seawater intrusion in Kelurahan Marunda, North Jakarta.

1. Introduction

Jakarta has the densest population in Indonesia with 10.3 million peoples in 2017 [1]. While water is the most basic need for humanity, Jakarta peoples with this massive amount find problems to obtain clean water sources. Only 40% of the citizen provided with clean water by the government agency (PAM) [2]. While the rest of them still rely on traditional wells or simple pump wells. In some locations, they found the groundwater is inedible for daily uses because it is brackish.

Some researchers have conducted on how the brackish water emerges. One study stated that the brackish water is not caused by seawater intrusion but is due to geological control of the structure. This control cause brines to rise from the bottom layer of the aquifer [3]. While other study stated that seawater intrusion caused this brackish water to emerge, especially in North Jakarta [4].

This study conducted to determine whether there is seawater intrusion in Jakarta's groundwater. To obtain the information, this study uses groundwater sampling, geoelectric resistivity, and the self-potential method. Groundwater sample data is acquired to determine the distribution map of groundwater quality. Then proceed with the acquisition of the resistivity geoelectric method to obtain information on the location, depth, and distribution of the high salinity zone in the Marunda village. This method used because it utilizes an electric current to investigate subsurface properties. Meanwhile, every single property has a unique resistivity and it can exactly identify brine. Brine identified with low resistivity in the geoelectric method ranged between 0-1 Ωm [5]. The results obtained will be compared to determine the direction of subsurface water flow.
This study has taken place in Kecamatan Cilincing, North Jakarta. Geologically, DKI Jakarta is directly adjacent to the coast in the northern region. This geological condition allows the Jakarta basin to be intruded by seawater especially in areas directly adjacent to the coast. This region consists of alluvium and beach ridge deposits [6]. Alluvium contains clay, silt, sand, gravel, and pebble, while beach ridge deposit contains fine to coarse sand and mollusk shells [7]. The rock content in this formation makes this area more likely to be intruded by seawater. Meanwhile, areas containing sand is more easily intruded because it has a higher permeability than alluvium. The geological map is shown in Figure 1.

![Geological map of study area modified from Turkandi, et al. [6].](image)

2. Method
Methods used in this study are the acquisition of three data from the location. These data include groundwater sampling, geoelectric resistivity, and self-potential methods. The parameters used in groundwater sampling are pH, water table, conductivity, and salinity. The data acquisition is then processed and modeled for the interpretation of the subsurface conditions.

3. Results and discussion

3.1 Groundwater data
Groundwater sampling resulted in 40 samples across the area. The water samples then measured in four different parameters, which are pH, water table, conductivity, and salinity. Figure 2a shows the water table contour of the area. Its elevation ranged from -0.5 to 6 m. It can be seen that the water table is decreasing towards the north.

The pH value of groundwater samples ranged from 6.5 - 8.4 (see Figure 2b). In the study area, the value is relatively neutral with ranging from 6.5 to 7.5, except in the Northwest to the Southeast which has a pH > 7.5. High pH might indicate high metal contents, but it needs further measurement.
The distribution of conductivity (in μS/cm units) in the study area is high in the north and low towards the south (see Figure 3(a)). In this result, there lies a very high conductivity value in the north. The conductivity of a solution can be influenced by metal contents or electrolyte solutions contained in the solution. The electrolyte solution in the form of salt also affects the conductivity value of a solution.

Figure 3(b) shows the distribution of groundwater salinity in mg/L units. The pattern of distribution of salinity values shows it is high in the northern region and lowers towards the south. This pattern resembles the distribution pattern of conductivity values. The value of dissolved salt content in measured groundwater has a range between 80 - 2500 mg/L.

The conductivity value of water can be influenced by two factors, dissolved metal contents and salt contents in the liquid. The number of metal minerals contained in water will affect the measured pH.
value while the dissolved salt content will affect the salinity of the solution. From the comparison of the distribution of conductivity and salinity values, it can be seen that their distribution patterns are relatively similar. Therefore, the conductivity values in the study area are most likely influenced by dissolved salt levels rather than metal content.

3.2 Resistivity data
The study area of geoelectric methods measured trajectories with each line stretching along 160 meters. The following figure is a map of the study area with the track carried out measurements marked with a red line.

![Figure 4](image)

**Figure 4.** The lines of geoelectric resistivity and self-potential measurements.

As shown in Figure 5, out of the five resistivity sections shown, it can be seen that anomalies of low type resistance appear on each line. The top aquifer layer mostly contaminated by saline water. Layers with resistivity value below 1 $\Omega m$ are indicated to be a manifestation of brine entering the layer marked with red. Another line in this study has a relatively similar resistivity value and range. These layers prove the potential of salt/brackish water emergence in the study area. Whereas anomaly 1-5 $\Omega m$ marked with green is suspected to be a layer of sandstone containing brackish water so that it has low resistivity.
3.3 Self-potential data
The self-potential data (see Figure 6) shows that the subsurface fluid flow inline 1-3 directed from north to south. Whereas the subsurface fluid flow inline 4 and 5 are directed south-north. The direction of this flow can be seen from the value of the low potential difference (yellow) in the south compared to the north with the high potential difference value (red). The distance of line 3 from the shoreline is around 1.20 meters.

Figure 5. Resistivity distribution of (a) line 1, (b) line 2 and 3, (c) line 4 and (d) line 5.

Figure 6. Self-Potential contour map of (a) lines 1-3 and (b) lines 4-5.
The direction of subsurface fluid flow can also be seen using gravity data, which processed into First Horizontal Derivative (FHD) as shown in Figure 7. The FHD gravity values indicate traces of subsurface fluid flow, while the direction of the flow will flow from low to high contrast values. From the figure, it can be seen that the direction of subsurface flow starts from a low value in blue to a high value in red. The results of this FHD show similarity to the geological formation map, where the flow is relatively Northeast to Southwest. From the geological and FHD maps below, it is suspected that seawater intruded towards the mainland through the formation of the coastal embankment (yellow) because this formation has a high permeability value so that seawater is easier to infiltrate the formation [7].

Figure 7. Comparison of First Horizontal Derivative (right) and geological map of the area (left) [7].

4. Conclusion
In this study area, the water table elevation is decreasing towards the North. The groundwater here tends to conductive and very saline water with a salinity of more than 1000 mg/L. The conductive water in the study area is more influenced by dissolved salts. Saline water is visible on the shallow aquifer layer in almost all resistivity lines. The saltwater or brackish water in shallow aquifers of Kelurahan Marunda is believed caused by seawater intrusion.

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