Correlation of Vp/Vs ratio against the resistivity value to determine the aquifers presence estimation in jetak sub-village, getasan sub-district, Semarang regency

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Abstract. Jetak Sub-Village, Getasan Sub-District, Semarang Regency, was an area that had found difficulty in getting clean water because it was not located in the groundwater basin area. The correlation between the Horizontal to Vertical Spectral Ratio (HVSR) and the Resistivity method could be used to determine the estimation of the aquifer's presence. Based on the interpretation of the correlation results of the HVSR model using the Vp/Vs ratio against the rock resistivity value showed the presence of shallow aquifers at a depth of between 20-50 m below the earth's surface in the sandstone layer. Sandstone based on HVSR at a location that has a Vp/Vs ratio of 1.8-2.3 and in resistivity modeling had a value of 21.1ohm-m. These results indicated that the aquifer is not a groundwater aquifer that can be used for needs during the dry season.

1. Introduction

Based on the report on the availability of groundwater in Semarang Regency, Getasan Sub-District is not located in Groundwater Basin Area (CAT) figure 1, so it is difficult to find groundwater. Jetak Sub-Village is part of Getasan Sub-District where in the dry season the shallow wells will run out, so it is necessary to find underground water wells to support the daily water needs.

The shear wave velocity (Vs) is one of the waves body whose direction of deviation is perpendicular to the direction of propagation. The value of shear wave velocity (Vs) and the ratio of Vp / Vs can be used to determine the lithology layer. Rock or soft material will have a relatively smaller Vs value compared to hard rock, because the value of the shear wave velocity is directly proportional to the density of the rock.

By using two-dimensional analysis and inversion of HVSR data, it is expected that the distribution of the P wave velocity (Vp) and S wave velocity (Vs) values to both the horizontal and vertical directions in the area around the measurement location. The characteristics of the soil and rock layers can be identified using Vp and Vs. According to [1] the comparison of the P wave and the S wave velocities that propagates on a medium depends on the medium characteristics.
By knowing the comparative value of Vp/Vs, it can be estimated whether the layer contains water or not [2]. A location below the surface which is estimated to contain water has a ratio of Vp and Vs greater than 1.4 [3].

To ensure that the rock layers contain water, measurements are made using the resistivity method where the aquifers layer can be determined based on the rock resistivity value. Vertical Electrical Sounding method with Schlumberger array assumes considerable importance in the field of groundwater exploration because this method is regularly used to solve a wide variety of groundwater problems. Such as determination of depth, thickness and boundary of a aquifer [4-9]. Correlating the Vp/Vs ratio value against the resistivity value can be used to determine the type of aquifer rock.

![Figure 1. Distribution of Groundwater Basins (CAT) in Semarang regency](image)

**Figure 1.** Distribution of Groundwater Basins (CAT) in Semarang regency

## 2. Methods

One of the methods to determine the condition and physical properties of soil using a geophysical approach is the HVSR method. The Horizontal to Vertical Spectral Ratio (HVSR) method is a method that calculates the comparison of seismic recording data from the horizontal component to its vertical component. The HVSR method was introduced by [2] to estimate the resonance frequency and amplification factor of rocks beds in an area of microseismic data. The HVSR method is typically used in three-component passive seismic (microtremor) seismic. The important parameters generated from the HVSR method are natural frequency and amplification. HVSR which is measured on the soil aims to characterize the seismic wave velocities both P wave and S wave at the depth direction of a place. Natural frequency and amplification are related to subsurface physical parameters[10]. The results of the data inversion are the profiles of the value of the S wave P wave velocities and rock layers density towards the depth [3] [11].

The Poisson's Ratio is the ratio of transverse contraction to elongation when the stem is stretched. Poisson's ratio can be measured from the arrival of seismic waves. Ideally, Poisson's ratio is 0.25 or the...
ideal elastic body. If $V_s$ is low, the $V_p/V_s$ ratio becomes high and $\sigma$ approaches 0.5. The relationship between Poisson’s ratio ($\sigma$) and $V_p/V_s$ ratio can be formulated as in the following equation:

$$\sigma = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)} = \left(\frac{V_p}{V_s}\right)^2 - \frac{1}{2}\left(\frac{V_p}{V_s}\right)^4 - 1$$

(1)

where $\sigma$ is Poisson's ratio, $V_p$ is the velocity of the P wave (m/s), and $V_s$ is the velocity of the S wave (m/s).

The geoelectrical method is one of the geophysical methods to study the electrical properties inside the earth and how to detect it [12]. This method aims to determine the subsurface conditions based on the electrical conductivity of the rocks. In this method, the current injection into the ground is carried out through two electrodes which are also connected to the power supply. The response given by the earth is in the form of a potential difference value received through two potential electrodes so that the subsurface rock resistivity value is obtained. The free electrons contained in the rock play a role in conducting the electrical current flowing in the rock. Apart from the free electrons present in rocks, the rock's ability to conduct electricity or the resistivity of the rocks is also one of the factors that influence the flow of electricity in the rock. The greater the resistivity value of a rock, the more difficult it is for the rock to conduct electric current, and vice versa.

The electrode configuration used in the measurement of this resistivity method uses the Schlumberger sounding configuration; this configuration can detect the non-homogeneity of rock layers and can penetrate the deep surface by widening the current injected into the earth so that the change in the resistivity value indicates the rock type. The measurement data obtained in the form of electrode position and pseudo resistivity values are processed using IPIwin2 software so that a subsurface model based on the depth and resistivity value of the rock is obtained.

3. Result and discussion

3.1. HVSR results

Based on geological observations in the site, the overall effective length that can be carried out for data collection is around 400 meters and the effective width is around 250 meters with 50 measurement points and the groundwater prospect is along the trajectory of points 16 to j2 is given in Figure 2.

The $V_s$ value for each rock type has a different value, so the $V_s$ value can be one of the parameters used for lithology analysis of subsurface structures. Based on the site classification the value of $V_s$ in Figure 2 includes the category of soft rock, rock and hard rock layers [13], in rocks where water is indicated is a rock that has a shear velocity value of $750 < V_s < 1500$ m/s.

The results of the mapping of the distribution of $V_p/V_s$ ratio of various measurement points have a value that varies between 0.5 and 21. This shows that in areas with low S wave velocities will have high $V_p/V_s$ ratio values. To determine the presence of fluid in the subsurface layer usually have a poison's ratio value ($\sigma$) ranging from 0.25 to 0.4 [14], if converted using the Poison’s Ratio the value of $V_p/V_s$ ranges from 1.73 to 2.45 in this case, the measurement results that are scattered in several locations are indicated by the presence of $V_p/V_s$ values ranging from 1.8 to 2.3, which are sandstone where water occupies the pores of the rock. $V_p/V_s$ ratio indicating the influence of fluid especially for sandy lithologies [15].

Based on this, locations that have $V_p/V_s$ values are associated with sandstone at location points 15, 13, 10 and 9 with a depth of 20 -50 meters in Figure 2.
3.2. Resistivity results
Based on the measurement results at the location point around Jetak Sub-Village with coordinates 07° 23' 36.7" and 110° 28' 28.7" have been modeled and interpreted by the existing rock layers as shown in the resistivity log of figure 3.

Figure 2. Distribution of Vp/Vs ratio of various measurement location 16 - J2

Figure 3. The resistivity interpretation model

Topsoil is in the form of a landfill at a depth of (0 – 2.01) m with very random varying resistance values, breccias sandstone insert at depth of (2.01 – 5.27) m with a resistivity value of 135-139 Ωm, breccias at depth of (5.27 – 22.9) m with a resistivity value of 772 Ωm, sandstone at depth of (22.9 - 48.7) m with a resistivity value of 21.1 Ωm, breccias at depth of (48.7 - 135) m with a resistivity value of 504 Ωm, breccias sandstone insert at a depth of (135 - undetermined) m with a resistivity value of
90.5 Ωm. There is a potential for shallow aquifers at a depth of (22.9 - 48.7) m with a resistance value of 21.1 Ωm, sandstone has a resistivity between 1-100 Ωm [1], [16] found sandstone as shallow aquifers having a resistivity value of 1 - 30 Ωm. The results of the correlation between the HVSR and Resistivity measurements show that at depth there is the presence of groundwater potential at a depth between 20-50 m subsurface in the sandstone layer.

4. Conclusion
Based on the interpretation of the HVSR model using the Vp/Vs ratio with rock resistivity values, it shows the presence of shallow aquifers at a depth of 20-50 m below the earth’s surface in the sandstone layer. Sandstone based on HVSR at a location that has a VP/Vs ratio of about 1.8-2.3 and in resistivity modeling has a value of 21.1 Ωm. There is a correlation of rock types between the Vp / Vs comparison value to the resistivity value, but in determining the rock type category in more detail uses the resistivity method rather than using the HVSR method.

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