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Research Paper

Geophysical Approach for Water Seepage Study in Near Surface Assessment

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ABSTRACT

Water seepage at urban area will affect the hydraulic conductivity and shear strength of soil that may cause subsurface problems such as landslides, sinkholes, cavities, ground subsidence and hazard to buildings. To delineate seepage pathways, geophysical data will be acquired. A study has been conducted at Penang to study the saturated zone, analyze the water flow directions and intensities to determine the causes of localized near surface problems by using the 2-D resistivity and self-potential (SP) methods. Five 2-D resistivity survey lines with minimum of 0.5 m electrode spacing were executed using Pole-dipole array. The flow directions and intensities of the water were determined using self-potential (SP) method with interval spacing of 1 m. The inversion results show the low resistivity value (1-100 Ωm) was dominant at the study area which was interpret as saturated zone. Resistivity value of 100-800 Ωm was interpret as alluvium. The result display by self-potential contour map shows the water flow from higher self-potential value (38 mV) towards the lower self-potential value (-22 mV) that is flow from west to east, which are related to seepage flow patterns, negative SP anomalies were related with subsurface seepage flow paths (recharge zone) and positive SP anomalies were related with areas of seepage outflow (discharge zone). Therefore, the two results have match and show good correlation in water seepage investigation, which validates the results.

1. Introduction

The classification of ground failure and various factors contributing to the instability using geophysical surveys is conducted in multi-hazard region. Apart from precipitation as a major factor of the phenomenon, grain size and type of soil can also be one of the important factors to be aware to study water seepage. The water seepage is a very important awareness that must be observed seriously to avoid and reduce the event of near surface problems. The geophysical methods approaches are suitable to study the subsurface structures and features and to correlate with the hazard factors to decrease the event occurrence. Geophysical methods have the potential of detecting water seepage at an early stage before it gives negative economic effects such as

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loss of property value, cost to repair broken structures and costs of treatment in the event of injury. Misinterpretation and lack of information about the shallow subsurface and water seepage from geophysical tools may lead to ground failure. Therefore, multi-disciplinary approaches should be taken to characterize soil in near surface study.

In this study, 2-D resistivity and self-potential methods were carried out to observe water seepage at one of the locations in Pulau Pinang, Malaysia. The 2-D resistivity will be used to monitor water infiltration through the saturated zone of a potential area. The methods of Self-potential (SP) and 2-D resistivity measurement are analyzed for characterization of the seepage flow through the anomalous body.

2. Theory

Both 2-D resistivity and Self-potential methods used electrical measurements. Electrical measurements are used for both 2-D resistivity and self-potential methods were used in mapping apparent electrical resistivity and water seepage flow respectively.

2.1 2-D Resistivity

Generally, current for resistivity (C1 and C2) will be injected into the earth through current electrode which was remarks at point A and B respectively in **Fig. 1**. The potential difference between a pair of potential electrode (P1 and P2) which were represent by M and N respectively are measured (Loke, 1999).

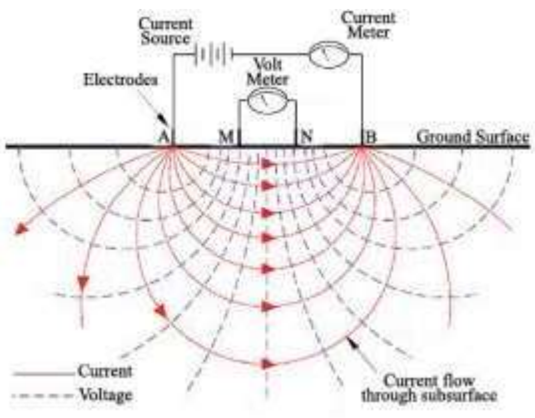

Fig. 1. Electrical resistivity configurations overview (Loke, 1999).

2.2 Self-Potential

Self-potential (SP) is a geophysical method that measure the natural voltage fields present in the subsurface. It has been widely used in recent subsurface studies with simultaneous action variations in groundwater flow, chemistry or temperature (Corwin and Hoover, 1979) of many different SP sources. To locate the anomalies of interest the reading may be positive or negative (Peck et al., 1974; Sowers, 1979). The pore space has an ability to displace fluid motion with excess mobile charge at grain surface. An electric field was created by the collection charge that drives a secondary return current (**Fig. 2**).

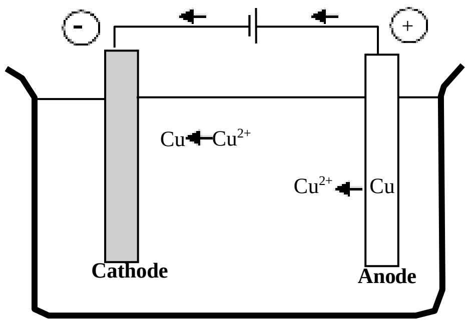

Fig. 2. Basic principles diagram for self-potential measurement.

3. Methodology

In order to study the water seepage, the geophysical methods were carried out using 2-D resistivity and self-potential (SP) methods. The protocol used is pole dipole array with 0.5 m minimum electrode spacing and 1.0 m interval spacing for SP method with the length of 20 m. There were five 2-D resistivity and SP survey lines were conducted on the same 2-D resistivity survey lines.

4. Geological Setting

Penang, Malaysia is mostly underlain by the igneous rock, all igneous rocks mainly composed of granitic rocks and alluvium that commonly consists of clay silt and sand (Ahmad et al., 2006). Universiti Sains Malaysia (USM) is composed of small area of marine deposits and medium to course-grained biotite-muscovite granite (**Fig. 3**).

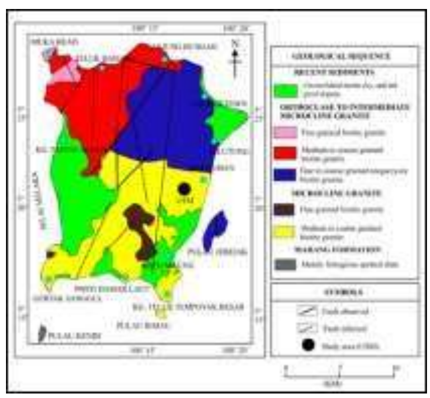

Fig. 3. Geological map of Penang Island including geology of USM (Ahmad et al., 2006).

5. Study Area

The study area was located at USM, Penang with coordinate of N05.35506955 and E100.3032099. The survey area is mostly flat area and was surrounded by campus buildings (**Fig. 4**).

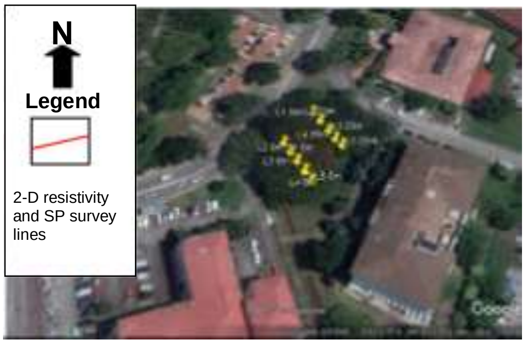

Fig. 4. Study area at USM, Penang, Malaysia (Google earth, 2017).

6. Results and discussion

All the 2-D resistivity lines have a length of 20 m. **Figure 5** shows the results obtained from inversion model of 2-D resistivity. As can be seen from the inversion model of 2-D resistivity, the inversion results show 2 main zones with resistivity values ranging from 1 Ωm to 800 Ωm. The first zone with resistivity values of 1-100 Ωm was interpreted as saturated zone. Resistivity values of 100-800 Ωm was interpreted as alluvium which consist of clay, silt and sand. The resistivity of the water influences the resistivity of the soils (Sjodahl et al., 2010). One of the factors that may cause to the increasing water level is influenced by the sandy silt. It is highly permeable and may cause to low resistivity value (Muztaza et al., 2018). The display results show that the saturated zone was thicker at southeast part. The results indicated that resistivity of surface water in the range of 1-50 Ωm was shown at the surface up to 1 m depth.

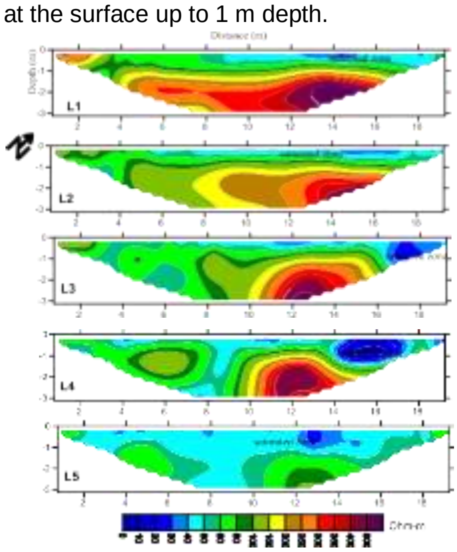

Fig. 5. Inversion model of 2-D resistivity for L1 to L5.

The self-potential (SP) contour map shows decrease self-potential values at the southwest part (Figure 6). It is confirmed by the inversion model of 2-D resistivity where the low resistivity value is increasing at the southeast part. Negative potential, ~ -10 mV are associated with surface water flow. Figure 7 shows that the surface water flow from higher value (38 mV) towards the lower value (-22 mV). The discharge zone (seepage outflow) will give positive SP anomalies while recharge zone (seepage flow) indicated as negative SP anomalies. Therefore, the seepage water flow is from northwest to southeast direction.

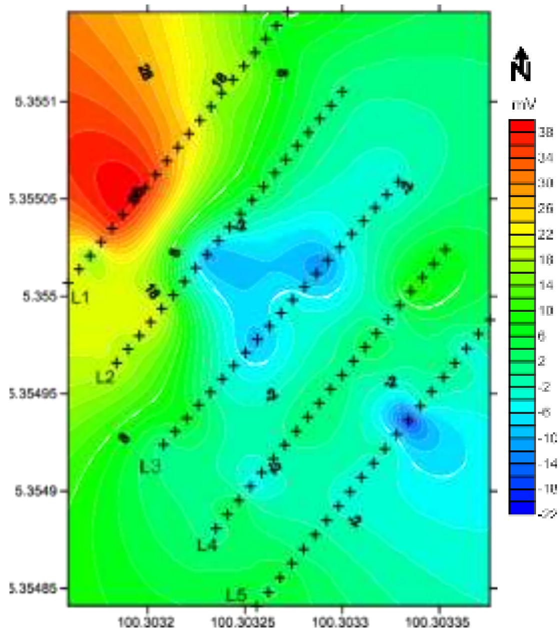

Fig. 6. Self-potential contour map from L1 to L5 produced by a horizontal subsurface flow

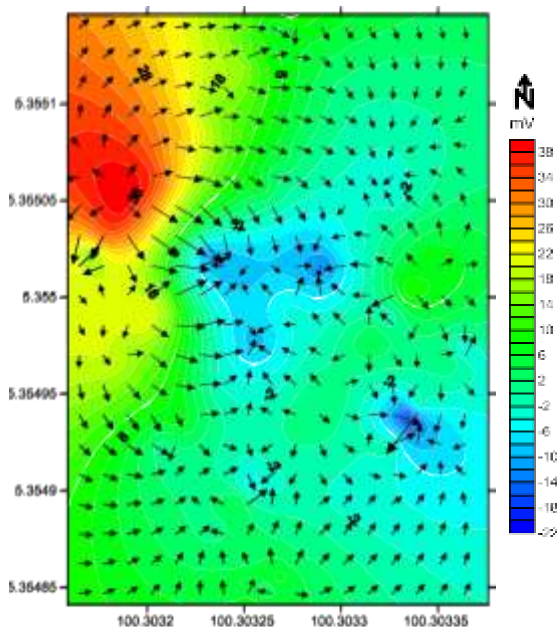

Fig.7. Water seepage flow from northwest to southeast direction produced by a horizontal subsurface flow

The qualitative interpretation of the SP response as presented in **Fig. 8**, is in a good agreement with the inversion model of 2-D resistivity image. Thus, the negative values of self-potential (~ -10 mV) is expected to be surface water flow and confirmed by inversion model of 2-D resistivity results with resistivity values of 1-50 Ωm. Therefore, water infiltration into the soil and increasing water seepage flow was located at these areas. This phenomenon can be shown in **Fig. 9** where the soil subsidence is located at the study area might be due to the water flow.

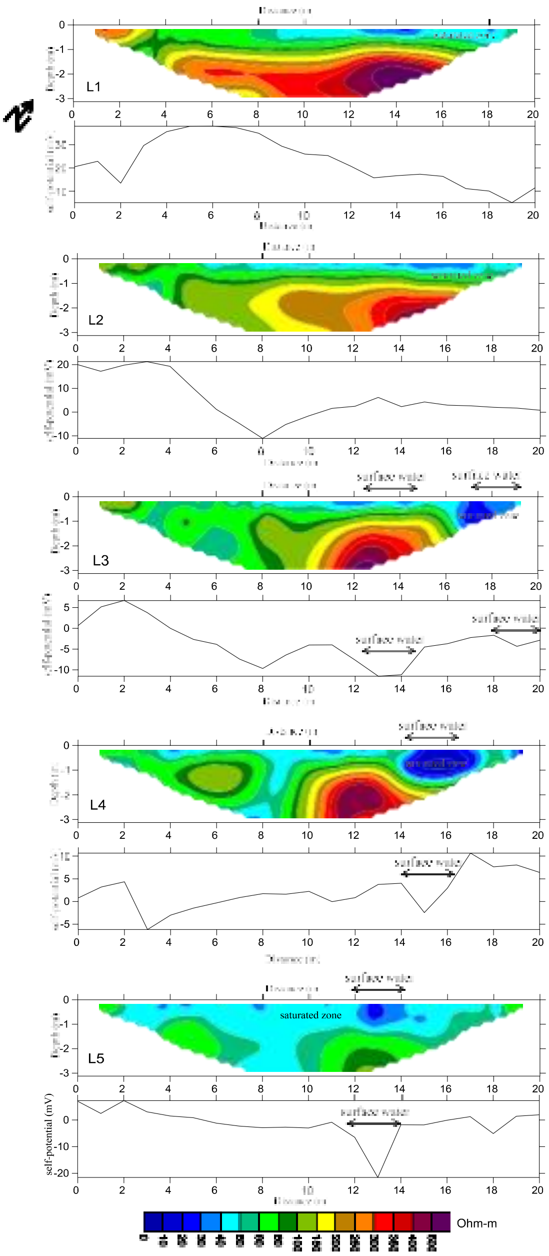

Fig. 8. Inversion model of 2-D resistivity and self-potential profile for L1 to L5

Fig. 9. Soil subsidence due to the water flow at USM, Penang.

7. Conclusion

The inversion model of 2-D resistivity shows low resistivity value of 1-100 Ωm as a saturated zone and SP methods allow to delineate water seepage. Taking the same relationship from the SP profile, the surface water is in the range of 1-50 Ωm and self-potential values of ~ -10 mV. Therefore, the integration of 2-D resistivity and self-potential methods can reduce the uncertainty in data interpretation.

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Symbols and abbreviations

Ωm	Ohm-m
mV	millivolt
2-D	two dimensional
L1	Line 1
E	Easting
N	Northing