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Identification of Carbonate Freshwater in Perak Island, Kepulauan Seribu Using Ground Penetrating Radar Method

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ABSTRACT

A research has been carried out to identify freshwater and its distribution in Perak Island, Kepulauan Seribu using Ground-penetrating Radar (GPR) method. This research location is known for an isolated carbonate platform located on the equatorial belt. A freshwater well was found in the middle of Perak Island and used for daily needs for residents and tourists. Ground-penetrating radar (GPR) provided a promising approach to investigate the extent of the freshwater lens or aquifer volume, and to gain detailed information about the geological and hydrogeological features of the aquifer. It can give a high determination image of the dielectric properties of the features from a few tens of meters on the surface. This research purpose is to detect the presence of subsurface freshwater accumulation and the reservoir. By performing GPR measurements at a frequency of 100 MHz and stacking number 32 to increase signal to noise ratio, the subsurface results depict the depth of the well as far as 20 m, while the target is located at 2 - 5 m below the surface. Analyzing the results of data processing, it is clear that there is a fluid boundary contrast that indicates the presence of fresh-water. The result indicates the barrier zone for separating saline water and groundwater at depth of 2.5 – 3.75 m. The section result also describes the presence of vertical barriers formed by secondary fracture to prevent seawater intrusion to the reservoir.

INTRODUCTION

For the necessities of daily life, the need of freshwater lenses are important resources either in islands or coastal areas. In coastal areas, the balance of saline water and freshwater is too sensitive in those environments for changing of basic conditions.

This study is located in Perak Island, Kepulauan Seribu. The physiographic of Pulau Seribu coral island is highly dominated by holocene carbonate sediment with high porosity and permeability properties. This condition allows saltwater intrusion to disturb the hydrogeologic setting of the island. Perak Island is one of the islands in Kepulauan Seribu has freshwater well without indication of saltwater intrusion.

This study aims at evaluating GPR capability to investigate near surface fresh water resources in Perak Island. For environmental and hydrogeological purposes, GPR has proven to be a powerful tool especially in rocks and sediments which has low electrical conductivity. It is successfully used for investigations in sedimentology and landform characterisation with high resolution (Bristow et al., 2000) and showed to be an outstanding tool for mapping both large-scale and small-scale in coastal barriers (Møller and Anthony, 2003; Nielsen et al., 2009; Bennett et al., 2009; Lindhorst et al., 2010). GPR has also shown its ability to detect groundwater tables in sandy aquifers and carbonate (Harari, 1996).

STUDY AREA

This research location is on Perak Island, Kepulauan Seribu. Perak Island has an area of 3.06 hectares and is located in the northern part of the Kepulauan Seribu. Kepulauan Seribu is located about 45 km from the northwest coastline of Java Island, geographically on latitude -5° 24’ to -5° 45’ LS and longitude 106°25’ to 106°40’ with 107.489 hectares wide, distributed in north - south trend. Kepulauan Seribu platform is separated from Java mainland by a major deep channel, which Van Bemmelen interpreted as a major Pleistocene river system draining westward from Sumatera (Park, 2004). Tectonically the setting of Kepulauan Seribu is a broad, shallow-water, back-arc basin, with a north-south pattern of faulting. Based on research conducted by Ganda Perdana, et al (2015), Kepulauan Seribu is an isolated carbonate platform located on the equatorial belt. The carbonate platform in Kepulauan Seribu build under tropical climate condition, with sea surface temperatures ranging from 26.5^0 C to 30^0 C and has the low salinity of sea level on average between 30-34% resulting from tremendous amounts of fresh water runoff from Sumatra, Java, and Borneo, all flowing into the South China and Java Seas. At the research location, a freshwater well was found in the middle of Perak Island. Residents and tourists use the freshwater well for their daily needs. According to information obtained from the island manager, the freshwater well has not been identified regarding its existence and depth. In order to understand the freshwater depth and its distribution, indirect assessment was performed. The

measurement of the depth of the well and its distribution was carried out using a ground penetration radar in this study.

Figure 1. Map of Kepulauan Seribu. Red arrow indicates the location of Perak Island (modified from Jordan, 2006)

Ground Penetrating Radar (GPR) is a survey method for land, buildings, and subsurface conditions (in intervals of several centimeters to a depth of 60 meters). This method detects objects buried underground using radio waves, usually in the 10 MHz to 1GHz range.

Ground Penetrating Radar (GPR) detects the difference in permittivity, permeability, and resistivity of an object buried in the ground. Ground Penetrating Radar (GPR) also can detect metal and non-metal objects.

The way it works is by analyzing the reflections of electromagnetic waves generated as a result of differences in the properties / dielectric constant of objects below the surface.

GPR consists of a signal generator, transmitter antenna, and receiver to detect reflected EM waves. The type of antenna used, the transmitted signal, and the signal processing method depend on several things, including the type of object to be detected, the depth of the object, and the soil medium's electrical characteristics.

Radar signals transmit as pulses, which are not absorbed by the earth but reflected in a particular time domain. The transmitter and receiver antenna configuration modes on the GPR consist of monostatic and bistatic methods. The monostatic method is when the transmitter and receiver combine in one antenna. In comparison, the bistatic method is when both antennas have a separation distance.

If a GPR pulse hits a layer or object with a different dielectric constant, the pulse will be reflected back, received by the receiver antenna, the time and pulse size are recorded.

To produce a good interpretation result, the GPR must meet the following requirements:

• Efficient coupling of radiation into the ground,
• Efficient penetration of electromagnetic waves,
• Generates a signal with a large amplitude from the object detected,
• sufficient bandwidth to produce a good resolution.

The three basic principles of GPR that distinguish it from conventional radar systems are; Operating bandwidth is placed at low frequencies to obtain sufficient depth of penetration of the GPR into the ground, most GPRs are short-range radar systems, and GPRs have relatively shallow penetration of only a few meters below ground level.

METHODOLOGY

By performing GPR measurements at a frequency of 100 Hz with stacking 32 to increase signal to noise ratio, also there is reference for the depth of penetration GPR in relation to frequency dominant. The target is located at under 2.5 m. To gain detailed information about the geological and hydrogeological features of the aquifer on the Perak Island. The location of the GPR measurement line shown in Figure 2.

PROCESSING

In this research we carried out measurements in Perak Island, Kepulauan Seribu with the location of the groundwater wells shown in Figure 2. Where, the yellow line in Figure 2 shows the measurement line that we studied. We

used the GPR method using a frequency of 100 Hz by looking at the depth of 16 m and 20 m below the ground surface and the length of the track as far as 50 m. In this research we focused on knowing the barrier zone of groundwater in wells and its depth in the area.

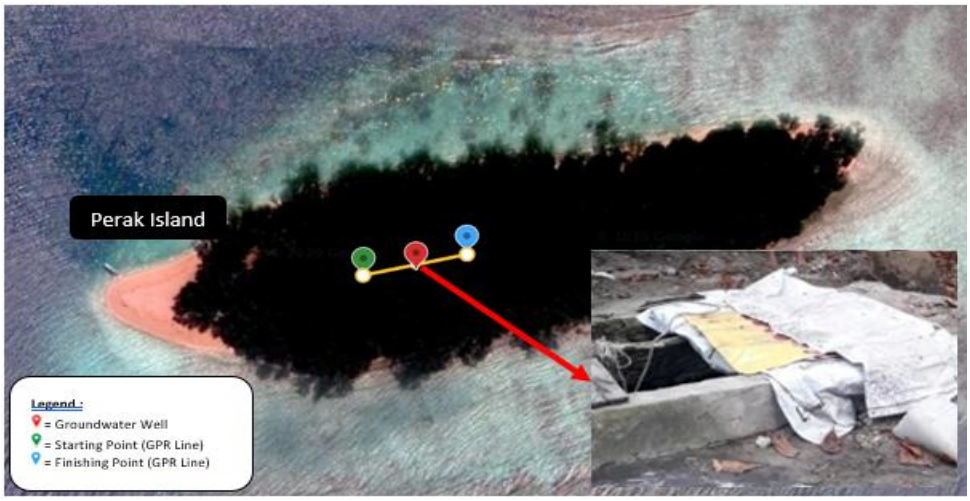

Figure 2. This figure shows survey design of GPR measurement in this research. The yellow line represents the path of the GPR instrument starting at the green dot and ending at the blue dot and across the well which is denoted by the red dot.

From the GPR data, we process the data using the Prism 2.6 software. Several processing steps applied on the data are background removal and adjusted the gain to get a more representative result.

RESULT

From the results of data processing on a line survey, the resolution of the GPR is obtained with a penetration depth of 20 m (Figure 3) . However, it is not clear the anomaly boundary for the groundwater zone. Then, we used a penetration depth of 16 m (Figure 4) to increase the resolution in the anomaly zone. After processing the data on line B, the anomalous limit of the groundwater zone is seen at a depth of 2.5 - 3.75 m which is marked by wave attenuation in that zone. So, we interpret the depth of groundwater as 1.25 m. In addition, there are several micro faults shown by blue lines, which reinforce that the fracture becomes a fluid pathway that can drain meteoric water into the groundwater aquifer, then get trapped accumulated, so that groundwater can emerge in Perak Island.

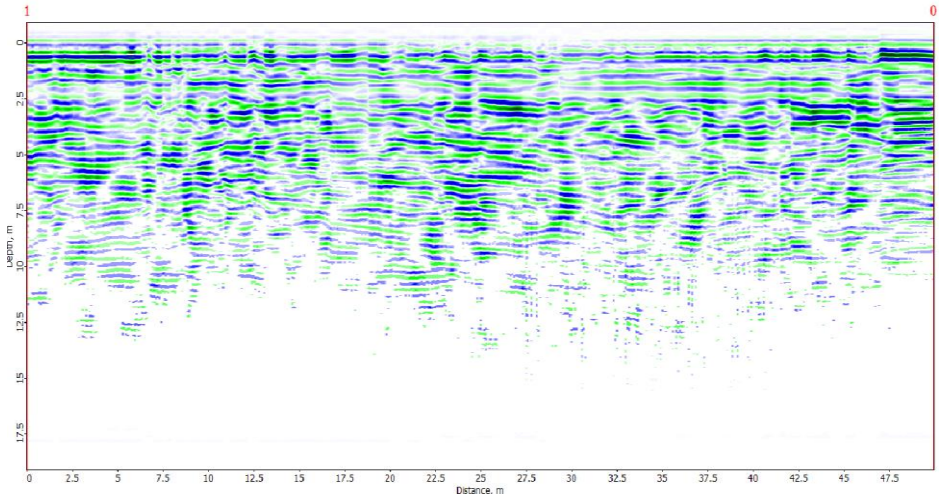

Figure 3. This figure represents the results of data processing. The resolution of the GPR is obtained with a penetration depth of 20 m. This figure does not show any interesting object.

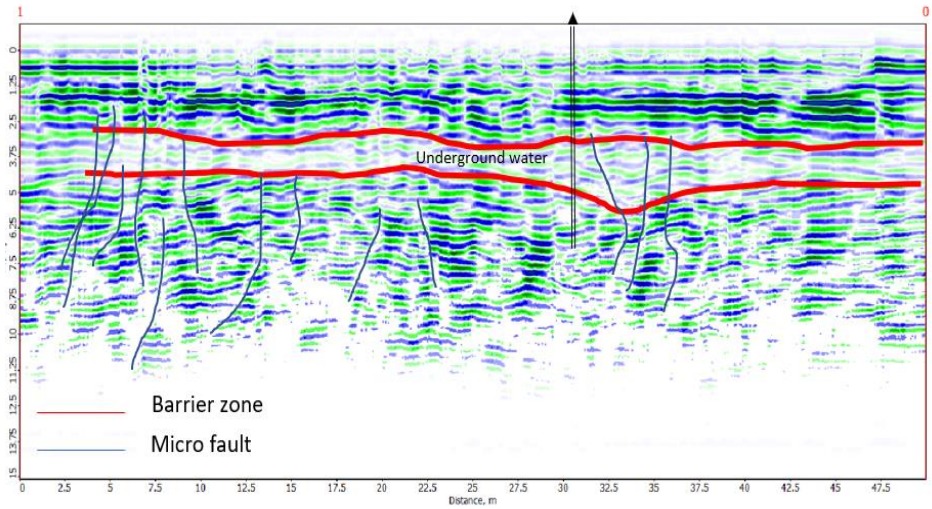

Figure 4. This figure represents the results of data processing. The resolution of the GPR is obtained with a penetration depth of 16 m. Red line represents the barrier zone and the blue line represents micro fault.

CONCLUSION

Our study shows the existence of groundwater in the middle of Perak Island. This phenomenon proved scientifically by measuring GPR method that presents the depict of subsurface nearby the groundwater well. The result indicates the barrier zone for separating saline water and groundwater at depth of 2.5 – 3.75 m. The section result also describes the presence of micro fractures that could be assumed as the pathway for migration of meteoric water to the aquifer. However, this research is limited to the acquisition pathway due to the lush environment, further research using geochemical analysis is needed to support this research.

Acknowledgments

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