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Utilizing 2-D Resistivity Method for Seawater Intrusion Study at Benteng Kuta Lubok, Aceh-Indonesia

Dr. Muhammad Syukri

Senior Lecturer at Geophysics Section, Department of Physics, Faculty of Sciences, Syiah Kuala University, Banda Aceh, Indonesia
e-mail: m.syukri@unsyiah.ac.id

Zul Fadhli

Postgraduate Student at Geophysics Section, School of Physics, 11800 Universiti Sains Malaysia, Penang, Malaysia
e-mail: zulcmc@gmail.com

Dr. Rosli Saad

Senior Lecturer at Geophysics Section, School of Physics,11800 Universiti Sains Malaysia, Penang, Malaysia
e-mail: rosli@usm.my

ABSTRACT

Research has been conduct using 2-D resistivity method to identify seawater intrusion. The study was conduct at Benteng Kuta Lubok, Aceh Besar, Aceh (Indonesia) which is Lamuri kingdom, built by Portuguese in 1600 AD. Nine survey lines (40 m each) of Pole-dipole array with minimum electrode spacing of 1 m and the spacing between lines is 20 m was design for the study. The 2-D resistivity inversion models show the study area consists two layers. The first layer with thickness of 5 m has interpreted as marine alluvium and the second layer with depth 0-8 m has interpreted as colluvium. The seawater intrusion with resistivity value of <10 Ohm.m was detected at line R1, R2 and R5 at depth <2 m and 15 m respectively.

KEYWORDS: 2-D Resistivity, Seawater Intrusion, Benteng Kuta Lubok, Marine Alluvium.

INTRODUCTION

Seawaters intrusion or infiltration of seawater into pores of rock will contaminate ground water. The difference between seawater and groundwater is Sodium Chloride (NaCl) ions that cause changes in the electrical properties. The value of groundwater resistivity is 10 - 100 Ohm.m, while seawater is <10 Ohm.m. Seawater intrusion occurs in all coastal aquifers, where they are hydraulic continuity because it has a higher density since its carries more solute than freshwater (Todd, 1960). Seawater intrusion is the movement of saline water into fresh-water aquifers. It is cause by groundwater pumping from coastal well or construction of navigation channels into fresh marshes. However, seawater intrusion can also occur because of natural process such as a storm surge from a hurricane (Barlow, 2003). Seawater intrusion is a key issue in dealing with exploitation, restoration and management of fresh groundwater in coastal aquifers (Kim et al., 2007). The increase of population, extensive water use, interbasin water transfer, and climate change will affect the groundwater level change (Tillman and Leake, 2010). It shows that groundwater over exploitation leads to salt-water intrusion in coastal area (Pousa et al., 2007), and for a long-term, groundwater abstraction pushes land subsidence occurrence (Seiler and Gat, 2007; Qing-hai et al., 2007). Furthermore, land subsidence may contributes to rise of sea level and lead to increase concentration of chloride as salinity plume forward to the inland (Todd and Mays, 2005; Nguyen et al., 2006). Since seawater has greater density than freshwater, it submerges into groundwater and influences its salinity. Seawater intrusion occurs when the balance is disturbed. The seawater intrusion affected by excessive pumping, beach and rock characteristics, water pressure of freshwater into the sea, fluctuations of groundwater in coastal areas and tides factors. The objective of this study is to identify the seawater using 2-D resistivity method.

GENERAL GEOLOGY

Benteng Kuta Lubok is located at the East of Banda Aceh. Geographically, the study site is situated in Lamreh village, Mesjid Raya sub-district, Aceh Besar regency, Aceh Province - Indonesia (Figure 1). At the nearest area, there is a freeport which increased the population of the surrounding area. Predominantly, Lamreh dominated by areas with an altitude of 100 m (MSL), few areas with altitude <10 m (MSL) and coastal areas with altitude >10 m (MSL). It is located in coastal areas with altitude 4-8 m (MSL). Benteng Kuta Lubok is heritage building of Lamuri kingdom, built by Portuguese in 1600 AD as base for trade. Geologically, Benteng Kuta Lubok has situated on the last fault of Seulimuem segment. Estimation of slip rate for the Seulimum segment is 2 cm/year and 10 km locking depth (Irwan et al., 2011). The lithologies of Benteng Kuta Lubok were Coralline Limestone and alluvium (gravels and sands).

Figure 1: Geology map of the study area (Bennet, 1981).

STUDY AREA

The study carried out at Benteng Kuta Lubok, Aceh, Indonesia (Figure 2). Nine (9) resistivity survey lines with length of each line are 40 m and the spacing between them is 20 m was design. The lines trending from southwest to northeast are perpendicular to the sea and mountain.

Figure 2: The orientation of 2-D resistivity lines (Google Earth, 2010).

THEORY OF 2-D RESISTIVITY METHODS

The ground resistivity has related to various geological parameters such as mineral and fluid content, porosity and degree of water saturation in soil/rock. Variations in electrical resistivity may indicate changes in composition, layer or contaminant levels (Loke, 1994). The principle of the 2-D resistivity method is by injecting electrical current into the earths through two electrodes, while the potential difference that occurs is measure through two potential electrodes. From the results of measurements currents and electrical potential difference, it obtained variations of electrical resistivity value in the subsurface on measurement point. The resistivity of soil or rock is depend on several factors that include amount of interconnected pore water, porosity, amount of total dissolved solid such as salts and mineral composition such as clays (Zohdy et al., 1974; Reynolds, 1997; Rubin and Hubbard, 2006). Figure 3 shows the basic array used for 2-D resistivity measurement and Table 1 shows the resistivity values of some type of waters.

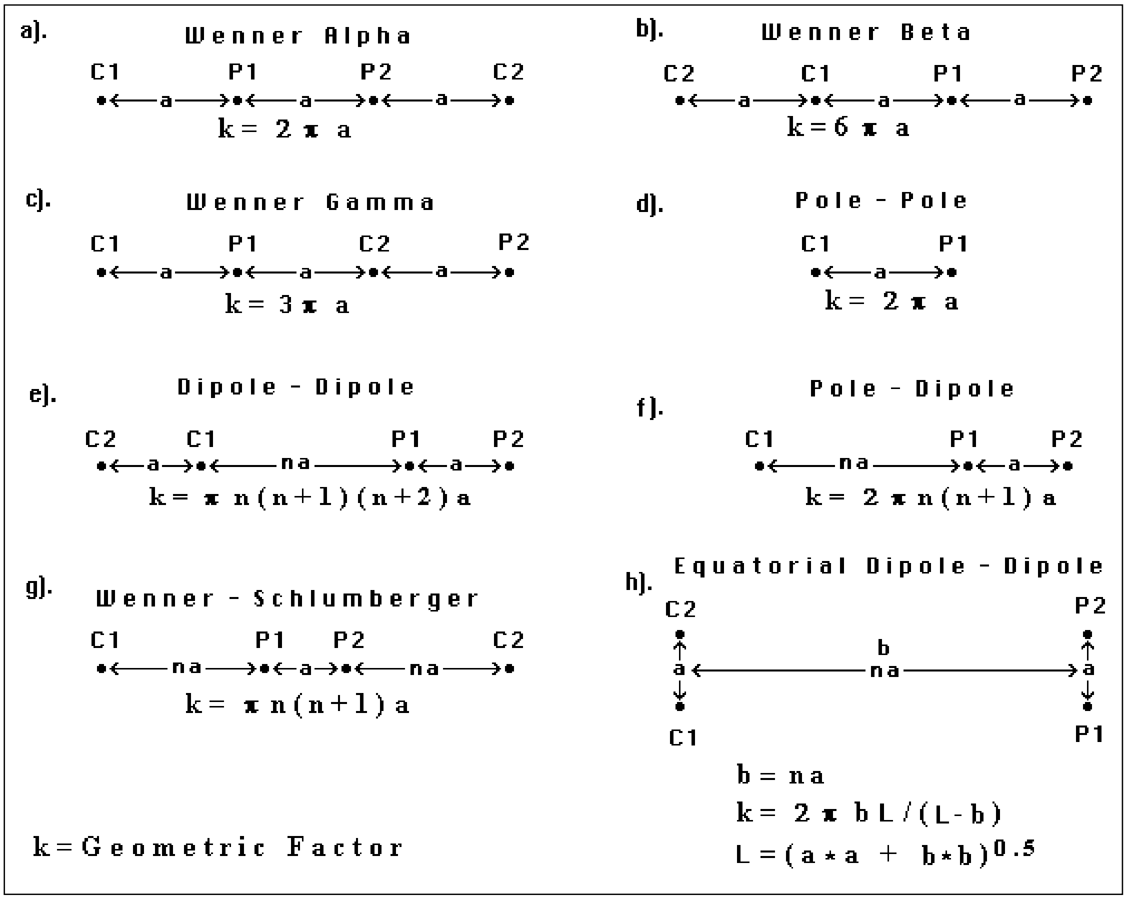

Figure 3: Common array for 2-D resistivity measurement (Loke and Barker, 1996)

Table 1: Resistivity value of some types of waters (Keller and Frischknecht, 1996; Telford and Sheriff, 1990).

Types of Waters	Ohm.m
Precipitation	30 – 1000
Surface water, in areas of igneous rock	30 – 500
Surface water, in areas of sedimentary rock	10 – 100
Groundwater, in areas of igneous rock	30 – 150
Groundwater, in areas of sedimentary rock	>1
Sea water	≈ 0.2
Drinking water (Max. salt content 0.25%)	>1.8
Water for irrigation and stock watering (Max. salt content 0.25%)	>0.65

METHODOLOGY

2-D resistivity survey lines R1-R9 conducted around the coastal area using Pole-dipole array with minimum electrode spacing of 1 m for a maximum total spread length of 40 m. Terrameter ABEM SAS4000 system used to collect the data with ES10-64C selector. A least-squares inversion of the resistivity data conducted using a finite element mesh with surface topography to generate a 2-D model of resistivity versus depth/ elevation. Field resistivity structures of 2-D resistivity data was processed using RES2Dinv software (Loke and Barker, 1996) for inverse interpretation and surfer software for gridding, contouring and final presentation.

RESULTS AND DISCUSSION

Figure 4 shows the 2-D resistivity inversion models of R1-R9. The result indicates the study area consists of two main layers with different resistivity values. The first layer with thickness of <5 m was interpreted as marine alluvium with resistivity value of <15 Ohm.m, while the second layer with depth of 0-8 m was interpreted as colluviums with resistivity value of >30 Ohm.m. The seawater intrusion was observed with resistivity values of <3 Ohm.m. The intrusion occurred at lines R1 and R2 at depth of <2 m and at line R5 at depth 15 m.

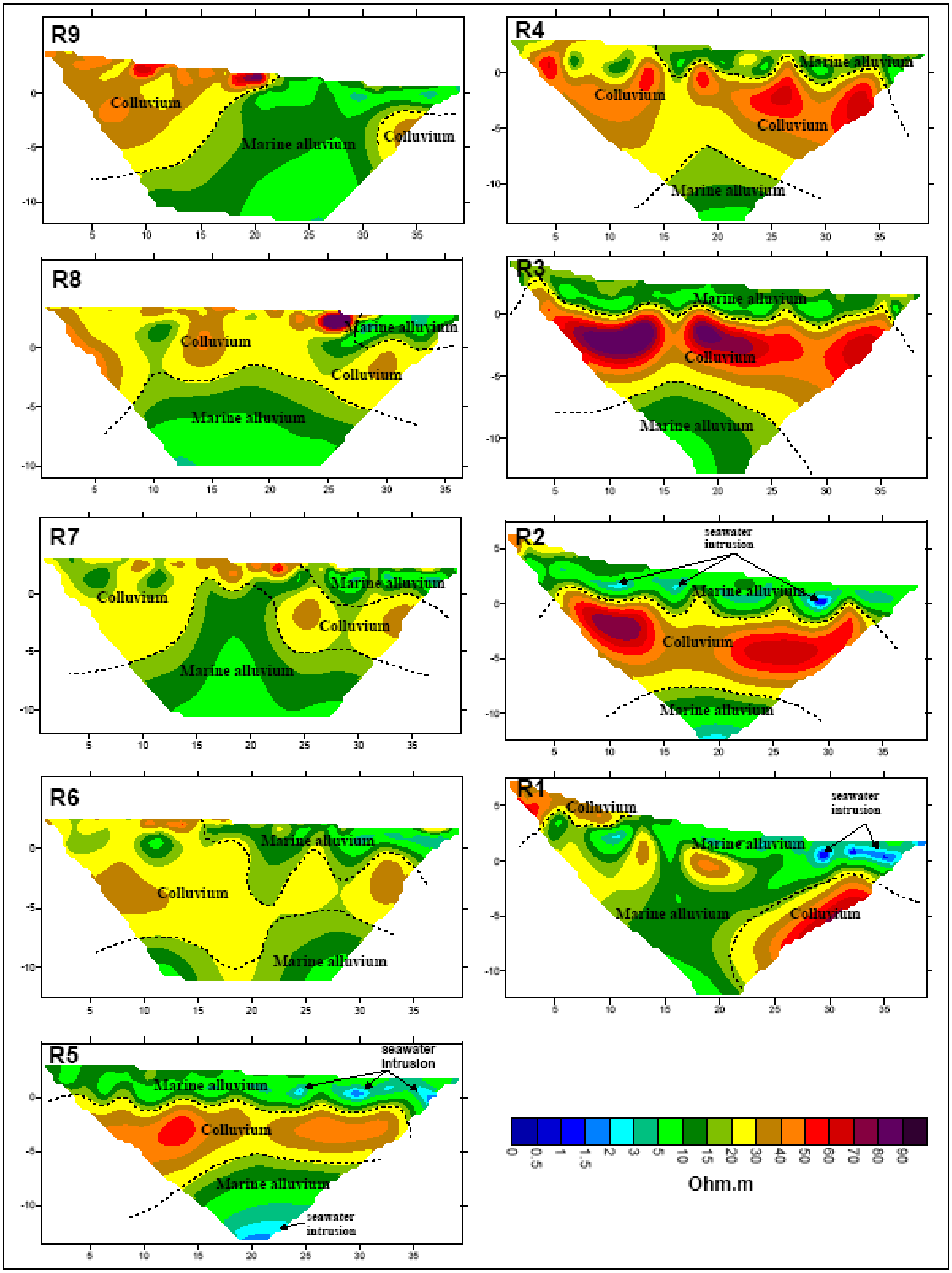

Figure 4: 2-D resistivity inversion model of R1-R9.

CONCLUSSION

The 2-D resistivity method is capable to identify seawater intrusion and provide information on underground layer. Two layers successfully detected at various depths. The seawater intrusion was detected at line R1, R2 and R5 at depth <2 m and 15 m respectively.

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