[Makara Journal of Science](https://scholarhub.ui.ac.id/science)

Volume 14
Issue 1 *April*

Article 19

4-25-2010

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Recommended Citation
Islami, Nur (2010) "GEOELECTRICAL METHOD FOR SUBSURFACE PROFILING COMPARISON: CASE STUDY IN TAWANG AND SABAK AREA, NORTH KELANTAN, MALAYSIA," *Makara Journal of Science*: Vol. 14: Iss. 1, Article 19.
Available at: https://scholarhub.ui.ac.id/science/vol14/iss1/19

MAKARA, SAINS, VOL. 14, NO. 1, APRIL 2010: 88-94

GEOELECTRICAL METHOD FOR SUBSURFACE PROFILING COMPARISON: CASE STUDY IN TAWANG AND SABAK AREA, NORTH KELANTAN, MALAYSIA

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Abstract

The study area is located in North Kelantan, Malaysia. The North Kelantan plain is covered with quaternary sediments overlying granite bedrock. The drainage system is dendritic with the main river flowing into the South China Sea. Geoelectrical resistivity profiling surveys were conducted to determine the characteristics of the subsurface and the groundwater within the aquifer. The geoelectric resistivity surveys are made up of twelve resistivity traverses at five different sites. Each site has two or more lines which are perpendicular and parallel to the beach line. The zone of brackish water is very clearly seen in the resistivity inverse model with the position around 20 m of depth. This aquifer is referred to the second aquifer. The subsurface profile in site 1, 2 and 3 which is perpendicular to the beach line shows a wavy pattern. The profile which is parallel to the beach line shows almost planar non wavy pattern. In site 4 and site 5, the profile shows an almost flat.

Keywords: resistivity, subsurface

1. Introduction

Ground water is among the nation's most important natural resources. It provides drinking water to urban and rural communities, supports irrigation and industry, sustains the flow of streams and rivers, and maintains riparian and wetland ecosystems. The importance of groundwater for the existence of human society cannot be overemphasized. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions.

A number of factors can affect the quality of a groundwater reservoir, such as contamination by salt-water intrusion or by toxic industrial chemic waste [1-4]. These pollutants pose common environmental problems that have created the need to find suitable methods for monitoring the extent of such environmental damage [5].

The geoelectrical imaging method has been widely used in environmental and geotechnical investigation for more mapping of complex geological structures as it can delineate the resistivity distribution of such structures [6]. Geoelectrical imaging surveys aim to determine the physical properties on the plane delineated by injecting current along a different path and measuring the associated voltage drops.

In this paper, the efficiency of the geoelectrical imaging method in detecting salt/brackish-water within aquifer and investigating subsurface profiling is examined. The field surveys included twelve resistivity traverses in five different sites of the surveyed area.

Review of Geology and Hydrogeology in the Study Area. The North Kelantan plain is covered with Quaternary sediments overlying granite bedrock. It is drained mainly by short rivers and streams which flow into the South China Sea. The central part of the plain is drained by the largest river in the region, Kelantan River, and in the South East, it is drained by Pengkalan Datu River. The thickness of the quaternary deposits varies from 25 m inland to about 200 m near the coast. The loose quaternary sediments consist of alternating layers of coarse gravels to silts or mixtures of the two [7]. There are two main aquifers. The first is shallow aquifer, whish is mostly unconfined but occasionally confined or semi-confined, whose thickness is normally 2-3 m and may reach up to 17.5 m. This aquifer is the first aquifer. The second aquifer is deep aquifer, which is mainly confined, whose thickness is usually more than 15 m, and this deep aquifer comprises three different layers, separated from each other by permeable strata of clay. This aquifer refers to the second, third and fourth aquifers [7,8]. Figure 1 shows the location map of the research area near Kampung Tawang (sites 1, 2, and 3) and Sabak (sites 4 and 5), North Kelantan, Malaysia. The RSO West Malaysia and Kertau 1946 are used as coordinate system and datum in the map.

Review of Geoelectrical Resisitivity Theory. Geoelectrical resistivity is often first encountered in physics when discussing the resistance of an ideal cylinder of length *L* and cross-sectional area *A* of uniform composition. The resistivity ρ appears as the material-specific constant of proportionality in the expression for the total resistance of the cylinder,

$$R = \rho L/A \qquad (1)$$

The total resistance *R* may be obtained experimentally through Ohm's law, $R=V/I$, where *V* is the potential difference between the ends of the cylinder and *I* is the total current flowing through the cylinder. Edge effects are not considered. The resistivity of the material, an intrinsic property of the material, is then related to experimentally measured extrinsic parameters by

$$\rho = (V/I)(A/L) = R_{app}K \qquad (2)$$

In the second equation, the resistivity is given by the product of the apparent resistance $R_{app}=V/I$ and a geometric factor $K=A/L$ that carries information about geometry of the cylinder. This type of product of an apparent resistance and a geometry factor will appear again when the resistivity of the ground is determined.

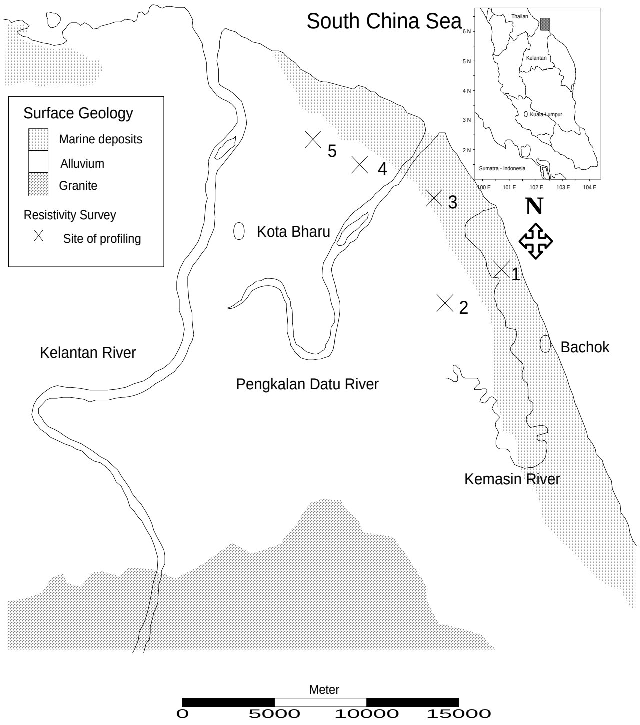

Figure 1. Map Showing the Location of Resistivity Survey Lines–North Kelantan, Malaysia

For the Wenner array which is separated by equal intervals, denoted *a*, the apparent resistivity is given by Telford et al., 1990 [9]:

$$R_{app} = 2\pi a(\Delta V/I) \qquad (3)$$

2. Methods

The purpose of geoelectrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock.

The 2D electrical resistivity imaging surveys were performed at the proposed sites using the ABEM SAS1000 resistivity meter and a multicore cable to which electrodes were connected at takeouts moulded on at predetermined equal intervals. A computer-controlled system was then used to select the active electrodes for each electrode set-up automatically. This computer-controlled system was included in the instrument ABEM SAS1000 which was used in the survey.

The Wenner arrays were used on twelve traverse lines of different lengths at five different sites near Kampong Tawang and Sabak. The maximum line spreading was 400 m in length, and the minimum spreading was 80 m in length, each line spreading depended on the available space of field. Data processing was conducted by a tomographic inversion scheme using the software RES2DINV [10]. In this scheme, true resistivity distribution in the subsurface is obtained by a linearized least-squares inversion of apparent resistivity pseudosections acquired along profiles.

The result of geoelectrical resistivity data (after the processing) is presented in contour section of true resistivities (Fig. 2, 3, 4, 5, and 6). In the section, the horizontal axis is the electrode spacing, and the vertical axis is the depth.

3. Results and Discussion

Site 1. Kampung Tawang is the location of site 1. The four lines were created in the marine deposit area. The reason for choosing this location was to identify the resistivity value of the saline water within water-bearing layers in that area as well as to determine the boundary depth of the fresh-water layer that overlies the saline-water layer.

The central position of Line 1A is about 600 m from the beach line and perpendicular to the beach line. The

Wenner inverse model of Line 1A shows an almost wavy interface between these two layers. The inverse model, with the low resistivity value of less than 2 ohm.m and is located at about 8 m of depth of the section, corresponds to the saline water. The fresh-water layer floats on top of saline water, since fresh water has a lower density than saline water.

The saline water/fresh water boundary is fairly well mapped and is shown in the inverse section. The high-resistivity values of the top layer correspond to the road embankment material, because the survey line was laid out on the road shoulder (Lines 1A, 1B, and 1D).

The location of Line 1B (800 m from the beach line) was also in a saline-water zone and parallel to the beach line. In the Wenner inverse model section (Fig.2), the fresh-water/saline-water boundary, which is less undulating in shape, is deeper compared to the inverse model of Line 1A. It is easy to recognize the boundary from Line 1A and Line 1B, which is the dip angle of saline-water interface, increasing to landward.

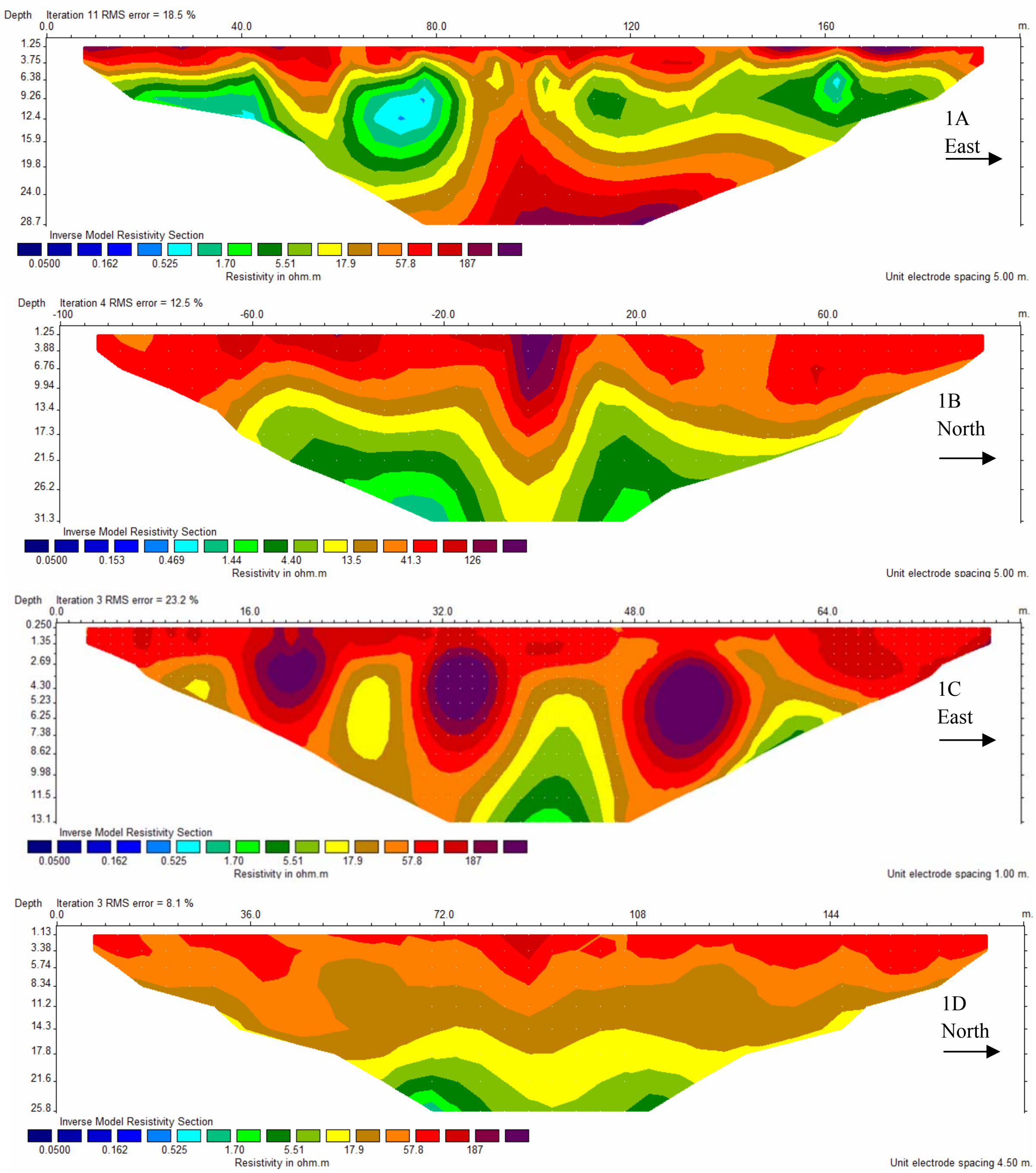

Figure 2. The Wenner Inverse Model for Site 1

Water table is very clearly shown in the inverse model of Line 1C, which is perpendicular to the beach line. The distance between Line 1C and Line 1D (parallel to the beach line) from the beach axis is about 1.7 km. The position of the water table is about 2.3 m with resistivity value of around 35 ohm.m. It can be clearly seen that 1 m electrode spacing in Line 1C results in the good appearance of water table compared to the other electrode spacing (5 m and 4.5 m).

Three zones of high resistivity value (above 500 ohm.m) can be clearly seen around 4 m of depth, which corresponds to very compact clay material. Low resistivity value appears between them. The four other lines parallel to the Line 1C (this section is not shown in this paper) have been conducted at 4 m intervals from Line 1C. These lines reveal almost the same pattern and shape as Line 1C's, which means that the compact clay material is formed parallel to the beach line.

Site 2 and Site 3. The second site is situated to the West of Site 1. The resistivity survey lines (Line 2A and Line 2B) were made almost perpendicular to the beach axis. The traverse of Line 2A was located at about 4.5 km west of the beach line. Line 2B was around 1.5 Km southwest of Line 2A, and was almost perpendicular to Line 2A. A total of 61 electrodes were laid in traverse Line 2A and Line 2B respectively.

The circular region of low-resistivity values at around 25 m of depth in the Wenner inverse model of Line 2A and Line 2B (Fig.3) corresponds to brackish water. The concentration of brackish water in this position of the section could be due to the concentration of marine deposits in that area.

On the third site, the resistivity survey of Line 3A was oriented the almost southwest to northeast direction. The centre of this line is situated about 600m from the beach line. The second line, Line 3B, was oriented to the almost west to east direction and about 2.2 km from the beach line.

The inverse model (Fig. 4, 3A and 3B), showing the low resistivity value of less than 3 ohm.m, which is located at about 20 m of depth of the section, corresponds to the saline / brackish water. The high-resistivity values of the top layer at Line 3B (around 40 and 72 m marks) correspond to the very compacted and dried material such as the foundation and a piece of floor cement of ex-housing.

Site 4 and Site 5. The fourth site is situated to the northwest of Site 1 in Sabak area. The resistivity survey lines (Line 4A and Line 4B) were conducted about 2.1 km from the nearest beach. The data for the 2D geoelectrical image for Line 4A and 4B were acquired in an area of polo field near the Sabak coconut plantation area. The survey line for Line 4A has an almost north-south orientation, which is perpendicular to the postulated intrusion boundary. The brackish-groundwater boundary in the Wenner inverse model for Line 4A (Fig.5) is clearly shown as a steeply dipping curve. The high-resistivity zone (around 10 ohm.m) corresponds to the fresh water. The source of fresh water is believed to be the groundwater recharge process, which occurs directly from rainfall and from surface run-off descending from the landward area into the coconuts fields. The low-resistivity zone corresponds to seawater intrusion from the South China Sea. The

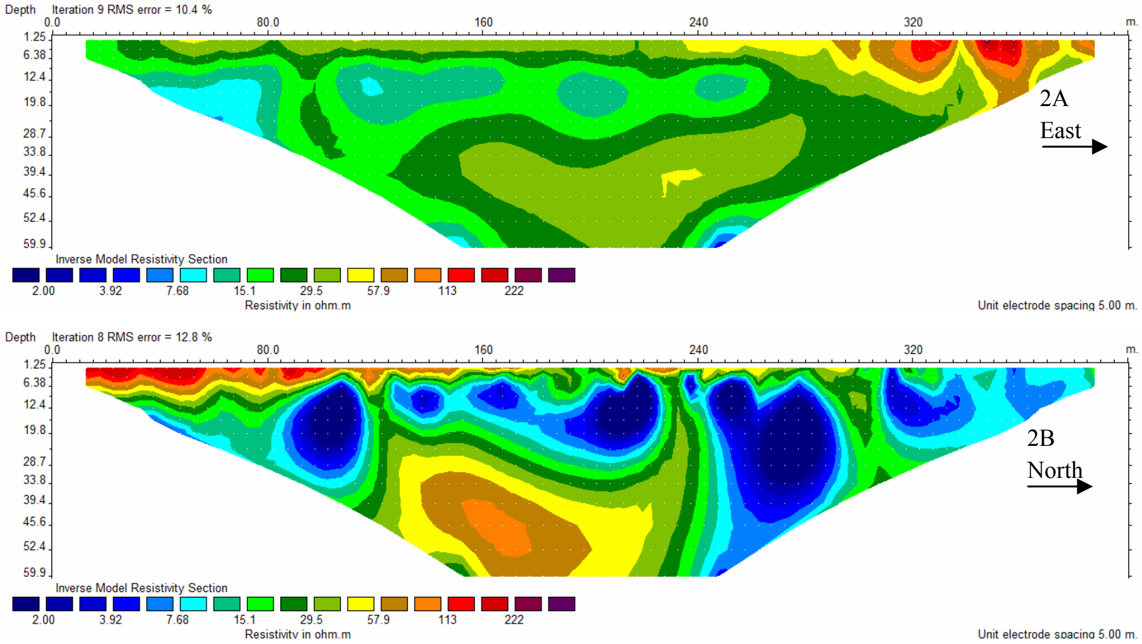

Figure 3. Wenner Inverse Model Section for Site 2

traverse of Line 4B is located perpendicular to Line 4A at the position of 84 m mark and crossing at the position of 0 m mark for line 4B. The depth position for the same resistivity zone matches exactly with both lines at the position of around 11 m depth. The region of low-resistivity values at the bottom (below 10 m) section in the Wenner inverse model (Fig.5) corresponds to brackish water.

Overall, it can be seen that the subsurface profile on sites 1, 2 and 3, which are perpendicular to the sea, show a wavy pattern. In contrast, the subsurface profile which is parallel to the sea shows almost planar non wavy pattern. This may be caused by the fact that near the beach line, the formation of the land is influenced by the direction of the sea wave movement. Based on the information from the Malaysian Meteorological Department (MMD), annual average wind direction and its velocity are almost east to west, ± 6 m/s. Eventually, this situation causes the sea wave to tend to be almost perpendicular to the beach line. It is able to create a wavy pattern of the land parallel to the beach, and even minor meandering river is highly possible to be produced.

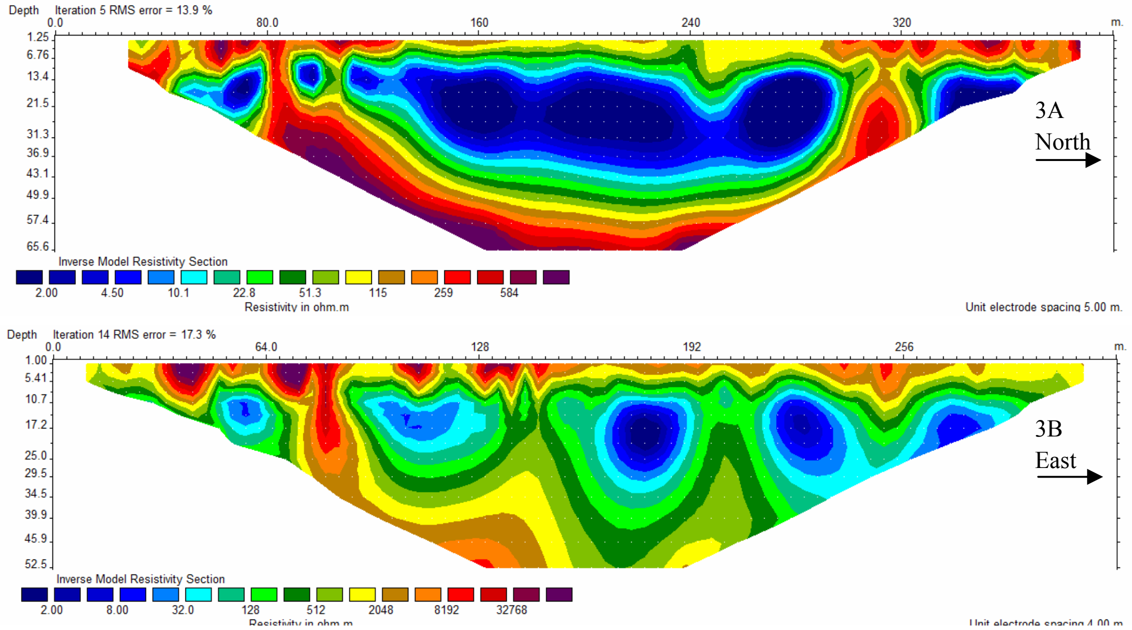

Figure 4. The Wenner Inverse Model Section for Site 3

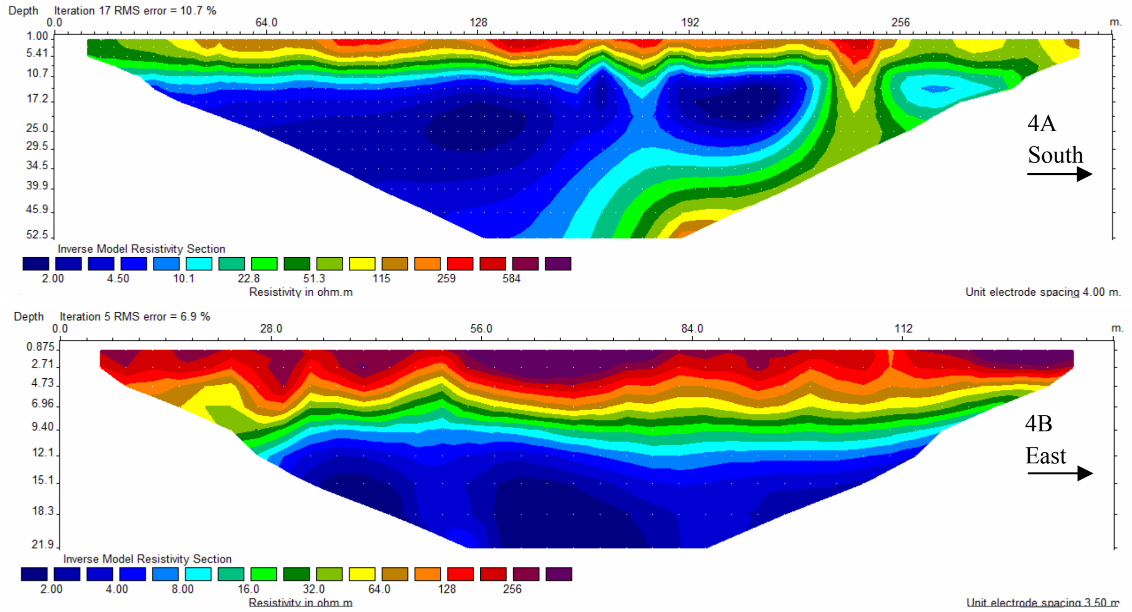

Figure 5. Wenner Inverse Model Section for Site 4

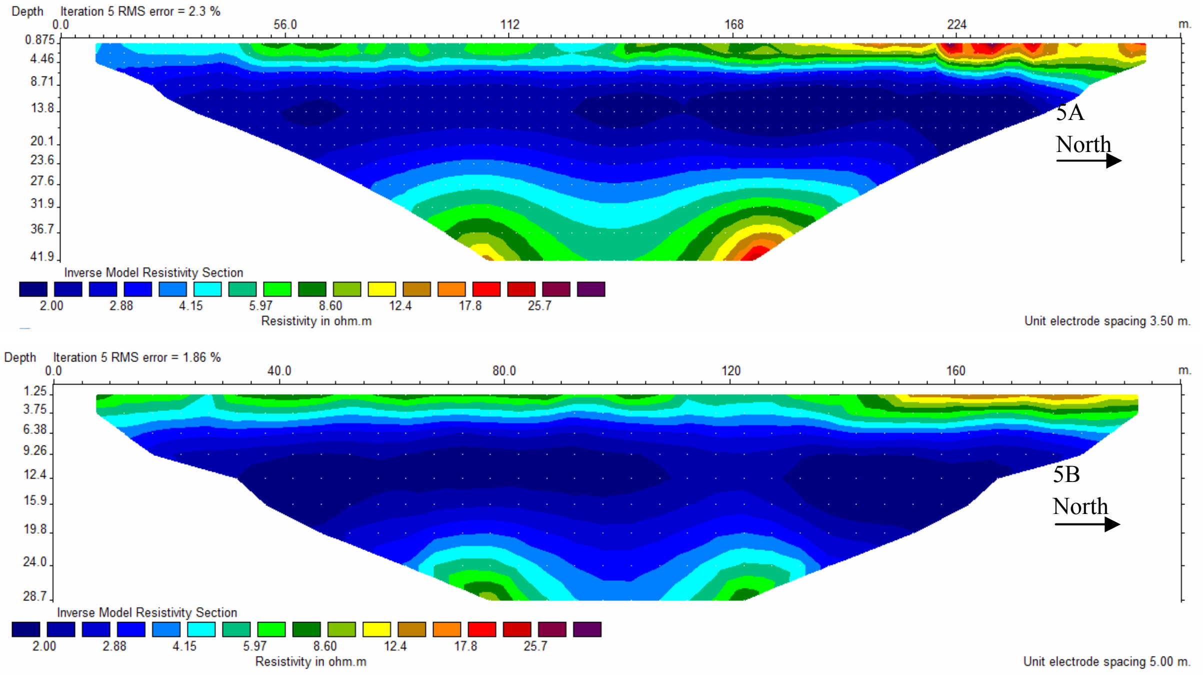

Figure 6. The Wenner Inverse Model Section for Site 5

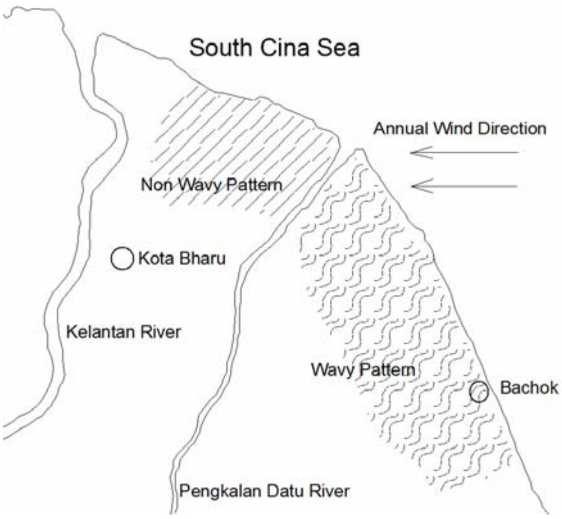

Figure 7. Annual Wind Direction and Pattern of Subsurface Profiling Around 5-30 m of Depth

Another thing that can be seen is that the low resistivity value appears between high resistivity values. This implies that low resistivity value is highly possible for saline/brackish zone. This probably comes from ancient sea water that has been trapped and mixed within sediment for a long period of time within each trough. On Site 4 and Site 5, the subsurface profile pattern is almost flat. This may be caused by the energy of sea wave that has been reduced because the position of this area is protected by the beach near Sites 1, 2, and 3. From the map (Fig.7), it can be clearly seen that the sea wave is not perpendicular to hit the beach nearest to Sites 4 and 5. This situation causes the wave energy of sea water to be not enough to create a wavy pattern like the one on Sites 1, 2 and 3.

4. Conclusion

Geoelectrical imaging method is very useful for subsurface and groundwater investigation in the study area. The zone of brackish water is very clearly seen in the resistivity inverse model with the position of around 20 m of depth. This aquifer is referred to as the second aquifer. The subsurface profile is very clearly imaged using the geoelectrical resistivity method. It can image the subsurface with brackish and fresh water zone. It also can be used to predict the pattern of subsurface profile.

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