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Research Paper

Identification of the Aquifer Layers Using HVSR Method in Tosoro, Semarang Regency, Central Java, Indonesia

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ABSTRACT: *The identification of aquifer layer was carried out in Tosoro. The aim of this research is to help Tosoro residents who often have water problems during the dry season. We determine the location of the aquifer layer by the HVSR method with the Poisson's ratio parameter and the ratio of Vp/Vs. The results of the research conducted in Tosoro Hamlet with 10 data collection points found a value of Poisson's and Vp/Vs ratios of different points. The Poisson's ratio value is produced from 10 measurement points between 0.21-0.47 and the Vp/Vs ratio between 1.64–4.07. The Poisson's ratio parameter for the case of determining the location of an aquifer is more than 0.25 and Vp/Vs ratio is more than 1.73. Based on these parameters the location of the study area is the prospect of groundwater, namely at point 1 depth of 10-21 meters, point 3 depth of 7-21 meters and point 4 depth of 16-49 meters.*
KEYWORDS: *Aquifer, HVSR, Poisson's ratio, ratio Vp/Vs*

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I. INTRODUCTION

Jetak is a village located in Getasan District, Semarang, Central Java. This village has Tosoro Hamlet which is the location of research in determining the location of the aquifer layer point which is where groundwater accumulates. Water is the main human need, both for the needs of drinking water, bathing and other needs. Human needs for water are very high but water supplies are small due to the long dry season. This can be seen in some river flows in Tosoro Hamlet becoming dry and many residents lacking water to meet their needs. According to Jetak village officials and local residents in Tosoro hamlet for more than six months, it has never rained because there are very few water sources and the wells of local residents are in drought. This is very troubling for residents considering that water is the main human need in life.

There are various water sources such as rainwater, surface water, groundwater and seawater (Susana, 2003). The largest source of fresh water on earth is derived from the soil. Groundwater is water that is below the surface of the soil in a water-saturated zone that fills the pores between soils or rocks and its movement follows Darcy's law. This water can be categorized into two, namely shallow groundwater or those found in free aquifers and those stored as deep groundwater in depressed aquifers. The presence of groundwater in the rock will largely depend on the presence of containers or basins or water-carrying layers or aquifers that have a fairly high graduation (permeability) of the rock.

As a result of the prolonged dry season, there are very few sources of rainwater and surface water so that the solution to meet the need for water in Tosoro Hamlet is to use groundwater. Groundwater is within the surface of the earth and the location of its existence cannot be seen directly by humans. So a way is needed to determine the source of groundwater, for example using the Geoelectric method and HVSR. Resistivity is a geophysical method by using the electrical properties of rocks to investigate subsurface states. HVSR is one of the passive seismic methods of Geophysics which is relatively cheap, easy and environmentally friendly.

The HVSR method is a method that compares the spectrum of horizontal components against the vertical components of microtremor waves. The results of the HVSR are in the form of frequency, amplitude and period. Microtremors are microwaves emitted by the earth and vibrations that come from humans in the form of traffic civilization, machine vibrations, and so on. The HVSR method produces a comparison between the P wave velocity and the S wave velocity so that it can determine (Vp)/(Vs) the Poisson's ratio value used as a parameter to determine the point where the groundwater aquifer is located. Poisson's ratio for determining water prospects is more than 0.25 and the Vp/Vs ratio is more than 1.73.

II. THEORY

Seismic Waves

Seismic waves are elastic waves that propagate within the earth. Seismic propagation depends on the nature of the elasticity of a rock. The tool for recording these waves is a seismogram placed above the earth's surface. A seismogram is the result of a recording of vibrations caused by the propagation of seismic waves from a source. Each seismogram has important information about the source of the seismic wave and the medium it passes through. Seismic waves consist of two types based on their propagation, some of which propagate through the earth called body waves or body waves and some that propagate through the earth's surface called surface waves or surface waves. (Body wave) Body waves are divided into two based on the direction of their vibration. (Surface wave) Surface wave consists of Raleigh wave (ground roll) and Love wave (Telford et al., 1976).

The surface of the Earth is always moving at a seismic frequency, even without earthquakes. This constant vibration of the earth's surface is called microtremor. The term microtremor is more commonly used in the field of earthquake engineering. The amplitude value of the microtremor is very small about 10-4 – 10-2 mm. Although the amplitude is weak, it gives noise to earthquake seismology researchers. Therefore, earthquake researchers call microtremors or seismicity sounds or noise (Okada, 2003).

The HVSR (Horizontal to Vertical Spectral Ratio) method is a geophysical method of comparing the spectrum of horizontal components against the vertical components of microwaves. Microtremor consists of the base variety of Rayleigh waves, it is suspected that the peak period of the H/V comparison of microtremors provides the basis of the S wave period. Comparison of H/V curves on microtremors is a comparison of the two components that theoretically produce a value. The dominant period of a location can be basically estimated from the peak period of the microtremor H/V comparison (Nakamura, 2000).

One of the important natural resources for humans that get special attention in their utilization and preservation protection is water resources. Water resources are natural resources that are very important in the survival of humans in general and the pace of regional development in particular. The development of the region, which is characterized by the rapid pace of development in various regions, will certainly be followed by the rate of population growth of an area. As the pace of regional development and population growth accelerates, it demands the provision of increasingly large areas of land and the need for water resources to support life. The availability and potential of water resources plays an important role in supporting the needs for daily interests for drinking, bathing, agriculture and so on. To meet the need for clean water, many water resources are utilized on the surface of this earth, in the form of surface water, for example rivers, reservoirs, lakes, lakes, swamps or other reservoirs, as well as subsurface water in the form of groundwater and springs (Santosan and Adji, 2014). Aquifers are rock formations that can store and pass sufficient amounts of water. Examples of aquifers are non-solidifying sand, gravel , sandstone, hollow limestone and dolomite, basalt streams, rocks and plutonics with many cracks. Based on the constituent geological structure, aquifers and groundwater are grouped into three, namely free aquifers, semi-depressed aquifers, and depressed aquifers (Fetter, 1988).

The ratio is the ratio between the speed of the P wave and the speed of the S wave in the seismic wave. Vp/VsPoisson's ratio is a measure of the compressibility of an object perpendicular to stress or the ratio of a latitudinal strain to a longitudinal strain. A cylindrical object as a sample is then pressed by a force, then the sample will shorten and make the radius increase. It's the comparison of changes in length and changes in radius that is what Poisson's ratio calls. This elastic constant was named by a French mathematician named Simeon Poisson (Sharma, 1997). The Poisson ratio or Poisson's ratio is the ratio of transverse contractions to longitudinal elongation when the stem is stretched. Poisson's ratio can be measured from the arrival of seismic waves. The value of Poisson's ratio is ideally 0.25 or called the ideal elastic body. If it is low, the ratio becomes high and Vp/Vs the σ close to 0.5. The value of Vs is low then the comparison becomes high and the Vp/Vs value of the σ is higher. If it is lower, the ratio is lower and the σ value Vp/Vs is lower. At conditions that have a vapor the value of Poisson's ratio is below 0.25 and the ratio is below . If the poisson ratio σ above 0.25 and the ratio above is a condition of high water prospects and porous (Hersir and Bjornsson, 1991).

The relationship between *Poisson's ratio* (*σ*) and comparison can be formulated as in equation Vp/Vs. If the *Poisson's ratio* (*σ*) will be zero, the *Poisson's ratio* (*σ*) is 1/4 or 0.25 (Hersir and Bjornsson, 1991).

$$\sigma=\frac{V_p^2-2V_s^2}{2(V_p^2-V_s^2)}\ \frac{(V_p/V_s)^2-2}{2[(V_p/V_s)^2-1]} \quad (1)$$

with *σ* is *Poisson's ratio*, Vp is the speed of the P wave (m/s), and Vs is the speed of the S wave (m/s).

III. METHODS

The acquisition of microtremor data was carried out on September 20, 2018 in Tosoro Hamlet, Jetak Village, Getasan, Central Java with 10 observation points. The data used in the study is primary data obtained from the acquisition of microtremor data carried out in Tosoro Hamlet, Jetak Village, Getasan, Central Java. The equipment used in this study are: Data logger GL240, 3-component seismometer, Geological compass, Laptop intel ® inside ™ core i3 and GPS. In data processing to determine the value of peak ground acceleration and ground shear strain, two steps are needed, namely the HVSR method to obtain amplification and frequency using Geospy software, then the second is to find the value of peak ground acceleration and ground shear strain using Microsoft Excel software and finally modeled with Surfer software.

The first stage is to find the frequency value and amplification using the HVSR method. The data obtained from the acquisition are signals in time series with each component (Z, N-S, E-W). In this first stage, the ambient signal is selected from the three components. The HVSR value is obtained by using software which contains several components to produce frequency and amplification. There are several parameters that must be considered, such as the Time Window Length, the amount of STA (Short Term Average) which is the average signal amplitude in a short time (0.5-0.2 s) and LTA (Long Term Average) which is the average amplitude over a longer period, and frequency sampling to determine the frequency (0.05-10.0 Hz). In the process of determining the frequency and amplification, it is necessary to pay attention to the Smoothing type. Incorrect selection will result in unexpected frequency output. The recommended smoothing type is the Kohno & Ohmaci Smoothing which will produce the right output for low frequencies. From the processing on Geopsy, data will be obtained in the form of an HV curve which is then used to search for the spectrum. Spectrum searching is done on Dinver software to get spectrum based on Inversion in the form of Fast Fourier Transform (FFT). The results obtained from the processor through dinver software are in the form of density, Vp, Vs, and depth.

IV. RESULTS AND DISCUSSION

The study was conducted September 20th, 2018. The purpose of this study was to identify the aquifer layer using the HVSR method in Tosoro Hamlet, Jetak Getasan Village, Central Java. This research is started from the design stage of the site survey that will be carried out. Furthermore, the stages of microtremor data acquisition in Tosoro Hamlet, Jetak Village on the 10 measurement points. The acquisition parameters that are considered are the distance between measurement points, the time of data collection of each measurement point, the geology of the research area and the noise that occurs when conducting research.

When acquiring the distance between the measurement points is 50 meters and the data retrieval time of each point is 10 minutes. During the collection of microtremor data there are various small vibrations caused by the geoelectric data retrieval carried out, people are walking and so on. After conquering the acquisition of microtremor data, it then carries out data processing. The contour value of each point of the research area can be seen in Figure 2 which is processed using surfer software. The figure shows that the elevation value ranges from 985 meters to 999 meters. The highest elevation values are at points 8 and 9 i.e. and the lowest elevation is at point 1.

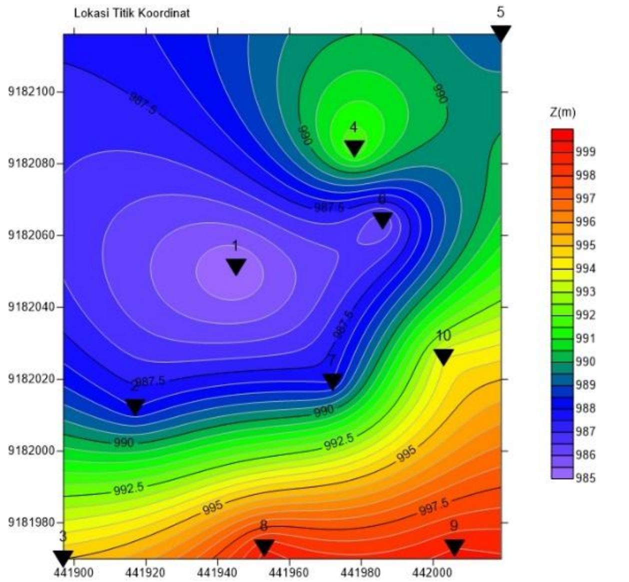

Figure 1. Contours of the study site

The aquifer layer identification of groundwater, one of the influencing factors is the frequency value and Amplification of the HVSR method. Microtremor vibrations at a location can be determined by calculating the spectral ratio between horizontal components and vertical components observed at the same location point so that they can be used to identify natural frequencies in the sedimentary layer. The ratio is derived from the maximum value and is combined by the softening of the soil as well as its amplification factor. The H/V resulting ratio of the maximum value responds to the characteristics of the soil. The HVSR result is in the form of frequency values (fo) and amplitude (Ao). The amplitude value on the time domain signal indicates the hardness or weakness of the signal received during the acquisition of microtremor (as shown on figure 3, figure 4 and figure 5).

The period value is obtained from the calculation based on the frequency value of the HVSR calculation results. Period is the result of the period, amplitude and frequency is presented in Table 4.1. It is noticed that the frequency value from 1/f 0.637084 - 7.68475 Hz, the period value is 0.130128-1.569652 and the amplitude value is 2.74357-4.49016. Frequency is the number of vibrations that occur in a unit of time. The vibrations that occurred in the study area ranged from 0.64 to 7.68 vibrations per second. The frequency value can represent the characteristics of the sedimentary layer. When viewed from the frequency contour of the research area, point 9 is the measurement point with the lowest frequency value of 0.64 Hz while at point 7 it is the measurement point that has the largest frequency with a value of 7.68 Hz. In Figure 4.3, the highest frequency contour is shown on the red contour at point 7 and the lowest frequency is shown on the purple contour at point 9. A smaller frequency value indicates that the site has a harder sedimentary layer compared to a larger frequency value. This is in accordance with the fermat principle where waves propagate through the shortest and fastest mileage. In mediums that have more gaps (soft), waves are more numerous and quickly pass through the medium so that the resulting frequency is greater than through a more compact medium. Based on this principle, points 1, 6, and 7 show a sedimentary layer with a softer structure compared to points 2, 3, 4, 5, 8, 9 and 10. The period is the time it takes to perform one full vibration. The period value is inversely proportional to the frequency value while the period value is directly proportional to the amplification value. The amplification factor gives an idea of the change in the acceleration of movement in the soil from bedrock to the surface. The change in soil acceleration from bedrock to surface due to the difference in the speed of movement of shear waves in bedrock and in the soil layer (sediment)(Vs).

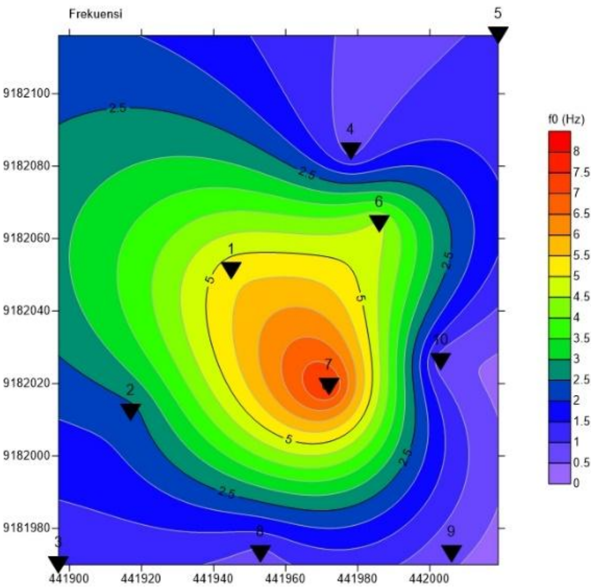

Figure 2. Frequency contours at the study site

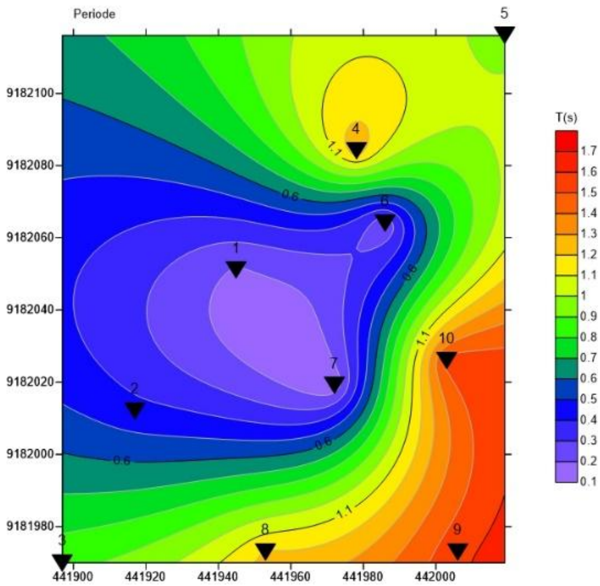

Figure 3. Period contours at the study site

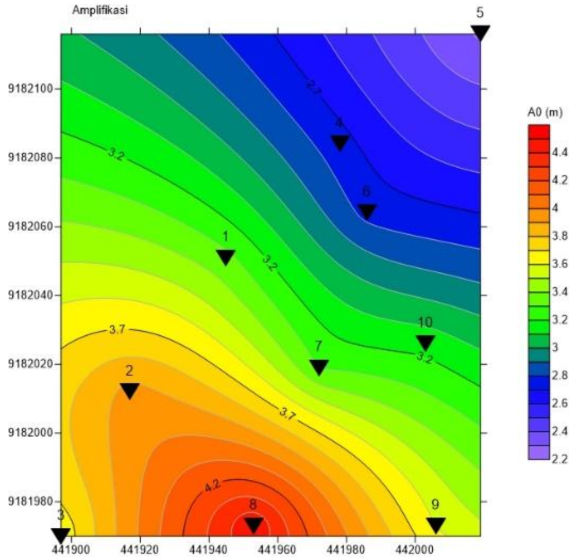

Figure 4. Amplification contours at the study site

The value of wave velocity and wave velocity S is obtained from the results of the 1D inversion of the HVSR calculation. After the V_p and V_s value are found, processing is carried out using surfer software to find out the contours of 2D modeling the distribution of Vp and Vs values. The Vp values are vary from 533.11 m/s to 4829.14 m/s and Vs values between 282.58 m/s to 2938.88 m/s. The highest Vp value at point 8 with location coordinates 110.474001°E - 7.400225°S at an altitude of 910.97 meters and the lowest Vp at point 2 with location coordinates of 110.473675°E, -7.399871°S at an altitude of 988 meters. The highest V_s value at point 8 with location coordinates 110.474001°E, -7.400225°S at an altitude of 910.97 meters and the lowest at point 2 with location coordinates of 110.473675°E, -7.399871°S at an altitude of 988 meters.

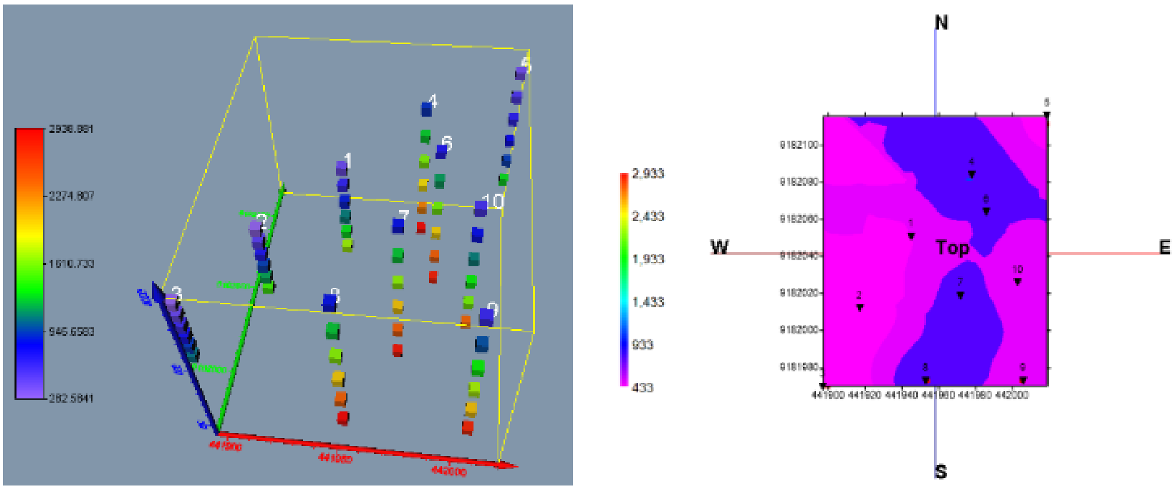

Figure 5. Observation Points distribution and 3D model of Vs

The Vp/Vs is one of the important physical properties or parameters used to determine the lithology of the subsurface layer. The ratio value of Vp/Vs comes from the comparison between the speed of the P wave and the S wave resulting from the HVSR calculation. The results of the ratio at the study site varied to have a value between 1.64 up to 4.07. The largest ratio value of Vp/Vs is at point 4 location at 110.474229°E, -7.399221°S at an altitude of 910.71 meters. The high value of Vp/Vs (more than 1.73) is a wet condition with the suspicion that there are rocks filled with water. The low-value of Vp/Vs (less than 1.73) are interpreted to be related to dry, gas-filled rocks. The greater the value, the higher the porosity value of a rock. Based on the comparison on the 10 measurement points of the study, it can be interpreted that the greatest possible location for which the water prospect is located is at point 4.

The value of Poisson's ratio is obtained from calculations using the value of P wave velocity and S wave velocity. Results from the calculation of Poisson's ratio 0.21 at the point up to 0.47. The lowest Poisson's ratio value is on the entire surface of the location of 10 measurement points with a value of 0.21 and the highest value is at point 4 with a coordinate location of 110.474229°E, -7.399221°E at an altitude of 992 meters. Poisson's ratio, which has the prospect of water below the earth's surface, is a value of more than 0.25.

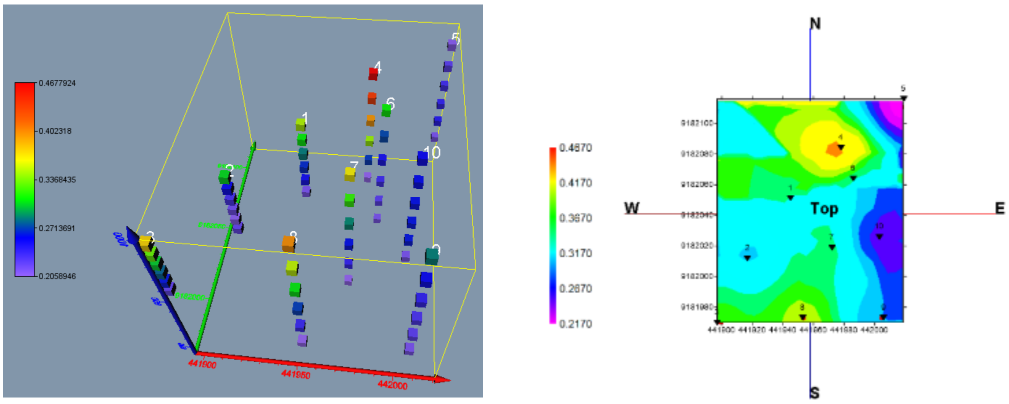

Figure 6. The *Poisson's ratio* points distribution and the 3D model.

The ratio value and Vp/Vs Poisson's ratio can be determined through a microtremor survey. The value of its frequency, period and amplification of the soil can be obtained using the HVSR (horizontal to vertical spectral ratio) method. The amplification value and frequency indicate the characteristics of the soil medium through which it passes. When a larger frequency indicates that a location of the study area has a softer sedimentary layer compared to a location that has a smaller frequency value. This is due to the propagation properties of a seismic wave. In a medium that has more gaps or is soft, more waves can and quickly pass through a medium through which it passes so that the resulting frequency is greater than when through a more compact or hard medium. This is due to the nature of surface waves that will become smaller when the deeper the location through which they pass. This phenomenon is caused by the dispersion in surface waves which is one of the wave properties, namely wave decomposition based on wavelengths throughout their propagation. The period value is inversely proportional to the frequency value, which is one per frequency size, while it is directly proportional to amplification. The value of an amplification gives an idea of the change (magnification) of the accelerated movement of the soil from the bedrock to the surface. The enlargement of the soil acceleration from the bedrock to the surface is due to the difference in the speed of movement of shear waves in the bedrock (Vs) and in the soil layer (sediment). The comparison Value between P wave velocity and the S wave velocity in the seismic wave which can be used as a parameter in determining the lithology of a layer of soil. A value that has a value above 1.73 is a state that has a high porosity so that it is possible to store liquid fluids such as water in the pores of rocks. Based on the measurement results from 10 measurement points, the ratio of Vp/Vs is distributed at 1.64 to 4.07. Poisson's ratio or Poisson's ratio is the ratio of transverse contraction to longitudinal elongation when the rod is stretched. For rubber and water, the value of Poisson's ratio is equal to 0.5, but for cork is equal to 0. If the value of Poisson's ratio is 0.25, the ratio of Vp/Vs becomes 3 or 1.73. In conditions that have steam, the Poisson's ratio value is below 0.25. If the value of Poisson's ratio is above 0.25, it is a condition of high porosity and water prospects.

When measuring microtremor at the research site, there is a surface water source in the form of a water reservoir near point 6 with coordinates 110.474228° East Longitude, -7.399528° South Latitude with an elevation of 979.32 meters. It can be observed in Figures 4.12, 4.13 and 4.14 that the Poisson's ratio of the area is about 0.21 to 0.31 and the ratio of Vp/Vs is about 1.66-1.91. The area that contains surface water sources has a frequency of around 4.867605 and an amplitude of 2.93636. Based on the comparison parameters Vp/Vs and Poisson's ratio, the research area in Tosoro Hamlet, Jetak Village, Getasan, Central Java has rock lithology consisting of sandstone, clay, and shale. Groundwater potential with shallow groundwater at point 1 with a depth of 10-21 meters, point 3 with a depth of 7-21 meters and point 4 with a depth of 16-49 meters.

V. CONCLUSION

The research could be concluded that from the acquisition of 10 points in Tosoro Hamlet, Jetak Village, Getasan, Central Java, it is known that the Vp/Vs value varies from 1.64 to 4.07. The value of Possion's ratio at the research location is between 0.21 to 0.47. The location of the point that has the lowest Vp/Vs is at 3 points, namely at point 4 elevation 910.7081, point 7 elevation 895, and point 8 elevation 910.9725 and the location Vp/Vs at point 4 with location coordinates 110.474229° East, -7,399221°LS elevation 992. The location of the point that has the highest Possion's ratio is at point 4 with location coordinates 110,474229°E -7,399221°S elevation 992. So from the value of Vp/Vs and Possion's ratio, which is known in Tosoro Hamlet has potential for groundwater aquifers, indicating that groundwater is at point 1 at a depth of 10-21 meters, point 3 at a depth of 7-21 meters and point 4 at a depth of 16-49 meters.

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