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Resolution Enhancement in Model Resistivity using the Data Levels Amalgamation Technique for Groundwater Exploration

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Abstract
In the past few years, significant effort has been made in developing field data acquisition in electrical resistivity tomography (ERT) method. This paper presents development of the data level amalgamation (DLA) technique in resistivity data processing. This technique carried out using two different optimized arrays. They are Wenner-Schlumberger and Pole-Dipole arrays. These two arrays is chosen after made full consideration in terms of the signal strength, total number of datum points, sensitivity changes and lastly investigation depth. The real field study for the DLA technique verification was carried out at Taiping, Perak, Malaysia. The objective of field study at this area is related to groundwater exploration. Based on the application of the DLA technique in the field study, it showed that this technique is capable in resolution enhancement in model resistivity with topography results. The DLA technique is useful in increase the technical merit of this geophysical method for Earth's subsurface imaging.

Keywords: Tomography, Amalgamation, Verification, Resolution, Technical merit.

Introduction

For many years, electrical resistivity tomography (ERT) method has been used for the Earth's subsurface imaging. This non-destructive geophysical method is used to determine the distribution of Earth's subsurface resistivity values. This physical parameter is associated with material or composition of the Earth's subsurface such as soil type and moisture content. Soil's study is one of a concern research in recent years. [1] studied the efect of cyclic pre-straining on very dense sand dynamic behavior. [2]demonstrated the applicability of principle of effective stress using suction stress characteristic curve concept for unsaturated soils. The application of this geophysical method in the Earth's subsurface imaging not only in engineering but also in environmental perspectives. In engineering studies, ERT method has been used for soil's characterization, slope monitoring and locating buried structure.

Combination of electrical resistivity, seismic refraction and geotechnical methods is proposed by [3] to study the soil characteristics at archaeology site. The study is carried out to identify the characteristics of subsurface due to suspected meteorite impact event. Slope monitoring is a challenging study. The slope monitoring requires geophysical survey along the same survey line but different times of field survey. [4]and[5] suggest high resolution of ERT method is needed to study the changes of resistivity distribution over different times during slope monitoring. Identification of man-made structure such as a buried bunker requires well understand of current respond toward the target. [6] proposed high resolution of ERT method is needed to identify the actual dimension and exact location of the buried bunker. [7]proposed 2D and 3D electrical resistivity imaging to reliably identify the depth of unknown bridge foundations. Meanwhile, in environmental studies, ERT method has been used for archaeology study. [8]proposed enhanced horizontal resolution technique at archaeological site. The study was carried out to identify the signatures of subsurface structure due to suspected meteorite impact event. Leachate flow is concern matter regarding to the dump site. [9]suggest the application of 2D electrical imaging surveys for leachate plume migration. Other research works related to application of electrical resistivity method for leachate study [10] and [11]. [12]proposed soil resistivity monitoring for an irrigation experiment. These previous study by various researchers indicate that this geophysical method can be used in engineering and environmental studies.

Even though this geophysical method is normally used by geophysicists, other non-geophysics background such as engineers and geologists also using ERT method for the Earth's subsurface investigation. Therefore, accuracy and technical merit of ERT method is a serious matter in data acquisition and data interpretation works. The improper use of this geophysics method will lead to misunderstanding of the reputation of this geophysical method. In this paper, the data levels amalgamation (DLA) technique is developed for enhancing the resolution of the ERT method. In application of this technique, a study site was selected for verification and confirmation of the DLA technique. This stage is a serious concern because each array has their own limitations and advantages in subsurface imaging. In this study, the selected study site is related to groundwater exploration for industrial purpose.

Geology settings

The selected study area is located in Malaysia. The study area is located at Taping, Perak State. Taiping is located at northern part of Perak State. The mono-mineral dominance of tourmaline in minerals overlaying in this area. The mineral also reflect a derivation predominantly from the continental source of granite and associated rocks forming the hills [13].

Methodology

In the past few years, significant effort has been made in developing field data acquisition in ERT method. This geophysical method works by measuring the potential value between the potential electrode pair while injecting current into the underground at the current electrode pair. Apparent resistivity is calculated by Equation 1.

$$\rho a = k\ (V/I) \quad (1)$$

where;
ρa is apparent resistivity,
k is geometric factor,
V is potential,
I is current

In this research, two suitable arrays were used in field data acquisition. They are Wenner-Schlumberger and Pole-Dipole arrays. The selection of these two different arrays is made after full consideration in term of the signal strength, the total datum points, the sensitivity to vertical changes and the investigation depth. These parameters are important in order to give optimum model resistivity results. Pole-Dipole array has good investigation depth compared to other arrays. Wenner-Schlumberger array is a hybrid array between Wenner-Alpha and Schlumberger arrays [14] and [15]. The signal strength of Wenner-Schlumberger array is good compared to Pole-Dipole array. Therefore, the DLA technique is developed in order to enhance the limitation of each array and capable to increase confident level of users in interpretation works.
During the field data acquisition, these two different arrays were used and carried out along the same line and same electrode position. Figure 1 shows apparent resistivity datum point's arrangement to build up a pseudo-section by a single array. Figure 1 also shows the development of the DLA technique in data processing.
The DLA technique has few advantages such as increase the number of datum point and provide overlapping data levels in pseudo-section. These advantages lead this DLA technique in enhancing the resolution of model resistivity results. This is supported by data level (**n**) and electrode spacing (**a**) are improved in model's inversion processing. All the data sets from both study areas were processed using RES2DINV program in order to produce an inverse model resistivity with topography.
The minimum electrode spacing used at Taipingstudy site is 10 m. The length of spread for Wenner-Schlumberger array is 400 m and for the second array which is Pole-Dipole with length of 800 m. These two different arrays also sharing the same centre of resistivity line. The decision to use different scalability of cables and electrode spacing was made according to their suspected depth of target.

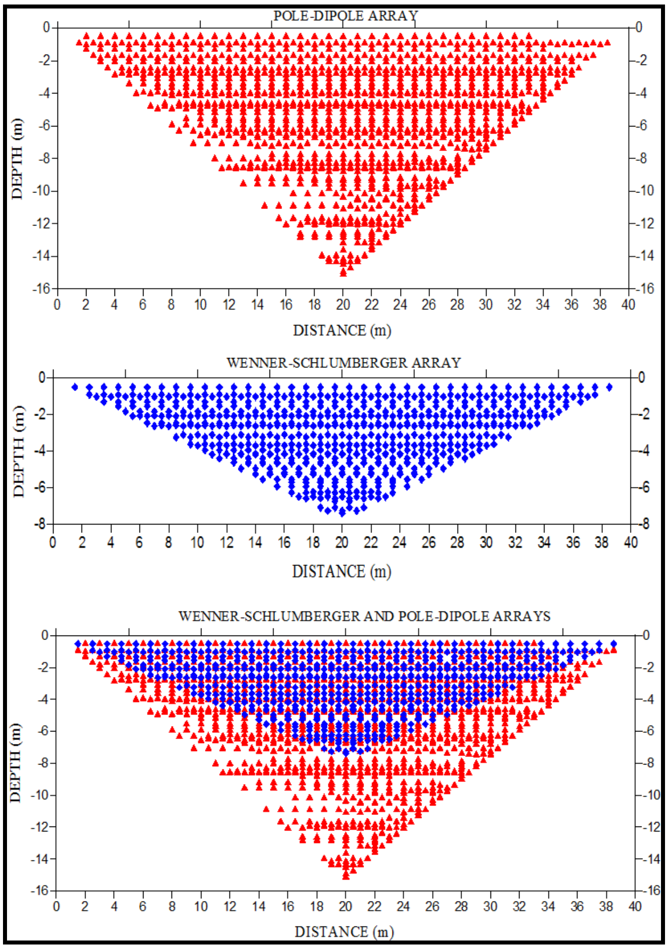

Figure 1: The development of the DLA technique for the datum point arrangement to build up a novel pseudo-section. The bottom pseudo-section shows the final data set's arrangement of the arrays used in the inversion work.

Results and Discussion

The results from the study area at Taiping is related to groundwater exploration (Figure 2). It showed that the Earth's subsurface at the second study are is made up of overburden which is classified as alluvium. This material is presented by resistivity values of 700 – 3000 **Ω**. m. The granitic bedrock is identify by resistivity values greater than 3000 **Ω**. m. From the model resistivity with topography results, it shows that the suspected groundwater is located 480 – 600 m and located at depth of 50 – 100 m from the Earth's surface (Figure 2). This groundwater can be considered as good quality groundwater because it is located at deep location. In addition, the groundwater is well preserved and away from contamination. Therefore, this groundwater is suitable for the industrial usage.

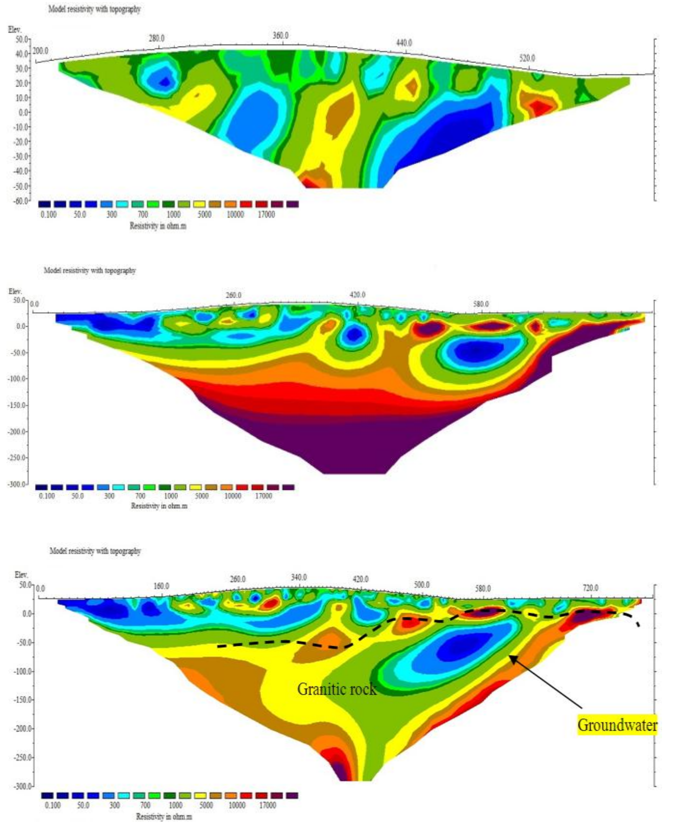

Figure 2: The model resistivity with topography using the DLA technique for the groundwater exploration at Taiping, Perak. (Top) Wenner-Schlumberger array, (Middle) Pole-Dipole array and (Bottom) the DLA technique.

Generally, the DLA technique developed in data processing is capable to improve the signal strength, the horizontal coverage, maximum datum points and depth of investigation. These parameters are important not only before the survey (survey's planning) but also in processing and interpretation of data. Therefore, optimum and high quality of model resistivity results can be produced by users [16]. The summary for all investigated parameters is tabulated in Table 1. In addition, constraint parameters is used in data processing to gives optimum results in model resistivity. These parameters is set in the computer program first before proceed to data processing. Table 2 shows constraint parameters used in data processing work from the study area.

Table 1: Investigated parameters using common arrays and the DLA technique.

	Parameters	Signal strength	Horizontal coverage	Maximum datum points	Depth of investigation
Arrays	W-S	Good	Moderate	665	95 m
	P-D	Moderate	Good	1387	320 m
	P-D + W-S	Good	Good	2052	335 m

**Note W-S = Wenner-Schlumberger; P-D = Pole-Dipole; W-S + P-D = the DLA technique*

Table 2: Constraint parameters used in data processing work.

Constraint Parameters	Value / Decision
Initial damping factor	0. 05
Minimum damping factor	0. 01
Factor to increase damping factor	1. 10
Optimize damping factor	Yes
Forward modeling method	Finite-difference

Conclusion

The DLA technique is successful in identify the potential area of groundwater location. The DLA technique applied in data processing is capable in enhancing the resolution of model resistivity with topography results. In addition, the DLA technique developed in this research is pretty good enough in producing good quality model resistivity results. Even though, the time taken using the DLA technique is twice, the outcome of good quality data in interpretation work is more important than rapid in field data acquisition.

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