An Experiment of Determining Buried Channel Using ERP and IP

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**Abstract.** Geophysical methods became an important technique for engineer since several decades. They have been used to study the engineering problem which has to be solved urgently. Detecting underground water channels is one of the most important issues in prevention and mitigation of water surge hazards in underground engineering. In this research, we use electrical resistivity profiling (ERP) and induced potential (IP) as the guide is proposed. By applying different configurations and varied electrode spacing, the water channel can be analysed by its resistivity and chargeability variation. The ERP method is sensitive to resistive layers which indicates the empty channel while IP can detect the presence of water. This is seen from both synthetic and measured data, where the resistivity of 60 \(\Omega\cdot\text{m}\) approximately implies that the channel is not filled with water, while in the area with moderate chargeability, ranging from 15 to 25 ms, indicates that water exists shrouding the channel. By understanding the known underground channel well, we can expand the study for other engineering problems and as references to apply the method in similar cases, such as the underground cavity which can be very important for infrastructure.

**Keywords:** ERP, IP, Channel, Synthetic data

1. Introduction

Geophysical method became an important technique for engineer including in Indonesia. They have been used to study the engineering problem which has to be solved urgently, such as in civil engineering field [1, 2, 3]. The problems such as the cavity collapse which can be caused by the human made or natural process. Here, the method such as electrical resistivity profiling (ERP) and induced potential (IP) can be the powerful tool to supply the information on sub-surface by providing the resistivity and chargeability variation of the material. Those techniques are also cost-effective and provide the fast result [2]. The ERP method is sensitive to resistive layers which is possible to detect the channel when it is empty. For ERP, if the water content is greater, the resistivity decreases [4, 5, 6]. IP can show the presence of water in material when clay content of the soil undergoing swelling due to increased water which can increase chargeability of the rock [4, 7]. By conducting these techniques, we can reduce the ambiguity. ERP is carried out in ITERA (Institut Teknologi Sumatera)’s campus area on the water channel by applying different configuration including Dipole-dipole, Wenner-alfa and Schlumberger array and IP measurements are conducted to verify the result. Theoretically, the dipole-dipole configuration provides higher image resolution comparing to the others, and it is sensitive to the resistivity changes horizontally [8]. This configuration is expected to produce satisfactory results for water channels. This research aims to distinguish the water channel from its surroundings, which sometimes have very contras in resistivities. By knowing the difference variation of the resistivity value, it is also a challenge to see the contras between air zone and the resistivity of the rocks or other materials surrounding the channel. Ones we can understand the known underground channel well, the study can be expanded for other engineering problems and as references to applied the method in similar cases, such as the underground cavity which can be very important for infrastructures.
2. Method

The ERP data measurement is done by injecting current downward surface through transmitter’s electrodes and measuring subsurface response by measuring the potential at the receiver electrodes. The multi-channel geoelectric ARES (Automatic Resistivity System) is used in this research. ARES equipment consists of four cables, each 120 m in lengths, which are connected to steel electrodes in the soil cover with the maximum electrode spacing 10 m. The Automatic Resistivity System works with 48 electrodes. We use an electrode spacing of 1 and 2 m, which results in a maximum penetration depth of 10 or 21 m, respectively. In this research, we carry out the data using three different configurations, namely Dipole-dipole, Schlumberger, and Wenner.

We have also carried out synthetic data for model experiments in order to explore the possibilities and limitations of the resistivity method. The forward modeling is conducted to generate synthetic data by making the model anomaly and assigning the different cells with a specific resistivity value [9]. The synthetic data should be equivalent to the data measured in the field. Synthetic data is calculated using the program ZonRes2D [10]. The inversion is performed for Wenner, Schlumberger, and dipole-dipole array using the software Res2DInv [11]. The models are inverted from both synthetic data and field data.
3. Results and Discussion

The background model anomaly is generated from geological information in the study area, which is mostly covered by tuff with a resistivity of 50 Ωm approximately. The first synthetic model consists of two empty channels with high resistivity of 500 Ωm with a diameter of 1 m. The depth of channel 1 is about 2.5 m from the subsurface and the second channel is very close to the surface (Figure 3a). From this model, we generate the synthetic data using different electrode configurations and then running the inversion. Figure 3b is the inverted model generated from the dipole-dipole array. The result shows two anomalies associated with the channels. Channel 1 can be found with moderate resistivity while channel 2 has high resistivity, seen clearly in the model. Moderate resistivity in channel 1 is caused by the material surrounding the channel. The synthetic models using Wenner (Figure 3c) and Schlumberger array do not see the anomaly of channel 1 while channel 2 clearly identifies from the model with high resistivity.

![Figure 3](image.png)

**Figure 3** 2D Synthetic model showing the empty channel 1 and 2 with high resistivity (a). The inverted model produced from first synthetic data with dipole-dipole array (b), Wenner alfa (b) and Schlumberger (d) configuration. 2D Synthetic model, channel 1 fully filled with water while channel 2 is empty (e). The inverted model of the second synthetic data with Dipole-dipole (f), Wenner alfa (g) and Schlumberger array (h).

The second synthetic model with low resistivity represents to channel 1 with fully filled of water while the second channel is empty (high resistivity). In inverted model using the dipole-dipole configuration, it is clearly displayed low resistivity anomaly (Figure 3e) associated to the water, and channel 2 which is represented by resistive zone. Similarly, in the first case, for Wenner, we see no conductive anomaly in channel 1 but channel 2 was seen clearly the resistive zone. Schlumberger configuration also displays the conductive zone but poor resolution for the bottom of the channel 1. From the two different synthetic models, the dipole-dipole array (Figure 3b & 3f) produce a reasonably good image, which can see both conductive and resistive zone. This is consistent with the theory. Thus, we made a third synthetic model, where channel 1 was partially filled with water, and channel 2 is empty (Figure 4a). Unfortunately, the inverted model does not see the target anomaly of channel 1.
From the result obtained from three different synthetic models above, so that in field measurements we combine ERP and IP methods using dipole-dipole array which is expected to produce the better result.

Figure 4 2D synthetic model (Experiment 3), showing channel 1 partially filled with water and channel 2 is empty (a), and the inverted model of dipole-dipole configuration.

Figure 5 shows the inverted result from the field data with 1 m electrode spacing using dipole-dipole and Schlumberger array. Inverted model of both dipole-dipole (Figure 5a) and Schlumberger (Figure 5b) does not show the clear target anomaly. Although, the area with a resistivity value of 60 Ωm can be found in the inverted model which is similar to the synthetic result at a depth 2 m approximately associated to channel 1, but the geometry of the channel could not visible. This is caused by the heterogeneity of the subsurface so that the target is obscured by the presence of material around it. To anticipate this, we continued the measurement by increasing the electrode spacing.
Figure 5 Inverted model with 1 m electrode spacing using dipole-dipole (a) and Schlumberger (b) configuration.

Figure 6 is the inverted model obtained from field data using dipole-dipole, Wenner and Schlumberger array with 2 m electrode spacing. The tree-models show the better result compare to the model with 1 m spacing. Among the three models, Dipole-dipole shows better image quality. The thickness of the target (channel 1), approximately 1 m, is more clearly visible with moderate resistivity similar to the synthetic result and even channel 2 shows a high resistivity value representing the empty channel. Based on the recommendations in the synthetic model, if the channel is partially filled with water or there is water seepage around the tunnel, then we extend our research by carried out IP measurements with 2-meter electrode spacing and dipole-dipole configuration.

Figure 6 Inverted model from field data using dipole-dipole (a) Wenner (b) and Schlumberger (c) configuration with 2 m electrode spacing.
Results from IP data (Figure 7) show the anomaly in the targets. Both channel 1 and 2 show the moderate chargeability, ranging from 15 to 25 ms. The higher chargeability in channels 1 and 2 indicates the presence of water around the channel. This may be caused by water seepage in the channel.

![Figure 7 2D inverted chargeability model obtained from IP field measurement with 2 m electrode spacing and Dipole-dipole array: Line 1 (Above) and Line 2 (Below).](image)

4. Conclusion

The results from ERP and IP show that combinations of these methods are able to locate the channel. ERP crossing the channel give responses from both experimental model and field data, and also the IP model can characterize the existence of the water surrounding the channel. Based on the combined resistivity and IP results, an interpretation model is proposed.

The case study presented here shows that ERP method is able to provide both the high resistive zones associated with the empty channel and IP can confirm the water seepage problems in channels. The resistivity method using dipole-dipole array is capable of identifying the target, indicating the width and depth of the zone. Meanwhile, IP can differentiate between area with the low and the high water content.

In the future, the study can be extent to identify other engineering problems and as references to apply the method in similar cases, such as the underground cavity which can be very important for infrastructures. The model should be tested to investigate other channel. It is also needed to do the lab measurement for different rock/material types in the study to compare the resistivity value in our results.

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