Integrated Very Low Frequency and Geoelectrical Resistivity Methods to Study Possibility Shallow Groundwater Pathway in Bedrock Area

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Abstract. Exploration of groundwater movement has a specific challenge in thick forest area and cover with the shallow hard rock. The use of active and passive geophysical method is needed for groundwater exploration. This study aims to explore the prospect of groundwater zone especially for the groundwater pathway in the area around the hot spring zone. Geoelectrical resistivity and very low frequency (VLF) methods were used with electrode spacing of 2 meter and reading stations of about 5 meter, respectively. The geoelectrical resistivity was carried out using the Wenner configuration in the sites around the hot spring. The results show that the VLF model indicates occurrence of the conductive zones at the depth of about 10 m. The geoelectrical resistivity data show the same pattern with the VLF image. These conductive zones which is appeared in the VLF model are indicating as the zone of groundwater pathway from the source to the hot spring zones. The geoelectrical resistivity data also showed the same possibility of groundwater pathway.

1. Introduction

In hard rock areas, it is rather difficult to find an accumulation of groundwater if compared in uncompact sediments [1]. Water moves and accumulates in the fissures. However, when compared to areas of soft sediment, groundwater moves and accumulates through the pores between sediment grains. The pattern of the path of the path of the water below the surface needs to be known to determine the source and potential of the water. The relationship of waterways needs to be obviously identified [2]. This is due to in hard rock areas, the underground water currents can sometimes be horizontally parallel but the flow is contradictory and can even irritably tiers without being interconnected. This pattern shows the association between water currents and other fracture systems becomes problematic to control. It is significant to predict the water source in the hot spring area, because it is a theoretically very potential for geothermal resource [3].

The geophysical methods are generally used to explore the subsurface incongruity. The depth of investigation may in the deeper target such as for the oil and gas industry purposes and hydrothermal system [4,5,6]. The geophysical methods also commonly used for the shallow target investigation such as for the structure study [7], environment and mitigation of disaster. Several studies have been reported for the geophysical exploration especially in the shallow target [8-9]. The investigations are including to study the occurrence of heavy metal in the shallow aquifer system [10], the investigation of slope stability, seawater intrusion in the coastal area [11,12]. However, the geoelectrical resistivity has also used to investigate the landfill area [13], which is the zone of fresh water and leachate can be

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map well in the first shallow aquifer, thus, the way on the treatment and management of the landfill can be improved. The geoelectrical resistivity is also very useful in the investigation of groundwater potential [14,15].

Rohul district is located about 150 km from Pekanbaru, the capital of Riau Province. Several hot springs were found about 35 years ago. The hot spring is now used as the tourist attraction and for the daily activity by local community. The hot spring is located about 10 km from the Bukit Barisan hill. Bukit Barisan is the main mountain range in the Sumatra Island.

This study aims to explore the potential of groundwater resources in the hard bedrock area by using very low frequency and geoelectrical resistivity methods. The target of this study was to confirmed and recognizes the possibility pathway of groundwater. This study was also providing the information about the source of groundwater which is reviving the hot spring by continual rate.

2. Methodology
In this research, integrated passive and active geophysical methods were used to investigate the groundwater in the bedrock area. The VLF method was used on the thick forest whilst the geoelectrical resistivity method was used on the relatively clear area. The VLF method usually uses a radio wave as the passive source. The frequency of the radio waves is ranging from 15 kHz to 30 kHz. The principal of VLF, is generating an electromagnetic field by a radio wave transmitter. The power of the source can be 100-1000 KW with a wavelength of 10-20 km.

The T-VLF equipment that is produced in France was employed in this research to collecting the magnetic data. The VLF line surveys were conducted in the old rubber planting with thick forest industry condition. The forest was dominated by old rubber plantation with other wild forest in between them. The interval of data reading was adjusted with around 6 meter. The total length of the VLF survey was 800 meter. As the passive method VLF is very suitable conducted in the thick forest. The VLF survey was focused in between the relatively small lake at the southeastern part of study area and the hot spring at the northwestern part.

The geoelectrical resistivity survey was conducted using Wenner configuration. A homemade resistivity meter was employed to carry out the survey. In the survey, 5 meter electrode spacing was used for more higher resolution. The data was processed to obtain the resistivity model in two dimensions. Figure 1 displays the site of VLF and resistivity survey. In the figure, the thick forest can be observed in the whole research area.

![Figure 1](image)

**Figure 1.** The location of VLF survey (White line) and geoelectrical resistivity (yellow line)
3. Results and Discussion
Figure 2 shows the result of the VLF data. The VLF model shows the conductivity value of the subsurface. More conductive zone will be interpreted as more possibility of electrical current. The possibility zone of conductive material is the accumulation of water in the subsurface. The results will be confirmed by the geoelectrical resistivity model. The two types of data provide the information of groundwater accumulation or groundwater zone at the study site.

The VLF data collection was carried out on the hill right after the hot springs. This area has shallow bedrock. Some rocks boulders were found on the surface. In Figure 1 shows the line survey which are adjusted to follow the direction of the descending hill. In Figure 2, the intersection of the Tilt versus Ellipse provides a possibility of conductive zone (in blue color). The nonconductive zone is characterized by the zone colored red, and the zones colored blue represent the more resistive zone. This blue zone is believed to be groundwater at shallow depths to a depth of 10 meter downward. The survey line was carried out right next to a hot spring with about 200 meters from the location of the hot spring. The conductive zones are also appearing starting from the ground level to a depth of 30 meters downward.

Figure 3 shows the geoelectrical resistivity model that was conducted using Wenner configuration. The survey line was carried out just 20 m side of the hot spring. In the geoelectrical resistivity model, the hard rock material is presented with colored red. While the soft material which is saturated by groundwater is colored blue. In the Figure 3, the possibility of groundwater accumulation can be found at the depth starting 70 meters downward relative to the mean sea level.

![Figure 2. The 2D VLF model](image)

![Figure 3. The 2D geoelectrical resistivity model](image)

Generally, the possibility of conductive zones at the VLF model are connected to the conductive zones that are appeared in the geoelectrical resistivity model. It can be concluded that the groundwater moves from the source to the hot spring uses the crack occurred in the hard rock zone.

4. Conclusion
The study was successfully to show the possibility of the groundwater in the study area. Both VLF and geoelectrical resistivity data show that the physical character of the subsurface in the area. The
subsurface is dominated by the hard rock, however the crack zone was possible to observe in both VLF and geoelectrical resistivity models. The crack zones are predicted as the groundwater pathway from the small lake as the source of water and move to the hot spring. The source of groundwater is believed and confirmed from the small lake which is located at the southeast part of the study area and the cracks are connected to the hot spring.

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