The potential of river discharge at the peak of the dry season in some disaster-prone area of Merapi Volcano

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Abstract. With a high level of volcanic activity and many people living in the disaster-prone area, sustainable disaster management in the Merapi Volcano area is still very much needed in the future. One of the needs in building disaster management is ensuring water resources available during the pre-eruption period. So far, springs are the primary source of water that has been widely used by residents in the volcanic foothills, which are prone to eruption disasters. However, at the time of the eruption, many springs were not functioning so that alternative water sources were needed. River water can be an alternative water source, and a study of river water's potential is required to ensure its feasibility. This study was conducted on the south to the southwest side of Merapi Volcano to analyze the quantity and quality of river water as an alternative water source. Data collected through observation, literature study, and document search. Data analysis performed using descriptive analysis, matching analysis, and statistical analysis using independent sample t-test and simple linear regression. The study results show that seven rivers in the south to the southwest slope can be used as water sources because they are not lava flows. These rivers have varying discharge and water quality. There is no difference in discharge and water quality between the top and the bottom of the volcano foot. When dry season is on the peak, three rivers have no flow because some springs locations are at the volcano's bottom. Overall, based on these findings, it can be emphasized that the use of water sources is needed to do at the closest point to the evacuation barracks. However, a water treatment installation needs to be provided in the evacuation barracks so that the river water is suitable for consumption.

1. Introduction
Natural disasters due to volcanism are one of the most threatening types of disasters in Indonesia, and this is inseparable from the existence of 129 active volcanoes [1], with their activities that continuously. Data from the Center for Volcanology and Geological Disaster Mitigation [2] shows that in the first quarter of 2020, there were at least 13 volcanoes whose activity was above normal. The high potential for volcanic hazard in Indonesia is inseparable from the Indonesian archipelago geological setting, located in the subduction zone of the world's major plates [3]. The volcanic eruption disaster that has happened a lot from time to time harms a large area and affects many
residents' lives. This condition requires adequate preparation in various aspects in order to form excellent and sustainable disaster management.

Based on the historical record of eruptions, 47% of Indonesia's eruptions occurred on the island of Java [3]. In Central Java, there is the Merapi Volcano, which is widely known as one of the most active volcanoes in the world [4]. A short return period of eruptions is a sign of Merapi's volcanic activity. Until now, Merapi Volcano has experienced eruptions more than 80 times, with a return period of eruptions occurring between 1 to 15 years, a massive eruption every 150-500 years, and a maximum interval of 12 years [5]. On the other hand, many people live in areas prone to the eruption of Merapi. After the big eruption in 2010, the Merapi hazard area's growth rate was even higher than the average national population growth [6]. Data from the Global Volcanism Program published by the Smithsonian Institution [7] shows that the population in a 30 km radius from Merapi's summit in early 2020 reached 4,348,473 people. The large number of people who live in this active volcanic area requires sustainable and innovative disaster management to reduce risks in the future.

One of the obstacles encountered in disaster management is handling refugees during the disaster emergency period, including the provision of clean water resources. Springs are the main water source that is widely used by residents in the volcanic foothills, which are prone to eruptions. Research conducted by Aurita and Purwantara [8] and Ratih et al. [9] showed that the springs in the southern to western foothills of Merapi volcano are good quality and sufficient quantity. Meanwhile, Sudarmadji et al. [10] showed that in Pakem and Turi Subdistricts alone, there are at least 37 springs used by the community to meet water needs. However, the problem is that during the crisis period, many of the springs died, or the drainage installation was unusable. The location of the springs is also mostly far from the evacuation barracks. As a result, the fulfillment of clean water sources is highly dependent on supplies from other regions. Of course, it requires a lot of money, and mobilization is not easy to provide clean water during a disaster emergency. Experience in Srumbung Subdistrict during the eruption crisis period in 2010; every household received a water reservoir that was refilled by waiting for the supply of water sources from other areas.

The water sources originating from rivers is necessary to meet water needs in an emergency of an eruption, namely by starting to carry out management during typical situations or signs of increased volcanic activity. Merapi volcano, a stratovolcano landscape, has many rivers that flow perennial, mostly the young south to the southwest side. In this area, many river channels do not originate from Merapi’s volcanic cone so that it does not become a lava flow path when it erupts. This existing potential can utilize optimally. For that, of course, a study on river water sources' potential is needed, both in quality and quantity. The big eruption in 2010 and several eruptions in early 2020 occurred at the beginning of the rainy season, where the flow rate in the rivers was large enough to be used as an alternative water source. However, at the beginning of the dry season, many rivers have reduced water discharge, so it is necessary to review their availability and suitability. Further studies are necessary to do after the quality and quantity requirements of clean water are fulfilled to determine which areas can be used for optimum utilization of river water spatially.

The southern to western slopes of the Merapi volcano is heavily affected by eruptions until now. In the past, eruptions had much impact on the southwestern side of Merapi [5], shown by the deposition of lava material that often occurs in the major rivers of this region [4]. Meanwhile, the maps of eruption-prone areas and eruption-affected areas published by the Geological Agency show that the southern slopes were the areas that were directly affected by the 2010 eruptions. After the big eruption in 2020, this area is also still the part most prone to experiencing the impact of disasters. For example, during the eruption on March 3, 2020, monitoring of the Himawari Weather Satellite Image showed that volcanic ash due to the eruption was detected moving towards the Southwest - Southeast. On the other hand, many people are living in this area. Data from BPS Magelang and Sleman Regencies [11], [12], [13], [14], shows that Cangkringan, Pakem, Turi, and Srumbung Subdistricts, whose areas are part of disaster-prone areas, in 2019 reached 152,390 people. With this condition, the provision of alternative water resources to support disaster emergency management is of greater urgency for the Merapi Volcano's southern slopes.
This paper provides alternative information about the characteristics of river discharge in the disaster-prone area of Merapi Volcano, at the beginning of the dry season. Thus, this paper has two specific goals. First, this paper describes the quantity of river water and its potential to meet per capita water needs in a disaster emergency. Second, this paper describes water quality in terms of physics and its suitability for consumption, based on water quality parameters.

2. Methods

2.1. Data collection and analysis

This research is a descriptive study with a geographic approach, namely, a spatial approach that discusses and analyzes the problem carrying by emphasizing geographic themes, especially location, place, and region. The data collected is river discharge and water quality, which includes temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), electric conductivity (EC), and Total Coliform. Data collection carrying by observation, literature study, and documentation. Determining the sample's location in field observations was carried out by purposive sampling, namely the upstream, which is in the transitional area of the mountain foot and the volcanic foot plain, and the downstream part, which is entirely in the form of the volcanic foot plain. The upstream part is included in the disaster-prone area (DPA) II, while the downstream part includes non-DPA. This location selection aims to compare the potential of river water at the top and bottom and consider the recommendation of the location for the use of water resources. In the observation process, measuring the river discharge is by the velocity-area method using a buoy (eq 1 and eq 2), or a slope-area method with the manning formula (eq 3). Water quality was measured in the field using a multiparameter Hanna meter, except for Coliform, analyzed in the laboratory. Data collection is also carried by tracing documents to determine the population, land use, characteristics of springs, which are the source of discharge, and characteristics of the research area's physical environment. Table 1 shows the relationship between data types, data collection methods, and the instrument used or data sources.

The formula used in calculating the discharge using a float is as follows:

\[ Q = V \times A \times K \] ................................ (eq 1)

Where \( Q \) is discharge (m\(^3\)/s), \( V \) is the mean flow velocity (m/s), \( A \) is wet cross-sectional area (m\(^2\)), and \( K \) is buoy coefficient. The value of \( K \) is determined by the Francis formula, namely:

\[ k = 1 - \frac{0.116}{\sqrt{1 - \alpha - 0.1}} \] ................................ (eq 2)

Where \( \alpha \) is the part of the submerged float divided by the depth of the water in centimeters, or expressed in terms of the depth of the shaft (h) divided by the depth of water (d)

Calculation of discharge is also carried out using the slope -area method where the flow velocity is calculated using the manning formula as follows:

\[ V = \frac{1}{n} \frac{R^2 S^{1/2}}{R^2 S^{1/2}} \] ................................ (eq 3)

Where \( V \) is flow velocity (m/s), \( R \) is hydrologic radius (m), \( S \) is hydrologic gradient, \( n \) is the manning roughness coefficient. The value of \( R \) is determined by dividing the cross-sectional area of wet / A (m\(^2\)) by the wet perimeter (m)
Table 1. The relationship between data types, data collection methods, and instrument used or data sources

| Variable                          | Data collection methods | Instruments / data sources                                      |
|-----------------------------------|-------------------------|-----------------------------------------------------------------|
| River discharge                   | Observation             | Floating method measurement equipment: Buoy, roll meter, yallon, stopwatch |
|                                   |                         | Measuring equipment for manning method: Water hose, roll meter, yallon |
| Water quality                     | Observation             | Multiparameter Hanna meter                                      |
|                                   |                         | Sample bottle to bring samples to the laboratory                |
| Characteristics of discharge source springs | Literature Study       | Ratih et al. [9], Ratih et al. [15], Sudarmadji et al. [10]     |
| Physical environmental conditions of the study area | Literature study       | Sutikno et al. [16], Purwantara et al. [17]                     |
| Population                        | Documentation           | Data from the Central Bureau of Statistics of Sleman Regency and Magelang Regency [11], [12], [13], [14] |
| Land use                           | Observation             | Digital camera, compass                                         |
|                                   | Documentation           | Indonesian Topographical Mapsheet Kaliurang, Pakem, Sleman and Muntilan |

Analyzed data is carried out by using descriptive analysis methods, matching analysis, and statistical analysis; descriptive analysis to provide a detailed description of the discharge conditions and water quality in the study area. To support this descriptive analysis, we used statistical analysis with independent sample t-test and simple linear regression. An independent sample t-test compares the quantity and quality of river water between the top and the bottom. We are using Microsoft Excel and calculations (eq 4 and 5) to perform this analysis also for simple linear regression to determine the relationship between water quality variables related to each other. Matching analysis is used to determine whether the water from the rivers in the study area is suitable to be used as a source of clean water fulfillment. The analysis is comparing the water quality of the research results with the international water quality standards from WHO, as well as the national drinking water quality standards based on the Regulation of the Minister of Health of the Republic of Indonesia No. 492 of 2010 [18] and the Republic of Indonesia Government Regulation No. 82 of 2001 [19] (Table 2). Matching analysis is also used to determine whether river water discharge can meet the per capita needs of refugees who accommodated in refugee barracks.

\[
t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{\sum x^2/n_x}{{n}_x-1} + \frac{\sum y^2/n_y}{{n}_y-1} - \frac{x^2}{{n}_x} - \frac{y^2}{{n}_y} - 1}} \quad \text{(eq 4)}
\]

where \( x \) and \( y \) are the means of the two samples, \( n_x \) and \( n_y \) are the sizes of two samples

\[
df = \frac{(SX+SY)^2}{\frac{(SX)^2}{n_x} + \frac{(SY)^2}{n_y}} \quad \text{(eq 5)}
\]

where \( SX = \frac{(\sum x^2/n_x) - x^2(\sum x^2/n_x)}{{n}_x-1} \) and \( SY = \frac{(\sum y^2/n_y) - y^2(\sum y^2/n_y)}{{n}_y-1} \)
Table 2. Standard standards of drinking water quality standards used in the matching analysis

| No. | Variable     | Indonesian National Standard | Standard International Standard |
|-----|--------------|-------------------------------|---------------------------------|
| 1.  | Temperature  | ± 3 °C [18]                  | 30 °C (WHO) [20]               |
| 2.  | TDS          | 500 mg/l [18]                | 500 mg/l (WHO) [20]            |
| 3.  | DHL          | -                             | 400 µS/cm (WHO) [20]           |
| 4.  | DO           | > 6 mg/l [19]                | 4.0 mg/l [21]                  |
| 5.  | pH           | 6.5 - 8.5 [18]               | 6.5 - 8.5 (WHO) [20]           |
| 6.  | Total coliform | 0 / 100ml [18]         | 0 MPN / 100ml (WHO) [20]       |

2.2. Research Area

We do this research on the south to the southwest side of the Merapi Volcano. Administratively, most of the research areas are in Sleman Regency, Yogyakarta Special Region, which includes Cangkringan, Pakem, and Turi Subdistricts. A small number of others are in the Magelang Regency area of Central Java Province, namely in the Srumbung Subdistrict. The area of the study is 116,66 km² (Figure 1). Geologically, the research area is composed of volcanic material from Young Merapi and Old Merapi. Old Merapi material occupies a minimal area, namely Turgo Hill and Plawangan, which, according to Newhall et al. [22], is the oldest part of Merapi. Meanwhile, the Young Merapi material dominates in an extensive area. Based on the Geological Map of the Yogyakarta Sheet, known that the volcanic deposits of Young Merapi include Young Merapi Volcano Deposits (Qmi), Avalanche Deposits from Hot Clouds (na), and lava domes and melting (d). The abundance of this Young Merapi material is because the south to west slopes is indeed the youngest part of Merapi [22]. The youngest material of pyroclastics and lahars found in the Southwest [23].

Geomorphologically, the research area located at the volcano's foot as part of the stratovolcano geomorphology of Merapi, which includes volcanic cranes, volcanic cones, volcanic slopes, volcanic foothills, lava fields, lava fields, and volcanic foot plains [24], [25]. This geomorphological characteristic affects the amount of rain in the form of orographic rain. At the foot of the volcano, rainfall reaches 1550 mm. High rainfall affects the hydrological system, which is characterized by many rivers and groundwater with large discharge. The indicate of groundwater potential is shown by potential aquifers with discharge reaching 0.005-0.01 m³/s [16]. Apart from being influenced by the amount of rain, high groundwater potential is influenced by the material's characteristics in this area, which has high infiltration capability [17].

The population in the study area in 2018 reached 60,337 people spread across nine villages. The highest population was in Wukirsari Village, Cangkringan Subdistrict, with 10,291 people, while the lowest was in Kemiren Village, Srumbung Subdistrict, which was 1229 people. The highest population density of 1210 people / km² was found in Donokerto Village, Turi District, while the lowest population density founded in Kemiren Village at 199 people/ km². Land use in this area varies, consisting of settlements, mixed gardens, moor, rice fields. There are natural land uses in the form of forests and shrubs on the border with the volcanic foot area. This region is a producer of agricultural commodities, including rice, corn, vegetables, and fruits.
3. Result and Discussion

One of the characteristics of Merapi Volcano as a stratovolcano is the many river valleys that develop in a radial flow pattern. Most of the rivers are part of the Opak Watershed in Merapi's volcanic foothills, while a few are part of the Progo Watershed. There are seven rivers in this area that do not head directly to Merapi's summit, namely Pelang, Sempor, Degong, Tangkil, Opak, Tepus, and Batang. These rivers are perennial even though the amount of flow is decreasing in the dry season. Sutikno et al. [16] explained that these rivers have varying discharge and quality. River discharge and water quality are possible things as alternative water sources in an emergency of an eruption. Intake of river water for this utilization is certainly not carried out at the time of the eruption, but during regular activity, until there are signs of increased volcanic activity. During this period, river water resources can be collected and processed in the evacuation barracks to use in emergencies. The study results on the quantity and quality of river water in the study area describe as follows.

3.1. River water discharge and its potential to fulfill per capita water needs

In this study, we measured the discharge of seven rivers. The discharge of each river is measured twice, namely in the upstream and downstream areas. The upstream area is included in the disaster-prone area (DPA) II, while the downstream area includes in the non-DPA. Based on field observations in the upstream area, we know that there are three rivers which at the peak of the dry season do not have flow rates, namely the Tepus, Pelang, and Opak rivers. Meanwhile, in the downstream area, all rivers have flow rates. Based on these conditions, this study's discharge measurements were all carried out at 11 locations, four locations in the upstream area, and seven locations in the downstream area.
The results of measurements at 11 locations showed an average discharge of 63.64 liters/second. The most massive discharge found in the downstream of the Sempor River, which is 230 liters/second, while the smallest discharge is found in the Tangkil River downstream, which is 9 liters/second. In the upstream area of the four rivers, the average flow rate is 36 liters/second. Meanwhile, in the downstream part, the average discharge is 91.28 liters/second. Overall, the river's amount of discharge in the downstream area is greater than the upstream area. In other words, rivers in the downstream area have the potential for better water quantity than upstream. However, the comparative test conducted shows that statistically, there is no significant difference between the mean river discharge in the upstream and downstream areas. Sometimes, the debit in the upstream area is more significant than the downstream area due to river water used for irrigation of agricultural land and plantations. Part of the discharge is channeled for agricultural land irrigation, thereby reducing the discharge in the downstream area. The results of the discharge measurements shown in Table 3 below.

| River name | River discharge (liter/second) |
|------------|-------------------------------|
| Batang     | 113                           |
|            | 61                            |
| Tangkil    | 61                            |
|            | 9                             |
| Sempor     | 38                            |
|            | 230                           |
| Degong     | 40                            |
|            | 39                            |
| Tepus      | 0                             |
|            | 170                           |
| Pelang     | 0                             |
|            | 20                            |
| Opak       | 0                             |
|            | 110                           |

Source: Primary data (2020)

The size of the river discharge in the area; this is inseparable from rain, topography, geology, vegetation conditions, and humans [26]. Topographic and geological factors appear to play an essential role in determining the size of the discharge. Three rivers that are dry in the upstream area but still have flow in the downstream area, possibly because the emergence of springs is at the river's bottom. This condition cannot separate from geological and topographic factors. In general, all rivers in this area have perennial flows, although they experience reduced discharge during the dry season's peak. Characteristics of rock types in this region, which are material from the volcanic activity of Young Merapi, function as productive aquifers [16]. A large amount of groundwater stored in the aquifer can then appear as springs that supply river flow so that it still has discharge at the dry season's peak.

The volcanic foot plain's topography supported the type of rock that can store groundwater, which is not too steep. The slope of the slope, which includes in the sloping-sloping category, causes the surface flow not to flow quickly, thereby increasing the chance of infiltration, and in the end, increasing the potential for groundwater, which provides a supply base flow for the river. On the other hand, the vegetation factor is also one factor that influences the amount of discharge. Vegetation cover will cause more and more water to disappear, either by evapotranspiration or through infiltration, so that it will reduce run-off, which can affect river discharge [27]. Around the river the flow rate is measured, there is quite a lot of vegetation, especially in the upstream river, so that the river flow discharge is not so large.

An important question related to the potential of river water discharge as an alternative source of drinking water in a disaster emergency is: "Can the available river discharge meet the per capita water needs of refugees in the evacuation barracks?". Referring to the Regulation of the Minister of Health of the Republic of Indonesia Number 28 of 2019 concerning the Recommended Nutritional Adequacy Rate for the Indonesian People [28], the standard of water needs per capita varies between people. The need for water between adults and children is different, so are men and women's needs. Since the
water adequacy analysis in this study was carried out to meet emergency disasters' needs, the figure for water needs per person used is a maximum figure of 2.5 liters per day.

Furthermore, the water demand figure is multiplied by the refugee barracks' capacity to find out the water needs of all the refugees in the evacuation barracks. There are refugee barracks in the study area with capacities ranging from 250, 300, to 500 people. In this calculation, maximum capacity is 500 people, so that the water need for evacuation barracks is 1,250 liters per day. The river, which has a discharge of 1,250 liters per day, means that in quantity, it has the potential to meet the needs of drinking water in the evacuation barracks closest to the river. Of course, this depends on the water storage capacity available in the evacuation barracks. By paying attention to the river discharge presented in Table 3, all rivers in the study area can be used as a good water source for the refugees in the evacuation barracks. The downstream section should be done the utilization of water by considering the yearly flow rate in the downstream area and the location of the refugee barracks in the downstream area so that it is more efficient to use in terms of distance and affordability water.

3.2. The physical quality of river water and its feasibility as an alternative to emergency drinking water

In this section, we elaborate on the results of measurements of several water quality parameters in seven rivers in the study area. Measurements were made at 11 locations, namely 4 locations upstream and 7 locations downstream. The upstream only allows for four measurement locations because, in the three rivers, namely the Tepus, Pelang, and Opak rivers, there is no flow at the dry season's peak. Meanwhile, in the downstream area, there are flows in all rivers. Water quality parameters discussed in this study are still limited to physical parameters of water quality, namely water temperature, dissolved oxygen (DO), total dissolved solids (TDS), and electric conductivity (EC), as well as one chemical parameter, namely water pH. There are variations in various water quality parameters between these rivers. Also, variations founded between the upstream rivers in the transition between the volcanic foot and the volcanic footplate and the river downstream are at the center of the volcanic footplate, mostly occupied by residents.

Water temperature is a parameter of water quality in the study area with small variations (Figure 2). Measurements made at 11 locations showed the highest temperature of 24.93ºC was found in the downstream of the Opak River, while the lowest temperature was 22.42ºC in the downstream of the Sempor River. The average water temperature in the study area was 23.61ºC. The average water temperature difference between the upstream area (23.37ºC) and the downstream area (23.74ºC) was also minimal. The results of statistical tests with the independent sample t-test also showed that there was no difference between the average upstream and downstream water temperatures. The type of land use in all sample locations, which are dominated by mixed gardens, is a factor that might have a strong influence on the small variation in river water temperature in the study area. As explained by Asdak [29], clearing of vegetation along riverbanks can cause more sunlight to penetrate the surface of the water, thereby increasing the water temperature. In the study area, the characteristics of mixed gardens with relatively similar dense vegetation in all sample locations caused river water temperatures to tend to below. Concerning the presence of vegetation in riparian areas (streamside), the research results of Swartz et al. [30] showed that a wide gap between vegetation affects increasing river water temperature. However, based on research conducted in mountainous areas, the effect of the gap between this vegetation is not significant. Meanwhile, the width of the river also affects the increase in river water temperature. Referring to this information, in the study we conducted, the type of land use and vegetation density also affected river water temperature, but the effect was not significant. The water temperature in the downstream Tepus and Pelang where the land use is in rice fields, provenly the water temperature is relatively the same as other locations.
The relatively narrow height range of only 270 meters also determines the relatively variable river water temperature. With a narrow coverage area, relatively homogeneous land use and landform, and insignificant altitude variations, the insolation variables and albedo values in this area are also relatively uniform. Martinus et al. [31] explained that the lower the altitude, the higher the water temperature. Following this information, this study's results also indicate an increase in temperature at each decrease in altitude. However, the narrow and homogeneous research area causes small temperature variations. The influence of altitude on river water temperature is also weak, shown by $R^2$, which is only 0.11. Furthermore, Effendi et al. [32] explained that water temperature could vary depending on humidity and sunlight exposure. This research conducted at the peak of the dry season, where the relative humidity is generally low, and there is much sunshine. Therefore, in the rainy season, the average water temperature can be lower than these measurement results.

The results of our measurements show low mean water temperature and little variation. Compared with previous studies, this condition is relatively the same as the findings of Effendi et al. [32]. The results of this study indicate a temperature range between 22-26°C, as a result of the influence of the mountains around the river. Furthermore, water temperature is an essential variable to know. Concerning ecosystems, Davie [33] explained that water temperature needs critical attention because of its interdependence with DO and controlling the rate of chemical reactions in rivers. Meanwhile, concerning drinking water, the effect of temperature on DO will determine the amount of dissolved oxygen as consideration for consumption. Referring to the Ministry of Health of the Republic of Indonesia [18], all river water in the study area has met the requirements of drinking water based on the temperature aspect.

The results of water pH measurements at all points get the number 6.5. We assumed the volcanic landscape's characteristics with the deposition of the erupted material with acidic minerals to affect the pH of the water, which tends to be acidic. Also, land use in the catchment area in the form of mixed gardens and agricultural land assumed to produce organic matter, affecting the acidity of river water. These results are relatively the same as previous studies conducted in the dry season. Saraswati et al. [34] lowered the pH value between 5.1 and 8.9 with a mean of 7.175. Alam et al. [35] obtained pH results from 5.86 to 6.86. Meanwhile, Effendi et al. [32] obtained a dominant pH of 6.5. In previous studies, the emergence of water acidity mainly relates to population activities such as bathing, washing, and sanitation, along with water bodies due to changes in agricultural land function into residential areas. Therefore, the residue from these activities carries organic material broken down by microorganisms so that the process consumes oxygen and emits carbon dioxide. With this result, all measurement locations in the study area comply with the national water quality standards but not according to WHO’s standards.
DO measurements obtained an average figure of 4.31 ppm or 54.72%. The average DO in the upstream area is 3.89 ppm or 49.48%, while the average in the downstream area is 4.55 ppm or 57.71%. Statistically, there is no difference between the average DO in the upstream and downstream areas. However, the overall range of values varied considerably, with one low value found upstream of the Batang River (Figure 3). According to Davie [33], DO is a water quality parameter that is very important for aquatic organisms' lives. High DO also affects the taste of the water, which is getting fresher. As discussed in the previous section, there is a correlation between water temperature and DO. Warm water will hold less dissolved oxygen than cold water. Thus, the higher the water temperature, the lower the DO value [29]. Meanwhile, Effendi et al. [32] explained that in addition to water temperature, DO influence salinity, water turbulence, and atmospheric pressure. The results of the analysis of the relationship between water temperature and DO from 11 samples showed that an increase in water temperature affected decreasing DO. However, the effect is very small with $R^2$, only 0.08. Simultaneously, the relationship between salinity DO indicated by a decrease in any increase in salinity with $R^2$ of 0.18. In comparison, the effect of atmospheric pressure on DO is an increase in DO at each increase in atmospheric pressure with $R^2$ of 0.25.

![Figure 3. Boxplot for dissolved oxygen in the study area](image)

The DO measurement results in the range of 1.15 to 5.51 ppm are small, for example, when compared to the results of measurements by Effendi et al. [32] in Cimbulawung River, which was between 7.16 up to 9.98 ppm. Meanwhile, Alam et al. [35], in their research in the dry season, obtained a minimum DO of 3.50 and a maximum of 7.20. A small DO figure is a normal condition in Merapi because the DO range in this area can be very large. Research results from Saraswati et al. [34] in three rivers, Code, Winongo, and Gajahwong, which also flow on Merapi's southern side, indicate that the DO ranges of these rivers are between 1 and 10 ppm. According to Davie [33], river water in the study area with an average temperature of 23.61°C can contain a maximum DO up to 9 ppm. Thus, the results of DO measurements in the study area, which only reached 5.51 ppm, are still far from the maximum DO. Furthermore, Asdak [29] explained that the minimum DO for human consumption is 4.0 ppm. With this threshold, the Batang upstream river water is the only one that does not qualify as drinking water.

TDS, which shows the amount of dissolved or deposited in water, is an indicator of water salinity [33]. TDS measurements carried out in 11 locations obtained an average value of 83.45 ppm. The upstream area has a smaller average TDS than the downstream area, 80 ppm compared to 85.43 ppm. Statistically, there is no difference in TDS between upstream and downstream. The seven rivers in this study are rivers that do not originate directly from the peak of Merapi. Therefore, the dissolved solid that enters the water discharge results from erosion from the land in the catchment area, in contrast to
rivers that originate from the peak of Merapi, which carry the rubble of the eruption product material in the volcanic cone area. Overall, the smallest TDS founded in the downstream of the Tangkil River, which was 75 ppm, while the largest TDS founded in the downstream of the Tepus River at 104 ppm. The second-largest TDS figure is in the downstream of the Pelang River with a TDS of 93 ppm. The land in the downstream area of Sungai Tepus and Sungai Pelang is widely used for rice fields so that the potential for erosion is more significant than in other areas where land uses are mixed gardens. Therefore these two regions have the largest TDS compared to the other 9 locations. Figure 4 below shows the results of TDS measurement data in the study area.

Figure 4. Boxplot for TDS in the study area

In general, the TDS in the study area is smaller than the results of the study by Saraswati et al. [34], which is a river that flows directly around Merapi's peak. The average TDS of the study was 186.54 ppm, while in this study, it was only 83.45 ppm. However, this result is still more significant than the study results by Effendi et al. [32], who obtained a TDS range between 27.40 - 53.80 ppm. The catchment area of the seven rivers in this study area, which is all in an active volcanic landscape, allows us to get many dissolved solids. Effendi et al. [32] further explained that high TDS could increase water temperature because solid materials absorb heat from sunlight. In the study area, an increase in TDS show to affect increasing temperature. However, this effect is minimal, with R² is only 0.03. The factors of vegetation cover and altitude assume to have more roles in influencing river water temperature. Referring to international standards from WHO and national standards, all rivers in the study area meet the criteria for drinking water quality standards in the TDS aspect.

The last aspect of the physical properties of river water that measures in this study is EC. Davie [33] explained that this EC is also an indicator of salinity. EC is the water's ability to deliver an electric current, which is a function of the concentration of the solution (water), including the total valence of dissolved ions and the level of ions that can move in the water. EC is closely related to TDS. Temperature also affects EC because ion movement in water is affected by temperature. River EC values are typically in the range of 10 to 1000 μS/cm. The results of TDS measurements in the study area showed a mean EC of 168.55 μS/cm. The EC range is between 135 and 208 μS/cm (Figure 5). The lowest EC value is found in the Degong River's upstream, while the highest found in the downstream of the Tepus River. Like the TDS measurement results, in this EC measurement again, the downstream of Sungai Tepus and Sungai Pelang are the places with the highest values. The downstream area also has a higher average EC value than the upstream area, although statistically, there is no significant difference. The average EC in the downstream area was 173.14 μS/cm, while in the upstream area, it was 160.5 μS/cm.
TDS strongly influences EC. The more dissolved solids in river water, the greater the electrical conductivity. Both the downstream of the Tepus and Pelang Rivers has the highest EC because their TDS values are also the highest. In the study area, the increase in TDS had a powerful effect on EC’s increase (Figure 6). The increase in temperature also affects the EC increase, but the effect is minimal, with $R^2$ only 0.16. In general, EC in the study area is smaller than the results of previous studies conducted by Saraswati et al. [34]. In this study, we found the rivers that flowed around Merapi’s peak had EC between 103.3 and 966 160.5 $\mu$S/cm, with an average of 399.16 160.5 $\mu$S/cm. As previously discussed, the river with its head at the peak of Merapi carries much cargo from the debris of the eruption material. The summary of the results of river water quality measurements in the study area shows in Table 4.

### Table 4. Results of water quality measurements in the study area

| Variable         | n   | Mean  | Median | SD   | Max  | Min  |
|------------------|-----|-------|--------|------|------|------|
| Temperature $(^\circ \text{C})$ | 11  | 23.61 | 23.66  | 0.80 | 24.93| 22.42|
| pH               | 11  | 6.5   | 6.5    | 0    | 6.5  | 6.5  |
To ensure the suitability of river water as an alternative source of drinking water in an emergency of an eruption disaster, we have conducted a matching analysis of the results of water quality measurements against drinking water quality standards. The analysis showed that of the six parameters measured directly in the field, namely water temperature, pH, DO, TDS, EC, and salinity, in general, the rivers in the study area were suitable for use as a source of drinking water. In this analysis, we also added one variable analyzed in the laboratory, namely total coliform. Total coliform is an essential variable because it is the primary indicator of water's suitability for consumption [20]. The results of this variable analysis show that all rivers in the study area do not meet the total coliform standard, and this is probably due to the influence of population activities both through land use for agriculture and domestic activities. Following the results of previous research by Sutikno et al. [16], rivers in the Merapi area are polluted by domestic waste so that if it is to as drinking water, it must be filtered and properly managed first. This research recommends that if the river water use as an alternative water source, it is necessary to provide a water treatment plant in the evacuation barracks so that the river water is suitable for consumption. Also, it is necessary to test other variables that have not been analyzed in this study to meet all the eligibility criteria according to the Regulation of the Minister of Health of the Republic of Indonesia [18]. The results of the water quality matching analysis shown in Table 5 below.

**Table 5.** Results of the matching analysis of several water quality parameters with water quality standards

| Parameters | Physical | Chemistry | Biology |
|------------|----------|-----------|---------|
| Temperature | TDS | DHL | DO | pH | Total Coliform |
| Unit | °C | Mg/l | µS/cm | ppm | - | MPN/100ml |
| Tangkil (U) | 24,23(**) | 76(**) | 152(**) | 5,21(*X***) | 6,5 | Not measured |
| Sempor (U) | 22,68(**) | 92(**) | 185(**) | 4,95(*X***) | 6,5 | Not measured |
| Degong (U) | 22,92(**) | 67(**) | 135(**) | 4,66(*X***) | 6,5 | Not measured |
| Batang (U) | 23,66(**) | 85(**) | 170(**) | 0,72(*X***) | 6,5 | Not measured |
| Tangkil (D) | 22,93(**) | 75(**) | 150(**) | 3,46(*X***) | 6,5 | 4900(*X***) |
| Sempor (D) | 22,42(**) | 89(**) | 178(**) | 5,33(*X***) | 6,5 | 11000(*X***) |
| Degong (D) | 24,08(**) | 68(**) | 136(**) | 5,51(*X***) | 6,5 | 13000(*X***) |
| Tepus (D) | 24,41(**) | 104(**) | 208(**) | 3,98(*X***) | 6,5 | 7900(*X***) |
| Pelang (D) | 23,96(**) | 93(**) | 186(**) | 4,39(*X***) | 6,5 | 2300(*X***) |
Batang (D) 23.45(**) 87(**) 180(**) 4.95(**) 6.5 4900(**)
Opak (D) 24.93(**) 82(**) 174(**) 4.22(**) 6.5 11 000(**)

Note: (*) parameters that are not in accordance with national quality standards, (**) parameters that are not in accordance with international quality standards (U) = upstream, (D) = downstream.
Source: Primary data (2020)

4. Conclusion
Active volcanic areas such as Merapi needs sustainable disaster management. One aspect that needs to provides in support of realizing this goal is the availability of drinking water. Some rivers still have flow during the dry season on the south to southwest slopes of the Merapi Volcano. These rivers also do not flow from Merapi's summit so they can use as alternative drinking water sources in emergencies. In terms of quantity, all rivers can meet water needs in the evacuation barracks. Water withdrawal can carry out in the downstream area adjacent to the evacuation barracks. In terms of quality, based on limited testing on several parameters, it is known that river water in this area can use as an alternative source of drinking water. However, it is necessary to provide a water treatment plant in the evacuation barracks, so that water sourced from river water treated first so that it is suitable for consumption. It is also necessary to analyze other water quality parameters to ensure the suitability of river water as a source of drinking water.

For the evaluation process, this study's limits to 6 water quality parameters. Future research is necessary to provide a follow-up to this research's results, namely by testing other water quality parameters, both physics, chemistry, and biology. Thus, complete information can be obtained as a consideration if the river water use as an alternative water source in a disaster emergency. In future research, we recommend carrying out a study on the development of water treatment installations in refugee barracks. This study is essential to build self-reliance concerning increasing community capacity to deal with disasters and build sustainable disaster management.

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