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# PREDICTION OF GROUNDWATER LEVEL IN SLOPE AREAS BY USING RESISTIVITY METHOD

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**Abstract**
*Nowadays, so many methods of in-situ testing such as piezometercan be applied to explore and investigate the presence of water in the ground especially in the hilly areas. The groundwater table is one of the main important factors in slope stability design. Therefore, a research has been conducted and a two-dimensional electrical resistivity imaging was carried out to predict the groundwater table at slope areas. These techniques can be used to image the slopes, measure and make predictions on the groundwater table. The groundwater table of the slopes is generally low, causing the soils to be mostly unsaturated except immediately after a rainfall. Generally, the rain water that infiltrates into the ground will increase the groundwater table and hence trigger slope failures. In the conventional method; a piezometer is normally used to monitor the groundwater level. However, the results that came from the piezometer are still not enough to be as a reference to predict the rise of groundwater table at the slope areas. As an extra precaution any measures, the two-dimensional electrical resistivity imaging method have been used to assist the monitoring works on slopes to get additional information and assist in the design of slope stability.*

**Keywords:**Groundwater, Two-Dimensional Electrical Resistivity Imaging, Slopes.

## 1. Introduction

In a tropical country such as Malaysia, natural processes such as weathering and erosion are very common. Such processes will contribute in the increasing amount of unconsolidated slope material and therefore further gave a greater possibility of natural hazards such as slope failures especially in hilly areas. This is assisted by infiltration of rain water as rains are very frequent in the tropical region. Thus may also increases the chances of having groundwater level beneath the slopes. Therefore, studies on the groundwater level in slope area have to be carried out. It can be as a prediction measure or initial steps to monitor the existing slope mainly at expressway areas where slope failures problem are very frequent.

There are many types of studies that can be carried out to investigate the presence of groundwater level. Especially nowadays, there are a lot of methods of in-situ testing that can be applied to explore and investigate the presence of water in the ground particularly in the hilly area. Example of common method is piezometer. This method is widely used where a hole need to be drilled for the installation of the piezometer. These methods require more care during the installation work to ensure a proper installation is done. Besides, if the vibrating wire piezometer is to be use the electric units have a risk to be damage due to lightning and the power source need to be maintained by replacing a new battery periodically. Because of this reasons, by incorporating the electrical resistivity survey in any soil investigation works it can helped the works more easily.

For the purpose of this study, an electrical resistivity survey is used to determine the groundwater level of two areas which are in Senai, Johor and Slim River, Perak. The objectives of this study are to predict the groundwater level of the slopes using resistivity images and soil profiles, then to compare the groundwater level between the values of piezometer with the resistivity images and finally to predict how far the groundwater may contribute to slope's instability.

## 2. Location of Study Area

The study areas are located at Senai, Johor Darul Takzim and Slim River, Perak Darul Ridzuan as shown in Figure 1 and Figure 2. The first location of this study is located at Senai, Johor Darul Takzim, where the site had experienced a slope failure in 2007. Studies on what triggered to this landslide had been carried out since the time of tragedy until recent. This slope has a height about 8 berms and a width of 240 meter and is surrounded by palm trees plantation before the tragedy of the slope failure. The second slope location is located at Slim River, Perak Darul Ridzuan. This slope is very steep and is higher than slope at Senai. It also surrounded by palm trees plantation.

Figure 1: Location 1 - Senai, Johor Darul Takzim, surrounded by palm plantation.

Figure 2: Location 2 - Slim River, Perak Darul Ridzuan surrounded by palm plantation.

## 3. Literature Review

The two-dimensional electrical resistivity imaging is a survey used to provide a linear depth profile of the variation in resistivity both along the survey line and with depth. The depth of the investigation is controlled by the distance between the current electrodes while the investigation depth increases with the electrode spacing. The steel electrodes will be installed to the soil surface layer at every 5 meter intervals along the survey line. Then the electrodes connected to the cable and resistivity meter. The resulting analysis will be used to obtain depths, thickness and resistivity of subsurface layers. An example of a two-dimensional electrical resistivity survey can be seen in Figure 3 (Loke, 2000). The laptop computer is used to automatically switches the current and potential electrodes on and off during the survey. It initially keeps the distance between the electrodes fixed and moves the pair along the survey line until the last pair of electrodes is reached. The process is then repeated until the target distance is achieved.

The groundwater occurs in two distinct zones which are separated by the water table or also known as phreatic surface. The two distinct zones mentioned here is phreatic water and vadose water. The phreatic zone is subject to the gravitational forces. It saturates the pore spaces in the soil below the water table. It also has an internal pore pressure that is greater than the atmospheric pressure and the water are tends to flow laterally. The vadose water zones are located above the water table where the water percolates and moving downwards to link together with the phreatic water below the water table (Whitlow, 2004). Figure 4 shows the occurrences of groundwater. Many researches conduct the study such as to investigate the flow of water through the vadose zone, the water changes in the water table due to water extraction, any leakage from damn or to investigate the chemical pollutants flow. Table 1 shows the example of studies conducted by previous researcher where the electrical resistivity surveys are implemented.

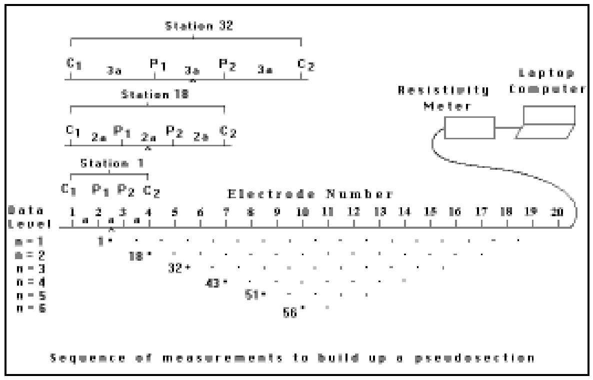


Figure 3: Two-dimensional electrical resistivity survey.

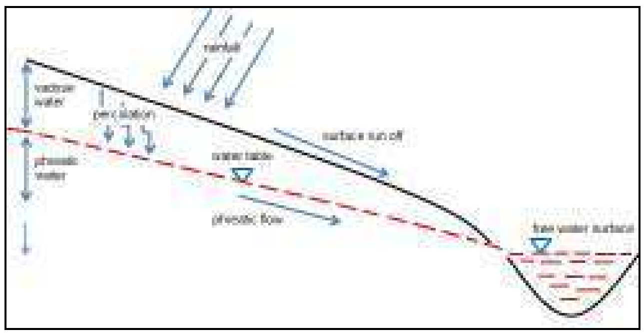


Figure 4: Occurrences of groundwater

Table 1: Some of the study by previous researcher using Two-Dimensional Electrical Resistivity Imaging Survey

| Author | Study | Finding |
|---|---|---|
| Friedel S., Thielan A., and Springman S.M. (2006) | Investigation of a Slope Endangered by Rainfall-Induced Landslides using 3D Resistivity Tomography and Geotechnical Testing | The combination of electrical resistivity survey and geotechnical survey able to helped to optimize the design of forthcoming monitoring experiment. |
| Mariappan. S., Hassan. N.R.N., Chong. S., and Subramaniam. S. (2010) | Remedial Measures Adopted for Slope Failure at Bukit Antarabangsa, Malaysia | To address the details of the geotechnical remedial works carried out reinstate the failed slope and the types of remedial works were adopted to stabilize the un-failed slope. |
| Rosli S., Hussien A.W.M., Nawawi M., Fouzan A. A. and Azar M. (2008) | Monitoring Slope Failure using 2-D Electrical Resistivity Imaging in Pahang, Malaysia | The result shows the factor which cause landslide is the subsurface boulders and the saturated zone which result subsidence of the surface. |

## 4. Methodology

The methodology of this study involves a field work by carried out two-dimensional electrical resistivity survey and analysis of the data. The sequences of the methodology are shown in Figure 5. The main equipment used in the resistivity measurement is ABEM Terrameter SAS 4000 multi electrodes system and Lund Resistivity Imaging cables. Two numbers of survey lines were determined at two different site studies. These lines are located near to the boreholes locations which were drilled at the top and bottom of the slopes.

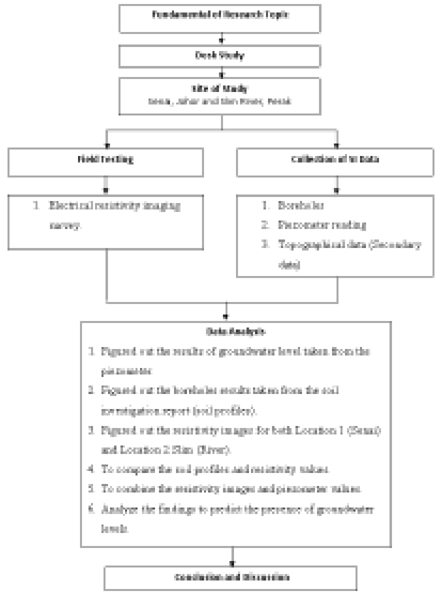


Figure 5: The sequence of the methodology in this study.

## 5. Result and Analysis

The result of this study was obtained in resistivity images and values. The resistivity value for Line 1 is about 1.00 oh.m to 1000 ohm.m for Location-1 at Senai, Johor. Meanwhile, the resistivity value for Line 2 is about 10.00 ohm.m to 12000 ohm.m for Location-2 at Slim River, Perak. The images of the resistivity measurement for both site studies can be seen in Figure 6 and Figure 7 together with the soil profiles. The results of resistivity images are displayed as scaled resistivity-depth pseudosections. Normally, the blue colour region represents a lower resistivity area, yellow or green colour region represents a medium resistivity area while the red or purple colour regions represent a relatively higher resistivity area.

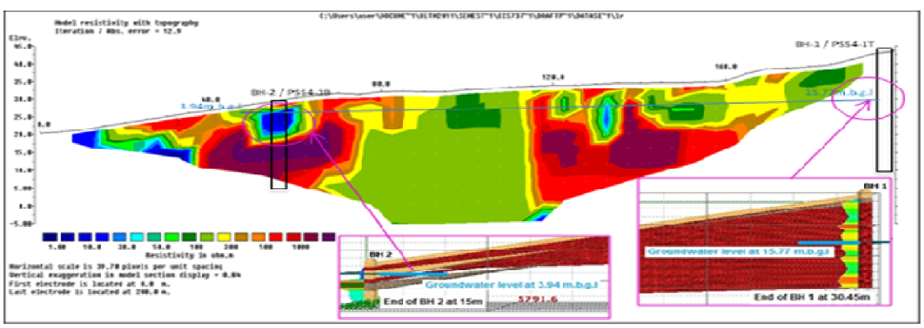


Figure 6: Comparison between Soil Profiles and Resistivity Values at Location 1 Senai

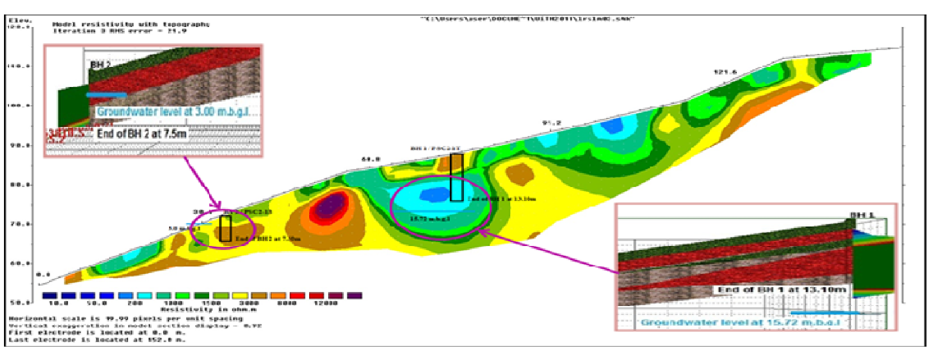


Figure 7: Comparison between Soil Profiles and Resistivity Values at Location 2 Slim River

Figure 8 shows the groundwater level for Location-1 Senai which is 15.77m below ground level for BH-1 which is located at the top of the slope and out of from the resistivity region. However, the BH-2 indicated the groundwater level is 3.94m below ground level. The piezometer reading shows that the groundwater level is matched and fell within the area of resistivity values that indicated the low resistivity and consist of higher water content. The results also shown that BH-2 was fallen at clayey material which is the typical resistivity values is around 1 ohm.m to 100 ohm.m (Table 2). It is shown that the groundwater level for Location-1 Senai was fell at the lower resistivity values which is around 1 ohm.m to 800 ohm.m, where the soil materials is consist of clayey and silt materials.

Figure 9 shows the groundwater level for Location-2 Slim River which is 15.72m below ground level for BH-1 which is located at the top of the slope. The BH-2 indicated the groundwater level is 3.0m below ground level. The result also shown that BH-2 was fallen at silt material which is the resistivity values is 3000 ohm.m. It is shown that the figure indicated that the groundwater level for Location-2 Slim River fell at a medium resistivity values and near to the lower resistivity area where consist of water content.

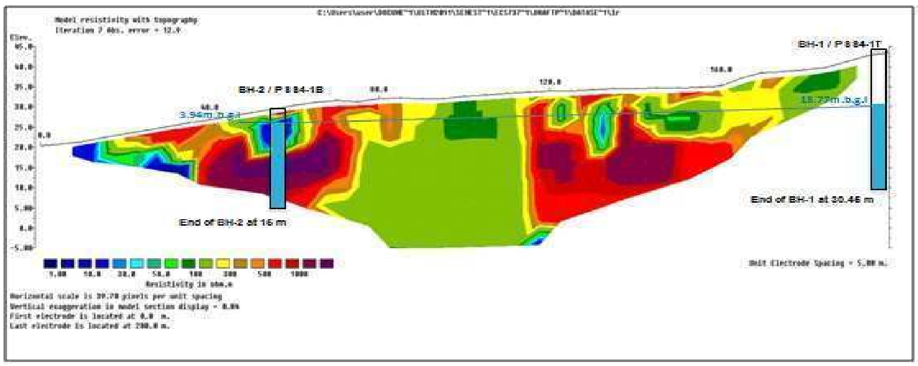


Figure 8: The depth of groundwater level from piezometer at Location 1 – Senai.

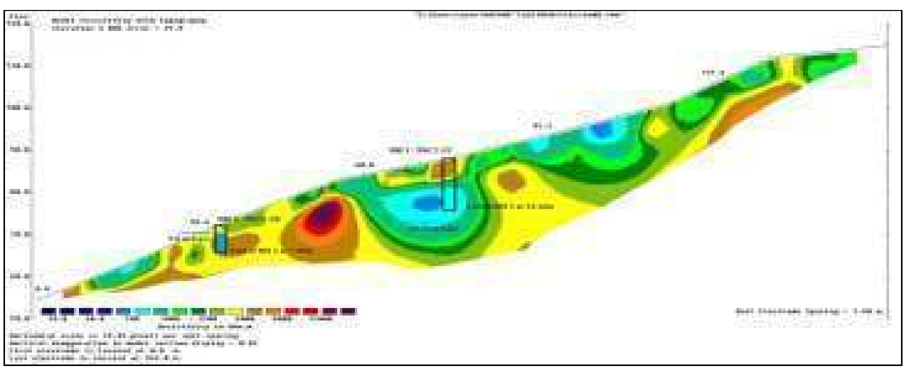

Figure 9: The depth of groundwater level from piezometer at Location 2 – Slim River

Table 2: Results of resistivity values at Location 1 Senai and Location 2 Slim River with Soil Profiles by referred the typical resistivity values.

| Types of soils and waters | Typical resistivity values of soil/rock materials (Ohm.m) | Line 1 (Senai) | Line 2 (Slim River) |
|---|---|---|---|
| | | Resistivity value (Ohm.m) | Resistivity value (Ohm.m) |
| Clay | 1-100 | 30-100 & 1-50 | - |
| Alluvium (Silt&Gravel) | 10-800 | 50 - 300 | 200 to 800 |
| Groundwater (fresh) | 10-100 | 10-100 | 10 to100 |
| Sand | 200-3000 | - | 1000 to 3000 & 1500 |
| Sandstone (rock) | 8-4000 | - | 200 & 3000 |

*Notes:Typical resistivity values of soil/rock material, M.H. Loke (1999) cited from Keller and Frischknecht (1966), Daniel and Alberty (1966) and Lightning & Search Technologies.*

## 6. Conclusion

The two-dimensional electrical resistivity imaging is carried out to predict the presence of groundwater level at slopes area. In order to study the resistivity images together with other destructive methods such as boreholes and piezometer the application on how to run the equipments are also discussed.

Therefore, it can be concluded that the two-dimensional electrical resistivity imaging is suitable as application in geotechnical engineering works, mining, hydrology, environmental, especially in slope engineering in it may helps to provide some data to minimize chances of slopes failures and landslides tragedy. It was proven that the application of this survey is appropriate to measure the distribution of resistivity on the ground surface. With the results from the resistivity images the layers of the ground's subsurface can be determined. It also can help to monitor the presence of the groundwater level at every soil layers. This is meets the objective of these studies.

Collectively, the results data from piezometer can also used to detect the groundwater level at the slope areas arise and results from resistivity survey were analyzed to ensure their similarity. This kind of resistivity survey is a good indirect predictor of water content and is an instrument that can measure the depth of slope profile. The cross section of the slope can also be made and visualize the distribution of the resistivity of the ground subsurface. Finally, the result shows that a groundwater level by piezometer and resistivity images located at the area where the slope failure occurred as in Figure 6 (Location 1Senai). It is proven that the groundwater level contributes to the slope failures. By this finding will meet the objective which is to predict how far the groundwater may contribute to the slopes instability.

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