Analytical comparison of electrode configuration on 2D geoelectric method for identification of water seepage in the lake body

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Abstract. The geoelectric method is a geophysical method based on the resistivity value of the material. The resistivity value gives an overview of the structure found at the observation site. The electrode configurations used are the Dipole-Dipole, Wenner-Alpha, Wenner-Schlumberger, and Pole-Dipole. The analytical measurement was carried out in the lake body with a track length of 48 meters. From the measurement results, we obtained a seepage of water in the lake body with a resistivity value <5 Ohmmeters. The observation site is dominated by clay type structure, which is found almost in all of the results of the geoelectric electrode configuration. Based on the results of the structural overview shows that the type of electrode configuration has advantages and disadvantages. The Wenner-Schlumberger configuration is very detailed with per layer structure and distribution but has the longest measurement time. Dipole-Dipole configuration has the advantage of being very sensitive to changes in vertical structure and the fastest measurement time, but not very good in horizontal structures. The Wenner-Alpha method is very sensitive to horizontal structural changes and has a moderate measurement time, but less sensitive to vertical structure changes. The pole-dipole configuration has a fast time and a moderate level of sensitivity at shallow depth. Based on the results, the Dipole-Dipole method is highly recommended because of the fast measurement time and the position of seepage can be found easier than the other methods.

1. Introduction
Lake or reservoir is an artificial civilian building that functions as a rainwater catchment area so it does not overflow in residential areas. Water seepage is one of the causes of erosion in lakes or reservoir [1]. To minimize the impact of water seepage, it is necessary to do some research in the study area. The existence of the lake needs to be monitored by the structure of the lake body to prevent water seepage. Some studies have succeeded in knowing the impact and also the rate of seepage that occurs. Heat pulse and ultrasonic waves are proven to be able to measure the water seepage rate, but special attention is needed to the measurement interval, tide elevation, research area, and water seepage points [2,3]. In this paper, we have a focus to find out the points or areas that have the potential to be affected by water seepage. We use the geophysical method to determine the position of water seepage in the lake body, which is the geoelectric method.
From many studies, geoelectric can be used for many kinds of interpretations. Geoelectric can be used for determine precursor of the earthquake, aquifer properties, aquifer hydraulic conductivity, ground-water contamination, etc [4–7]. Some studies have the same focus as this paper, which is to find the location of water seepage using the geoelectric method. But they only use Schlumberger and dipole-dipole configuration [8,9]. Based on that, the paper we made is the result of data processing using four kinds of configurations, namely: Dipole-dipole, Wenner-Alpha, Wenner-Schlumberger, and Pole-dipole. With the existence of (four) different configurations, it is expected to determine the location of water seepage and what configuration is appropriate to use in the study area.

2. Methodology

The urgency of this paper arises because of the impact that water seepage can have on the body of the lake and also to find out which geoelectric configuration is more suitable to determine the position of the water seepage in the body of the lake. The survey itself used four geoelectrical configurations: Dipole-Dipole, Wenner-Alpha, Wenner-Schlumberger, and Pole-Dipole. The acquisition trajectory is located at the body of the lake along 48 meters from east to west, can be seen in figure 1(a). With the acquisition trajectory it is easy to take measurements and become a controlled variable due to differences in each geoelectric configuration used.

The area for data measurement is at Penggilingan, Cakung, East Jakarta. In general, it is necessary to analyze the geological map to determine the conditions around the area to make correlations in the data processing. From the Geological Map [10], it was found that the Geological structure of the study area was composed of Alluvium. The area of the study site is a former swamp that was dense so that when it rains there is a lot of puddles caused by the nature of the Alluvium material.

From the data measurement, we obtained the value of electric current and voltage which is then calculations were performed to get the apparent resistivity data. After getting apparent resistivity data, the processing is continued until it gets the true resistivity data. The true resistivity data was processed using RES2DINV software. RES2DINV is a special software in processing data from the geoelectric measurement using inverse method. We use Least-Square Inversion method to process the true resistivity data. Least-Square Inversion is a data processing method that focuses on managing iteration to get the smallest error value. From the data processing, it is obtained that the 2D true resistivity cross-section can be seen in figure 2-5. Systematically and more presently, the steps can be seen in figure 1b.

![Figure 1.](image-url)
3. Results
From data processing, we get four kinds of cross-sections representing four geoelectric configurations. The resistivity value which indicates water seepage is less than 4 Ωm and mostly less than 2 Ωm. In the cross section it is seen in dark blue.

![Figure 2](image)

**Figure 2.** (a) 2D measured apparent resistivity (b) 2D calculated apparent resistivity and (c) 2D true resistivity cross-section of the Dipole-Dipole configuration geoelectric.

From figure 2(a-b), we get the 2D measured and calculated apparent resistivity cross-section. These results need further processing in iteration so that the RMS error value can be reduced. The difference can be seen through the location of potential water seepage point. In measurements using the Dipole-Dipole configuration with a path length of 48 meters, a depth of 6.82 meters and an RMS error of 29.3% were obtained. The depth and length values are quite balanced and the measurement time is not too long to make this method is the most suitable method in the geology of the study area. From figure 2(c) we can see the point of potential water seepage at the location of the lake as many as 4 points (marked with a red line) with a resistivity value <2 Ωm. The first point is found at a distance of 8-20 meters with a depth of 2 meters. The second point is found at a distance of 24-30 meters with a depth of 2 meters. The third point is found at a distance of 32-34 meters with a depth of 2 meters. The fourth point is found at a distance of 36-38 meters with a depth of 2 meters.

![Figure 3](image)

**Figure 3.** (a) 2D measured apparent resistivity (b) 2D calculated apparent resistivity and (c) 2D true resistivity cross-section of the Wenner-Alpha configuration geoelectric.
The results of the 2D measured and calculated apparent resistivity cross-section in figure 3(a-b), shows the difference is not far from 2D true resistivity cross-section. But still, it needs iteration processing so that the cross-section is smoother and clearer. In measurements using the Wenner-Alpha configuration with a length of 32 meters, a depth of 5.23 meters and an RMS error of 14.4% were obtained. The length is different from the other configuration because the electrode mounting distance and is only used to duplicate the results of other configurations. From figure 3(c) we can see the point of potential water seepage at the location of the lake as much as 3 points (marked with a red line) with a resistivity value <4 Ωm. The first point is found at a distance of 11-13 meters with a depth of 0.25 meters. The second point is found at a distance of 9-22 meters with a depth of 2 meters. The third point at a distance of 25-28 meters with a depth of 2 meters.

![Figure 3](image)

*Figure 3. (a) 2D measured apparent resistivity (b) 2D calculated apparent and (c) 2D true resistivity cross-section of the Wenner-Schlumberger configuration geoelectric.*

In measurements using the Wenner-Schlumberger configuration with a path length of 48 meters, a depth of 7.28 meters and an RMS error of 15.6% were obtained. The depth value is bigger than the other configuration because the longest time measurement. From figure 4(c) we can see the point of potential water seepage at the location of the lake as much as 2 points (marked with a red line) with a resistivity value <2 Ωm. The first point is found at a distance of 9-16 meters with a depth of 3.46 meters. The second point is found at a distance of 25-35 meters with a depth of 3.46 meters.
Figure 5. (a) 2D measured apparent resistivity (b) 2D calculated apparent and (c) 2D true resistivity cross-section of the Pole-Dipole configuration geoelectric.

There is a large potential point for water seepage in figure 5(a-b). It is necessary to further process whether a smaller RMS error value will get the same result. But in fact, 2D true resistivity shows 3 smaller potential seepage points. In measurements using the Pole-Dipole configuration with a path length of 48 meters, a depth of 3.53 meters and an RMS error of 16.7% were obtained. The depth value is very shallow because this configuration usually used for shallow depth. From figure 5(c) we can see the point of potential seepage of water at the location of the lake as much as 3 points (marked with a red line) the resistivity value <2 Ωm. The first point is found at a distance of 3-6 meters with a depth of 2.2 meters. The second point is found at a distance of 23-25 meters with a depth of 2.2 meters. The third point is found at a distance of 36-38 meters with a depth of 2.2 meters.

4. Discussion

Based on table 1, information is obtained that the Wenner-Schlumberger method has the deepest penetration among the other methods. The Wenner-Alpha method has the smallest error RMS value of 14.4 meters. From the results of the Dipole-Dipole configuration, horizontal detail can be seen to produce a point of potential seepage to 4 points. If the Wenner-Alpha configuration has the potential for water seepage, the detail leads to vertical with 2 points found. The Wenner-Schlumberger configuration is very detailed vertically and horizontally resulting in a structural cross-section at the measurement location. Whereas the Pole-Dipole configuration only gets details with a maximum depth of 3.53 meters.

Table 1. Differences in Geoelectric Measurements

| Configuration         | Depth (m) | RMS Error (%) | Resistivity (Ωm) |
|-----------------------|-----------|---------------|------------------|
| Dipole-Dipole         | 6.82      | 29.3          | <2               |
| Wenner-Alpha          | 5.23      | 14.4          | <4               |
| Wenner-Schlumberger   | 7.38      | 15.6          | <2               |
| Pole-Dipole           | 3.53      | 16.7          | <2               |

Based on the explanation, it can be concluded that the geoelectric configuration must be selected based on the case. This is because each configuration has its own sensitivity level. In this case for determining the seepage potential in the body of the lake, we get the result that the Dipole-Dipole configuration is the more suitable configuration, this is because the dipole-dipole configuration has a fairly balanced value between depth and length, it also displays more water seepage potential points
(this needs to be watched out because it is very dangerous when it has four potential water seepage points), and also have medium processing time. Even so, there are drawbacks because the RMS error value is greater than other configurations.

5. Conclusion
In the results of Geoelectric measurements with four configurations (Dipole-Dipole, Wenner-Alpha, Wenner-Schlumberger, and pole-Dipole), we found the potential water seepage with a resistivity value <2 Ωm and depth of 2 meters. The Wenner-Alpha configuration has the lowest error RMS value with a value of 14.4% and the Wenner-Schlumberger configuration has the deepest penetration of 7.38 meters. The Pole-Dipole configuration has too shallow coverage, so it is not suitable in the conditions and problems that exist in the study area. The Dipole-Dipole configuration has a fairly balanced value between depth and length, also have medium processing time. To determine the potential for water seepage in the body of the lake in this observation we recommended to use the Dipole-Dipole configuration because with this method the results obtained are more potential points.

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