

Geoelectrical survey and groundwater chemical analysis in Sumowono Groundwater Basin

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Submission date: 30-May-2022 12:11PM (UTC+0700)

Submission ID: 1846952069

File name: Putranto_2021_J._Phys._Conf._Ser._1943_012003.pdf (2.06M)

Word count: 3035

Character count: 15229

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To cite this article: T T Putranto *et al* 2021 *J. Phys.: Conf. Ser.* **1943** 012003

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Geoelectrical survey and groundwater chemical analysis in Sumowono Groundwater Basin

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Abstract. Sumowono groundwater basin is an inter-regency groundwater basin located in Central Java Province. The administrative areas are Semarang Regency, Temanggung Regency, and Kendal Regency. Hilly regions dominate the study area. This study aims to identify the subsurface lithology and analysis of the water type of groundwater samples. The methods were geoelectrical survey using Schlumberger array and physical and chemical of groundwater samples analyses from dug wells and springs. The results of the geoelectrical survey conduct five types of lithology with the resistivity value from 0 to more than 190 Ω m. They are claystone, tuff, tuffaceous sandstone, sandstone, and breccia. The chemical properties of groundwater samples indicate that the pH has a range from 6.4 to 7.27 with electrical conductivity (EC) from 71.6 to 511 μ S/cm. Moreover, the Total Dissolved Solids (TDS) start from 45.8 to 327 mg/L. The water types are Mg^{2+} - Ca^{2+} - HCO_3^- -Cl⁻, Ca^{2+} - Mg^{2+} - HCO_3^- -Cl⁻, Ca^{2+} - Mg^{2+} - HCO_3^- , Ca^{2+} - HCO_3^- -Cl⁻, Ca^{2+} - Mg^{2+} - HCO_3^- - SO_4^{2-} , and Ca^{2+} - HCO_3^- - SO_4^{2-} .

1. Introduction

The Sumowono Groundwater Basin is located in Central Java Province. Administratively, the Sumowono groundwater basin is in Semarang Regency, Kendal Regency, and Temanggung Regency. Specifically, it is at 396658-426897 East Longitude and 9197102-9215729 South Latitude (Figure 1). With geomorphological characteristics, it is dominated by hilly areas with an average rainfall of 1,383 mm/year [1].

A Geoelectric survey is a geophysical method using electric currents to determine the condition of the underground layer. This survey is usually define the subsurface condition by measuring the resistivity value of the rock [2]. It is also used to determine aquifer geometry and distribution [3]. The aquifer geometry includes aquifer thickness and aquifer depth [4]. Researchers in the world mostly conduct this survey because it is advantageous and efficient. The application of this survey is very appropriate to describe the subsurface condition because the porosity and permeability properties of rocks are very suitable to be combined with rock resistivity [5]. Rock resistivity that differs from the measurement results is usually due to the mineral content in the rock. Then the resistivity values are grouped and combined with the geological conditions in the study area. This measurement can also determine the potential for groundwater in aquifers [6]. Geoelectric investigations collect a lot of



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information related to existing geological structures and mineral content which can affect the chemical content, in this case, groundwater quality.

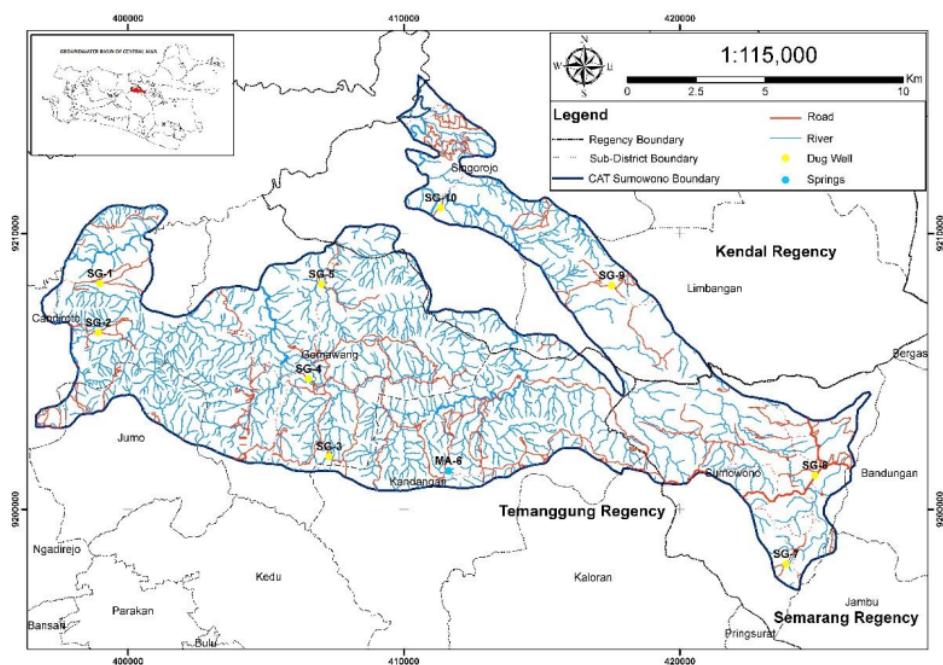


Figure 1. Study area and interest points of groundwater sampling

Chemical analysis of groundwater is usually carried out to determine the quality of groundwater such as the content of cations (Ca^{2+} , Mg^{2+} , $\text{Na}^{+}+\text{K}^{+}$) and anions (Cl^{-} , SO_4^{2-} , HCO_3^{-}) as well as the pH, TDS, and EC values. The major cations and anions can be plotted on a stiff diagram showing changes in water composition. The quality and hydrochemistry of groundwater can change at any time, depending on the interaction of groundwater with rocks that store groundwater, which ultimately affects the water type [7]. The pH value, electrical conductivity/EC, and TDS can be used to determine the quality of groundwater. The pH of the water represents the relative amounts of free hydrogen (H^{+}) and hydroxyl ions (OH^{-}). Moreover, the pH value is influenced by the soil where the water flows. Also, the factors of water sources, rainfall, and contaminants significantly affect the pH value. pH in water analysis is used as an indicator of relative acidity. Value > 9.5 indicates alkaline, while value < 3 indicates acidity [8]. The normal pH range for drinking water is from 6.5 to 8.5. In comparison, the EC value estimates the total amount of dissolved solids in water which is usually controlled by lithology, salt solubility, basic chemical properties, and human activity [9]. Changes in groundwater chemistry are strongly influenced by the dissolution and deposition of minerals in rocks that become aquifers [10].

The purpose of this study is to determine the condition of the subsurface condition by measurement the resistivity value using the geoelectrical survey. Moreover, it has another objective to assess groundwater quality and water type.

2. Geology and hydrogeology setting

The Sumowono groundwater basin is located at the topography of 260-1,010 masl with the dominance of lithology in the form of volcanic rocks. The rock stratigraphy in Sumowono from old to young deposits, according to [11], consists of andesite intrusion (Tma) and basalt intrusion (Tmb). It then

follows by The Kerek Formation (Tmk), which consists of alternating claystone, marl, and limestone (Figure 2). While the volcanic product, there is the Penyatan Formation (Tmp), whose lithology is composed of tuffaceous sandstones, volcanic breccias, tuffs, claystone, and lava flows which dominate the Sumowono groundwater basin. Furthermore, the Kaligetas Formation (Qpkg) with lithology of volcanic breccias, tuffs, lava flows, tuff sandstones, and claystone. There are also volcanic rocks of Mount Kemalon and Mount Sangku (Qks) in the form of solid plagioclase sortie to fine crystalline, dense to fine-grained hollow lava with hornblende phenocryst. The Jembangan volcanic rock (Qj) in the form of a lava flow. Gajahmungkur volcanic rocks (Qhg) are composed of andesite lava flows. Sindoro Volcano (Qsu) lava flow andesite augite olivine. Sumbing volcanic rocks (Qls) are composed of augite hyperstein lava. The youngest lithology is alluvium deposits (Qa) in the form of gravel, gravel, sand, and silt.

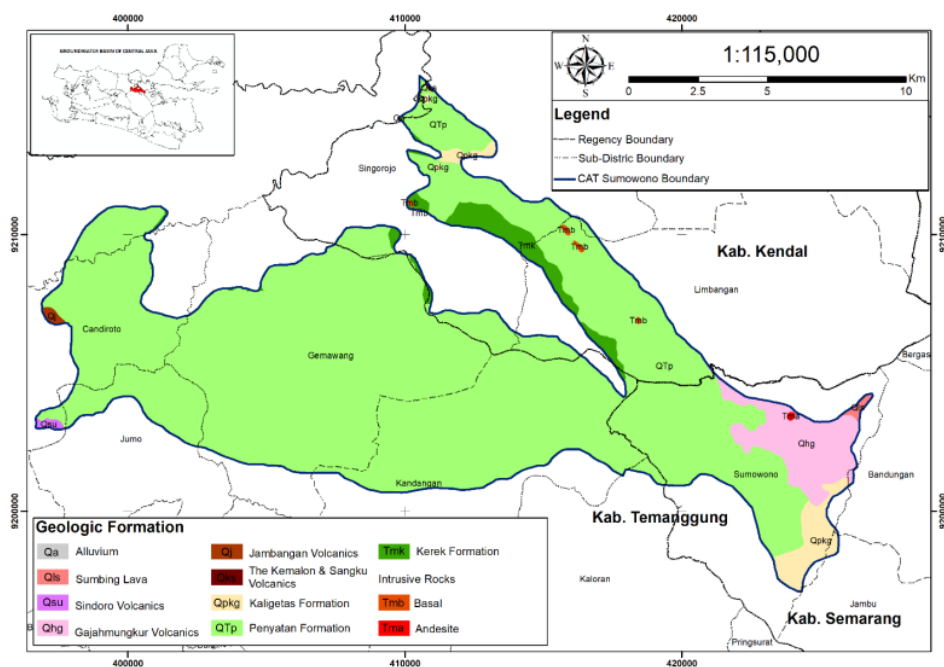


Figure 2. Regional geological map of Sumowono groundwater Basin [11].

Based on the Regional Hydrogeological Map of the Pekalongan Sheet [12] and the Semarang Sheet [13], the Sumowono groundwater basin has two types in which aquifer flow fissures, fractures, and channels and its productivity from medium to high. The second aquifer flow in which fissures or porous with low productivity and region without groundwater abstraction (figure 3).

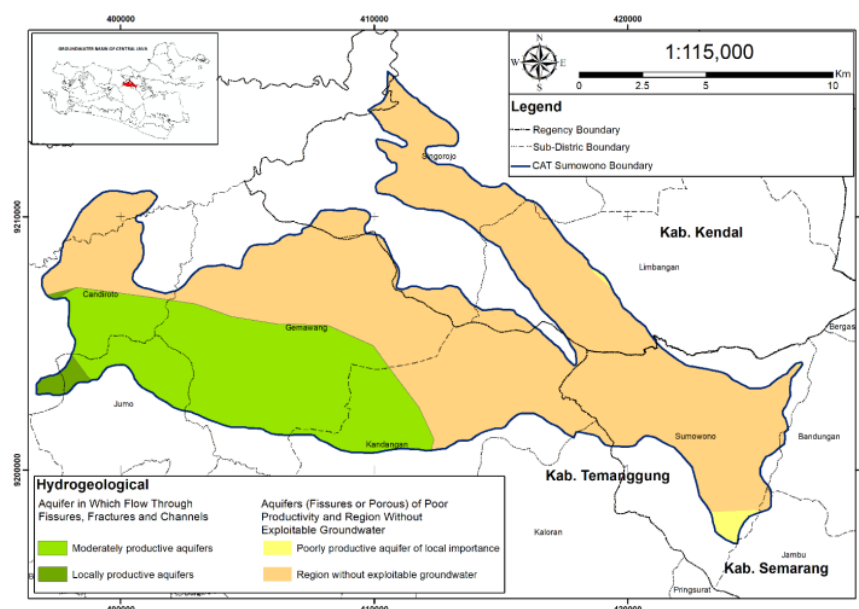


Figure 3. Regional hydrogeological map of Sumowono groundwater Basin [12-13].

3. Methods

A hydrogeological mapping was carried out to present data on subsurface conditions and analysis of groundwater quality in June 2020. Hydrogeological mapping was conducted geoelectrical measurements of 10 points (Figure 4) using the Putranto resistivity equipment. The Schlumberger array method was applied with a measurement path length of 400 m and a potential point of 25 m in the resistivity measurement. The geoelectrical survey employed Vertical Electrical Sounding (VES) to obtain the rock resistivity by injecting currents into the ground [4]. With a path length of 400 m, it is estimated that vertical depth data is 130-150 m deep or one-third of the maximum electrode current [14]. From the data of the geoelectrical measurements in the field, a matching curve analysis was carried out to obtain the actual thickness, depth, and resistivity values of the rock, because the resistivity value measurement in the field campaign was an apparent resistivity value. Furthermore, the results of the matching curve analysis were correlated in 3 dimensions to determine the distribution of rocks.

Groundwater samples were taken from 9 dug wells and 1 spring for analyzing their physical and chemical properties, including pH, TDS, and EC using a portable multi-meter multiline 3510 IDS. Indeed, the chemical analysis of the main cations and anions of groundwater was analyzed in the Envilab geochemical laboratory. The pH, TDS, and EC values were analyzed spatially using Surfer 11 and ArcGIS 10.4 software. Visualization of groundwater hydrochemical values is plotted in a stiff diagram using Aquachem software.

4. Result and discussion

4.1 Geoelectrical survey

The results of the analysis of 10 geoelectric measurement points in the Sumowono Groundwater Basin, there are several types of lithology obtained based on the rock resistivity value in the [2] as shown in Table 1 below. The soil which is deposited on the top has varied from 2.14 to 462. 29. The lowest resistivity is claystone, with a resistivity up to 5 Ω m. The volcanic product has a ranges from 10 Ω m to more than 190 Ω m. The highest resistivity indicated compact rocks such as breccia. Tuff and tuffaceous

sandstone have a range from 5 to 30 Ωm . At the same time, sandstone has a resistivity between 30-180 Ωm . The distribution of subsurface conditions can be depicted in figure 5 in the fence diagram.

Tabel 1. Rocks resistivity value

Lithology	Resistivity (Ωm)
Soil	2.14-462.29
Claystone	0-5
Tuff	5-10
Tuffaceous sandstone	10-30
Sandstone	30-180
Breccia	>190

Breccia is found in GL 4 with a thickness of hundreds of meters in the east. Sandstone is identified extend dominantly in the south with the thickness of hundreds of meters as shown in GL 1. Tuffaceous sandstone spreads mainly thicker in the northeast, more than 100 m, and becomes thinner to the center up to 45 m which is across GL 6 to GL 8. At the same time, tuff is dominated in the west in GL 9 to GL 10. The thickness is from tens of meters up to 45 m. Claystone is locally deposited in the south across GL 2 to 3 with a thickness from 10 to 53 m.

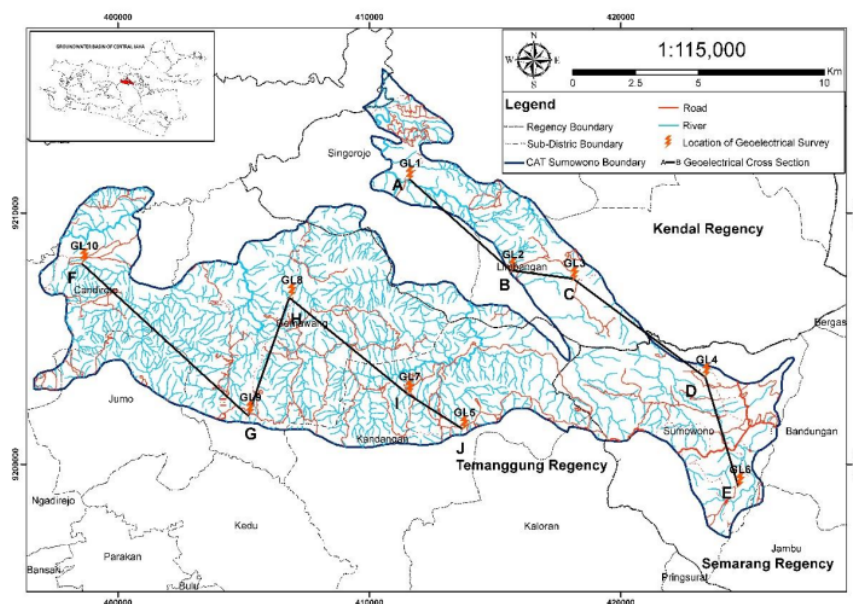


Figure 4. Geoelectrical survey points and its cross-section of subsurface interpretation.

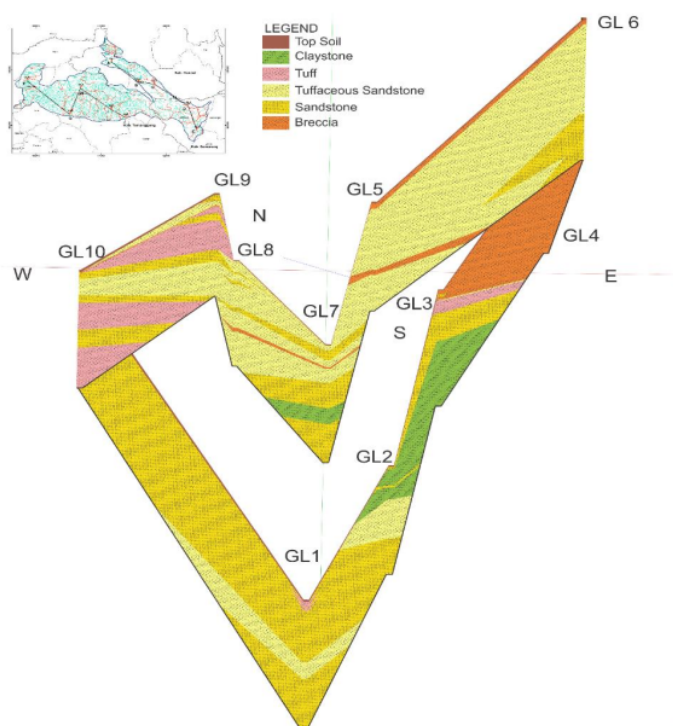


Figure 5. The fence diagram shows the lithology distribution based on the result of geoelectrical measurement.

4.2. Hydrochemical analysis

Figure 1 shows the groundwater sampling location with the results of the hydrogeochemical analysis of 10 groundwater samples in the Sumowono Groundwater Basin is presented in Table 2 below. The result showed that the highest EC value, 377 $\mu\text{S}/\text{cm}$ (Figure 6) was in the Muncar, Gemawang (SG-05) area, and the lowest EC value, 71.6 $\mu\text{S}/\text{cm}$, was in springs (MA-06) located in Rowoseneng Village, Kandangan. Overall, the resulting EC value indicates a safe condition for use, marked with an EC value below 1,000 $\mu\text{S}/\text{cm}$ (Figure 6). The TDS value of the Sumowono Groundwater Basin area as a whole sample has a value that is included in the secured category because it is less than 500 mg/L. The highest TDS value is 241 mg/L in the Muncar, Gemawang area and the lowest TDS value of 45.8 mg/L locates in Rowoseneng Village Kandangan with an average of 152.9 mg/L (Figure 7). Overall, the pH value of the Sumowono Groundwater Basin is neutral in the range of 6.4-7.27 [15].

A hydrogeochemical analysis of groundwater shows the dominance of major cations and anions in meq/L, which is presented in the stiff diagram (Figure 8). The order of cation dominance is $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ + \text{K}^+$. Meanwhile, the main anion concentration is $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$. Calcium is the dominant cations in almost all samples (SG-1, SG-2, SG-3, SG-4, SG-5, SG-6, SG-7, SG-8, SG-9) due to the groundwater may interact actively with volcanic sedimentary rocks (the Penyatan Formation) such as tuffaceous sandstones, sandstone, tuff, and volcanic breccia. Meanwhile, the high precipitation in the Sumowono Groundwater Basin affects the dominance of bicarbonate (HCO_3^-) in anions. Thus, the primary water type is $\text{Ca}^{2+} - \text{HCO}_3^-$. This type of water is natural water [16]. The hydrogeochemical analysis conducts six water types, namely $\text{Mg}^{2+} - \text{Ca}^{2+} - \text{HCO}_3^- - \text{Cl}^-$ scattered in the western part of the study area. $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{HCO}_3^- - \text{Cl}^-$ develops in the eastern region, while $\text{Ca}^{2+} - \text{Mg}^{2+} - \text{HCO}_3^-$ distributes in the

south and the west. Furthermore, $\text{Ca}^{2+}\text{-HCO}_3^- \text{- Cl}^-$ is located in the center, $\text{Ca}^{2+}\text{-Mg}^{2+}\text{-HCO}_3^- \text{- SO}_4^{2-}$ in the south, and $\text{Ca}^{2+}\text{-HCO}_3^- \text{- SO}_4^{2-}$ in the north.

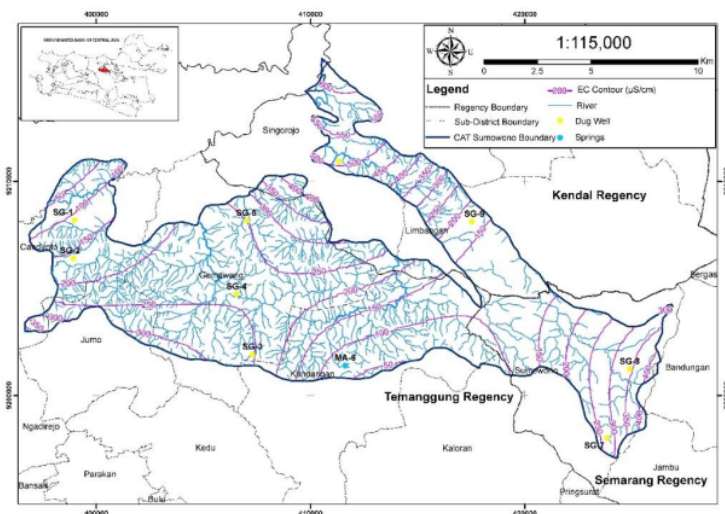


Figure 6. Electrical conductivity map of the groundwater samples.

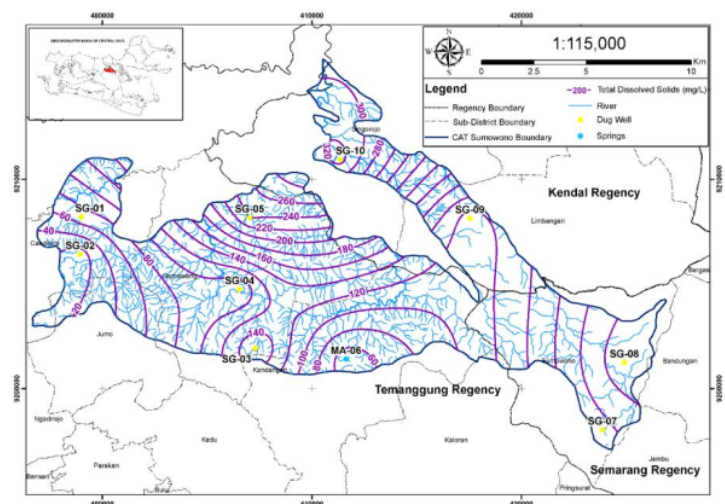
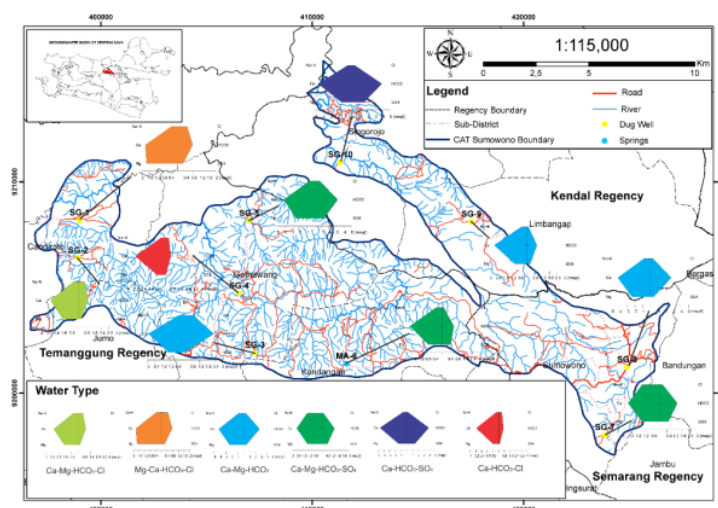


Figure 7. Total dissolved solids map of the groundwater samples.

Tabel 2. Hydrogeochemical analysis of groundwater samples.

Sample Code	Location	EC $\mu\text{S/cm}$	pH	TDS mg/L	Mg^{2+} mg/L	Ca^{2+} mg/L	Na^+ mg/L	K^+ mg/L	Cl^- mg/L	HCO_3^- mg/L	SO_4^{2-} mg/L
Maximum Allowed (Permenkes 492/2010)			6.5-8.5	500			200		250		250
SG-01	Sidoarjo, Candirot	111	7.22	71.04	21.6	36.6	6.83	5.85	16	46.8	11
SG-02	Plosogaden, Candirot	158	7.25	101.1	21.6	61.6	8.64	8.47	22	61.6	12
SG-03	Kandangan	256	7	163.8	16.6	59.3	9.21	3.76	24	143	27
SG-04	Gemawang	123	7.1	78.72	10.9	63.9	7.01	3.02	16	41.9	7.3
SG-05	Muncar, Gemawang	377	6.97	241.2	30.9	82.9	9.89	11.5	27	193	63
MA-06	Rowoseneng	71.6	6.4	45.8	9.55	35.9	6.82	3.36	3	38.2	22
SG-07	Ngadikerso, Sumowono	271	7.04	173.4	17.6	51.5	14.1	31.7	9	88.7	34
SG-08	Lajan, Sumowono	340	7.16	217.6	29.7	85.6	10.8	15.5	13	168	22
SG-09	Kedungboto	171	7.27	109.4	12.7	53.9	8.24	3.57	4	49.3	13
SG-10	Kaliputih, Limbangan	511	6.85	327	18.3	94.5	12.3	4.55	8	239	72

**Figure 8.** The stiff diagram shows major cations and anions to define the water type of groundwater samples

5. Conclusion

As a result of the geoelectrical survey, there are five lithologies, namely claystone, tuff, tuffaceous sandstone, sandstone, and breccia. Claystone has the lowest up to 5 Ωm . The volcanic product has ranged from 10 Ωm to more than 190 Ωm . The highest resistivity indicated compact rocks such as breccia. Tuff and tuffaceous sandstone have a range from 5 to 30 Ωm . At the same time, sandstone has a resistivity between 30-180 Ωm . Breccia is found in the east. Sandstone is identified to extend dominantly in the south. Tuffaceous sandstone spreads mainly thicker in the northeast and becomes thinner to the center. At the same time, tuff is dominated in the west, and claystone is locally deposited in the south.

The order of cation dominance is $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ + \text{K}^+$. Meanwhile, the main anion concentration is $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$. There are six water types, namely Mg^{2+} - Ca^{2+} - HCO_3^- - Cl^- scattered in the western part of the study area. Ca^{2+} - Mg^{2+} - HCO_3^- - Cl^- develops in the eastern region, while Ca^{2+} - Mg^{2+} - HCO_3^- distributes in the south and the west. Furthermore, Ca^{2+} - HCO_3^- - Cl^- is located in the center, Ca^{2+} - Mg^{2+} - HCO_3^- - SO_4^{2-} in the south, and Ca^{2+} - HCO_3^- - SO_4^{2-} in the north.

Acknowledgments

This research is funded by the Research Institution and Public Serving of the Diponegoro University with the scheme Development and Application Research (RPP) with the No. 326-69/UN7.6.1/PP/2020.

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PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10