Volcanic Springs, An Alternative Emergency Water Resource to Support Sustainable Disaster Management in Southern Flank of Merapi Volcano

S Ratih, H N Awanda, A C Saputra, A Ashari
Department of Geography Education, Faculty of Social Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
arif.ashari@uny.ac.id

Abstract. The activities of Merapi Volcano which still pose risks over time require good and sustainable disaster management. Identification of potential water resources that can be utilized in disaster emergency situations is needed to support the management of the disaster. For the southern slope of Merapi Volcano as an area directly affected by the eruption in 2010, the availability of water resources and infrastructure is a very important part to be ensured in the pre-disaster phase. This paper aims: (1) analyze the potential of springs, (2) analyze the spatial pattern of the distribution of springs with the distribution of population settlements, (3) design the use of springs for handling disaster emergencies; in disaster eruption prone area of the southern flank of Merapi Volcano. To achieve these objectives a field survey and secondary data collection were carried out through library research and document tracking. The data that has been obtained is then analyzed descriptively with a geographic approach supported by the application of geographic information system analysis. The results: (1) The area of southern flank of Merapi Volcano has many springs with varying quantity and quality, which generally can be used to meet water resource needs in disaster emergency situations. (2) the distribution of springs in disaster-prone areas is clustered according to geomorphological factors, while the distribution of settlements is random. The pattern of spreading of springs and settlements needs to be considered to determine the spring regulation system to meet the needs of the population, in addition to other considerations, namely population, population density, water needs per capita and administrative factors, (3) in this writing several wells have been chosen which can be used to fulfill needs in disaster emergency situations. In conclusion, the active volcanic area has a very good potential for springs which can be used to meet resource needs in disaster emergency situations. Management of existing potential well is very necessary in supporting sustainable disaster management.

1. Introduction
Vulkan Merapi as one of the most active volcanoes in the world has short eruption cycle characteristics. Data Merapi eruption from the Geological Agency [1] shows that Merapi volcanoes have been erupted more than 80 times since the 1600s. During this period the eruption event averaged within 1-5 years with a rest period of 1-2 years [2] or 1-7 years with a period of inactivity of at least 12 years [3]. The last two eruption events occurred in 2006 and 2010. In the two eruption events the southern slope was the area most affected by the eruption. Eruption in 2006 resulted in a hot cloud glide reaching a distance of 7 km [2], while the 2010 eruption that was far greater resulted in a 9 km
hot cloud glide causing 347 people to die [1] and material losses of up to 3.56 trillion rupiah [4] As the area directly affected by the eruption, on the southern slope of Vulkan Merapi there were fatalities, damage to settlements, damage to infrastructure, and vegetation that burned [5]. In 2018, Vulkan Merapi has experienced an increase in activity. Since May 2018 there have been several phreatic and magmatic eruptions, and until September 8, 2018 there is still volcanic activity from Vulkan Merapi in the alert or level II category [6].

The data above shows that Vulkan Merapi activities continue to occur continuously and still pose a threat in the future. On the other hand, the number of residents living in disaster-prone areas on the southern slopes of Vulkan Merapi is still high. Based on BPS Data Sleman Regency in 2017 there were approximately 47,347 residents who lived in villages whose territory was included in the disaster-prone area of Vulkan Merapi [7] namely in Turi District [8], Pakem District [9], and Cangkringan District [10]. In addition to the population, the population growth rate in disaster-prone areas is also quite high after the eruption in 2010 which was 2.7%. This figure is higher than the average national population growth of 2.5% [11]. A large number of people with high population growth rates plus the potential for disasters in the future and a history of past disasters causing disaster risk on the South Slope of Vulkan Merapi. In disaster risk reduction efforts a good disaster management system is needed. So far the government and the community have sought good and optimal disaster management in reducing the risk of the disaster of the Vulkan Merapi eruption. This well-managed disaster management system needs to be supported by providing updated data. One of the important data to be provided is the potential of resources that can be utilized to meet the needs in disaster emergency situations.

Water resources are basic needs that are very important for life. In the context of disaster management, these water resources must be ensured and guaranteed to be available during disaster emergency situations. Young volcanic landscapes such as the southern slopes of Vulkan Merapi have the potential for high water resources so that they need to be managed optimally to meet the needs in these emergency conditions. The potential of water resources is indicated by the presence of many productive aquifers and springs. Aquifers with high productivity, high permeability, and shallow groundwater, are formed from young volcanic material from Merapi and are widely distributed on the South Slope of Vulkan Merapi. Meanwhile springs are also found on the South Slope of Vulkan Merapi, which is on the volcanic slope landform, volcanic foot, to volcanic foot plains. These springs form a pattern following the contour known as the spring belt [12]. Springs belt is a typical type in volcanic landscapes. Springs belts are formed due to the influence of slope buckling factors which cause the volcanic aquifer to be cut off. Springs appear circularly in the strato volcanic morphology, especially in areas with sharp slope changes so that the topographic surface cuts the groundwater face [13]. The pattern of springs belts on the southern slopes of Vulkan Merapi provides greater opportunities for optimal management. This is because the distribution of springs that form a certain pathway will simplify the management process.

The presence of springs that are scattered to form the pattern of springs belts is a very important potential to be utilized in ensuring the availability of water resources during the disaster emergency period. This paper aims to provide various information on spring water on the southern slopes of Vulkan Merapi, to support the management of these water resources. Information on springs includes (1) the potential of springs indicated by the quality and quantity of water from springs, patterns of distribution of springs related to the distribution of settlements, consideration in managing water resources, and (2) design of water resource utilization in relation to meeting water needs disaster emergency situation. Then the paper is organized as follows. Section 2 describes the basic concept of the pattern of distribution of volcanic springs, Section 3 describes the research method, section 4 describes result and discussion, and section 5 explains the conclusion of this work.

2. Theoretical Framework

Springs are where the groundwater comes to the surface as a stream of water flow [14], both from rock or soil and then enters a large body of water [15], often forming a stream, pond, or marsh [16].
Springs is also an in which groundwater ecosystem reaches the surface of the earth at or near the land-atmosphere interface or the land-water interface [17]. This second event shows that springs can also appear under large bodies of water including lakes (sublacustrin springs), rivers (subriverine springs) and oceans (submarine springs in both geothermal gaps and karstic cracks in coastal areas). Wells as the appearance of groundwater to the surface can also be categorized as artificial spring resulting from tapping and pumping of groundwater by humans [16]. Springs appear in most ecosystems on the surface of the earth ranging from fresh water to sea water [15].

Purnama [14] explains that springs are different from seepage, Springs come out in the form of flow while seepage is a gradual release of ground water and spreads on the ground. Meanwhile Glazier called seep or seepage as small springs that emerged by groundwater or percolating from the soil. Springs conditions are influenced by high rainfall, rock formations, and topography. The source of water from springs is basically also from groundwater that appears to the surface of the ground for several reasons [14]. Before becoming groundwater the source of water comes from precipitation. Rain and melted snow seep into the rock layers into groundwater in aquifer layers, namely porous rock material [16]. Springs usually have good enough water quality and have not experienced pollution so it is very much used to meet drinking water needs both by the community directly and through industry [14].

Because these springs are found in most ecosystems on the earth and appear in various landscapes, the conditions vary so much that they are then classified as springs. Glazier [16] explains that springs are very diverse so they are classified into various categories, namely based on geology, hydrology, water chemistry, water temperature, ecology, and their use by humans. Based on geological conditions springs are classified according to location of discharge, bedrock, geologic structure, and topography. Based on the geographical conditions of springs classified according to location. Based on the hydrology condition of the spring, it is classified based on the magnitude of discharge (discharge), source of discharge, at spring conduit type, size of aquifer and length of flow path, location of aquifer, source of recharge water, direction of flow, cause of discharge, and variation or persistence of flow. Based on chemical conditions, spring water is classified according to pH and hardness, total dissolved solids, principal ions, dominant cation type, dominant anion type, nutrient concentrations, and oxygen level. Based on water temperature grouped according to temperature and human body temperature, absolute temperature range, variation and magnitude of temperature, relation to fauna and flora, and human sensation with therapeutic applications. According to Ecology springs are grouped by habitat type, habitat type of thermal springs, habitat type of seepage, springside (habitat) habitat, habitat size (associated springside areas), biogeographic isolation, proportion of species restricted to springs. Based on conservation priority springs are classified according to relative value of resources at springs. Based on human use springs are grouped based on drinking use, based on yield, based in purpose, and human modification.

Springer and Stevens [17] through discharge and type of springs classifying springs into several types, namely: cave, exposure springs, fountain, geyser, gushet, hanging garden, helocrene, hillslope, hypocrene, limnocrene, (carbonate) mound-form, and rheocrene. Meanwhile the classification of springs that are quite widely used by various researchers in Indonesia [13] [18] [19] is the Meinzer classification based on spring discharge. There are eight classes of spring discharge, namely: class I discharge> 10 m$^3$ / second, class II discharge 1-10 m$^3$ / second, class III discharge 0.1 - 1 m$^3$ / second, class IV discharge 10-100 liters / second, class VA debit 1 - 10 liters / second, class VI 0.1 - 1 liter / second, class VII discharge 10 - 100 ml / second, and class VIII discharge <10 ml / sec [14].

Springs are one of the potential water resources to be utilized. This potential is influenced by generally good water quality [14] as well as the quantity of water which is also sufficient especially for domestic needs. Volcanic landscape is a region that has the potential of large water resources. This is inseparable from the high potential of groundwater in the region which is supported by a lot of rainfall. High place elevation and good porosity and perforability material are physical environmental conditions that strongly support the availability of water in volcanic landscapes. Younger volcanic landscapes have higher groundwater potential than old volcanic [13] so that springs are more common,
larger spring discharge, and spreading pattern of springs is more regular. Merapi Volcano, especially on the southern slope, is an example of a region that has high water resource potential as indicated by the number of springs [12]. Genetic factors and morphology of strato volcanoes play an important role in determining the magnitude of the potential of water resources in the stratovolcano cone. Verstappen [20] explained that the constituent factor of Strato vulcanization is the dominance of ash and pyroclastic material and high rainfall which causes lava flows. This material has high permeability and porosity so it has a large capacity for storing groundwater. Furthermore the deposition of the material produces concave slope appearance which consists of three sectors which are limited by two break of slope. The highest and steepest slopes are formed by ash and/or clastic originating from the destruction of lava plugs, falls or landslides, under the influence of gravity. The second zone with wet transport by lava forms fluviomalcan slopes. The third zone is formed by fluvial deposits.

The height of the strato volcanic morphology causes a lot of orographic rain on the volcanic cone and upper slope. With material that has high permeability, this area serves as a recharge of groundwater areas that absorb a lot of rainwater into the aquifer layer. As a result of the break of slope, the aquifer was cut and caused springs to appear. Santosa [13] explained that most springs that are in the body of a volcano are found in changes in landform units. There are three spring emergence units, namely the spring unit on the volcanic slope where the spring appears because a large slope factor that causes rainwater can only seep into the pyroclastic formation above the watertight lava flow formation. Furthermore, in the volcanic foot unit, a spring belt is found on the tip of the Young Merapi lava flow in the west and the end of the Old Merapi lava flow in the east. Third, in volcanic plain units there are also many springs which are caused by differences in slope due to changes in morphology caused by changes in rough rock texture to fine texture.

The cone-shaped morphology of the stratovolcano allows the formation of a spring pattern that coils along the break of slope so that it is called a volcanic spring belt. Regarding this phenomenon Simoen [21] explains that the shape of the strato volcano consists of volcanic cones, volcanic slopes, volcanic feet, volcanic foot plains, and fluviomalcan plains. Each part is characterized by slope bending. The existence of buckling slopes is what causes the appearance of springs that form a pattern of springs around the volcanic cone belt. Explanation from Santosa [13]; and Simoen [21]; give confirmation about the pattern of spreading of springs in Vulkan Merapi which forms the springs belt pattern on changes in land unit units. In each segment of the change of slope there is a bend of the slope which causes the appearance of the springs to surround the volcanic cone and form the pattern of the springs belt. However, because the upper part is a recharge area, the concentration of springs is mainly in the unit of landform between volcanic foot and volcanic foot plains. Meanwhile, bending the slope located at the top is not too much related to the appearance of water.

The pattern of springs belts that are characteristic of volcanic landforms can also change due to the development of morphology caused by the operation of the denudation process. In the form of the young stratovolcano the pattern of the springs belt is still clearly visible but in the older volcanic springs the belt becomes irregular. The position of the spring can shift backwards due to erosion or more advanced due to sediment deposition. Vulkan Lawu and the western side of the older Vulkan Merapi show symptoms of this spring shift, while the young Vulkan Sindoro and the southern part of Vulkan Merapi show a regular pattern of springs belts because the relative denudation process has not taken place intensively. Santosa [13] conducted a study in Vulkan Lawu and showed that the development of old Vulkan Lawu had an effect on the pattern of the springs belt becoming more irregular due to exogenous processes such as erosion and denudation. Ashari [19] in his research on the eastern slope of Vulkan Sindoro found symptoms of spreading of springs on the eastern slope of Vulkan Sindoro which were more regular because the effects of the erosion process and mass movements had not been intensive in settling landforms. Meanwhile Aurita and Purwantara [18] conducted a study on the western slope of Vulkan Merapi which found a pattern that was clustered but not in the pattern of springs belt but in the radial river valley due to the cutting of aquifers. Whereas Ruth et al. [7] from the study on the southern slope of Vulkan Merapi showed that there was a pattern
of springs belts on the buckling of transitional slope forms between volcano slopes, volcanic feet, and volcanic foot plains.

3. Method

This research was conducted using a geographic approach, namely the spatial approach. The use of a spatial approach is carried out to identify the distribution of springs and their variations that are influenced by physical environmental conditions. A spatial approach is also carried out in drawing up the design of springs utilization for disaster emergency situations, namely paying attention to the distribution of springs and the distribution of springs users' settlements. The geographic theme used as the foundation in this research is location and place. This theme is used in compiling a description of the pattern of distribution of springs, the pattern of distribution of settlements, and the design of routes in the use of springs to settlement zones and refugee zones.

This research was carried out on the southern slope of Merapi Volcano. The location of the observation is determined by systematic sampling. Systematic sampling is done by making observation paths in each unit of land with a focus on the transition of units in the form of volcanic slopes, volcanic feet, and volcanic foot plains. Determination of this observation path refers to the statement of Sutikno et al. [12], Santosa [13], and Simoen [21] who said that the appearance of Strato volcanic springs is in the slope bending area or the slope changes found on the slope, feet and volcanic plains. Data is collected through observation, documentation, and literature. Observations were made to obtain spring location data, pH, temperature, salinity, dissolved oxygen, electrical conductivity, and water quality. Water quality data was obtained by taking the sample which was then carried out laboratory tests and direct measurements in the field using a multiparameter meter. Data taken from documents include population data, land use, and geological conditions of the research location. Literature studies are conducted to complement observational data that have been carried out both through textbooks and journals, especially Sutikno et al (2007) and Simoen (2001). Table 1 shows the relationship between data collected, methods of data collection, and instruments used or data sources in documentation and literature studies.

| Variable | Method of collecting data | Data instruments / sources |
|----------|---------------------------|---------------------------|
| Location of springs | Observation | GPS |
| Geological, and geomorphological conditions, and land use around springs | Observation | Kompas Geologi, Yallon, Observation Sheet |
| | Documentation | Yogyakarta Sheet Geological Map scale of 1: 100,000 |
| | Literature review | Indonesian Rupture Map of Kaliurang Sheet and Pakem Scale of 1: 25,000 |
| Discharge of springs | Observation | Sutikno et al (2007), Verstappen (2013), Simoen (2001) |
| Population conditions | Documentation | Water containers and stopwatches that are used for debit measurements with volumetric methods |

To answer problems in the study used matching analysis, GIS analysis, and descriptive analysis. Matching analysis was used to determine the classification of springs. Matching analysis was also used to determine the quality of spring water by matching the results of laboratory tests with the criteria for drinking water quality standards in Permenkes RI No. 32 of 2017. Analysis of Geographic Information Systems (GIS) is used to analyze patterns of distribution of springs, settlement patterns in the area of the foot and volcanic plains, as well as the distance between the
locations of refugee barracks and points of location of springs. Analysis of spreading patterns of springs and settlements using the Average Nearest Neighbor Analysis method found in ArcGIS 10.3 devices. This analysis technique must pay attention to the value of P and score Z. Kurniati et al. [22] explain that the Z score is a number determining the type of pattern of object distribution. There are three distribution patterns, namely clustered indicated by a negative z-score, a uniform pattern (dispersed) indicated by a positive z-score, and a random pattern indicated by a z-score in the range of zeros. Furthermore, to obtain the design of springs utilization when an eruption is used buffering technique between the location of the refugee barracks and the locations of springs. The buffer method is done by making a circle of radius which indicates the distance between the location of the evacuation and the spring. The buffer method is supported by a network analysis method to determine the most effective route for water flow from selected springs to settlements or evacuation centers. Furthermore descriptive analysis was also used to analyze the distribution of springs locations related to the use of the springs. Descriptive analysis is done by paying attention to the spatial approach which contains geographic concepts such as location, distance, and affordability. Descriptive analysis by considering spatial approaches is used to strengthen GIS analysis. Figure 1 shows the procedures carried out in this study.

4. Result and Discussion

4.1. Research Area

This research was conducted on the southern side of Merapi Volcano which is administratively included in the Turi, Pakem, and Cangkringan Subdistricts, Sleman Regency, Special Region of Yogyakarta, Indonesia. Astronomically the research area in the UTM 1984 WGS coordinate system Zone 49 S is located at coordinates 430156 MT - 441484 MT and 9154934 MU - 9166320 MU. The research area is bordered by Central Java Province, which is in the west with Magelang Regency, the north with Boyolali Regency, and east with Klaten Regency. The research area in the southern part is bordered by Tempel, Sleman, Ngaglik and Ngemplak Subdistricts, which are still part of Sleman Regency, Yogyakarta Special Province (Figure 2). Judging from its position on the area prone to the eruption of Mount Merapi Volcano, the research area is included in Disaster Prone Areas I, II, and III (Figure 3). KRB III includes Wonokerto Village, Girikerto District Turi, Purwobinangun Village, Hargobiangun Pakem District and Umbulharjo Village, Kepuharjo, Gelagahharjo Cangkringan Sub-District which has the potential to be affected by hot clouds, lava flows, rock avalanches and toxic gases. Based on the Merapi Volcanic Eruption Prone Area Map and the area affected by the 2010 eruption, a portion of the study area included areas that were directly affected by the 2010 eruption [5].
Figure 1. Research procedure
Figure 2. Research area
Figure 3. Disaster prone zone in the research area
Geomorphologically, the study area is divided into crater landforms, volcanic cones, volcanic slopes, volcanic feet, and volcanic foot plains [12]. In particular, the study area was focused on the transition area between the volcanic slopes, volcanic feet, and volcanic foot plains with considerations of springs appearing in the area. Springs arise as a result of differences in slope so that there is an intersection of aquifers in the transition zone of landform or slope bending [13]. The morphology of Vulkan Merapi in the form of strato volcanoes results in the presence of landform units which have an impact on various rainfall conditions. Annual rainfall in volcanic landforms reaches 1734 mm, volcanic feet reach 1550 mm, and volcanic foot plains reach 1186 mm [12]. The highest rainfall was found in the form of volcanic slopes with pyroclastic material in the form of bombs, lapilli, and sand. The material has excellent porosity and permeability resulting in large amounts of recharge and groundwater reserves. Furthermore, due to this condition, the southern slopes of the Merapi volcano have large geohydrological resources, which can be utilized by the community to meet their daily needs, especially in disaster emergency situations.

Geologically the study area is composed of sedimentary material from the Merapi Volcano and the Old Merapi Volcano Deposition. The young Merapi Volcanic deposits are widespread and dominate the research area while the Merapi Tua Volcanic deposits are only rarely found in the parasitic cones of Bukit Turgo and Plawangan with an area of only 2 ha (Dinas PU and Energi SDM, 2011). Young Merapi deposits consist of tuffs, ash, breccia and agglomerates, while the Old Merapi deposits are composed of breccia, agglomerates, lava including andesite and basal containing olivine [23]. The broad distribution of the material of the Young Volcanic Deposition is supported by the more porous material properties affecting the potential of high groundwater deposits in the southern slopes of Merapi. The next high geohydrological potential also affects land use in the southern slopes of Merapi, namely naturally there are forests and shrubs, while land use by many people develops wetland agriculture in addition to mixed gardens and moor. Based on the data of Sleman Regency land use in 2015 there were 10 types of land use in the southern slopes of Merapi Volcano namely grass, irrigated rice fields, rainfed rice fields, rocky land, moor, settlements, shrubs, buildings, forests and gardens.

4.2. Potential of springs in Disaster Prone Areas in the South Slope of Merapi Volcano

The potential of springs is judged by the quantity and quality of springs to meet the needs in the emergency situation of the eruption of Mount Merapi volcano. Springs in the study area are based on Meinzer spring discharge classifications including in grades VI and class VII. The biggest spring discharge was found in Karangnongko Springs of 5 liters / second, included in the VI discharge class. Whereas the smallest spring discharge was found in the Spring Spout Springs of 0.1 liters / second, including in class VII. Springs in the research area have generally been used by the public for domestic needs [7]. Springs discharge in the study area is shown in Table 1 below.

In disaster emergency situations, the potential for springs is very important to help meet water resource needs. Thus in addition to the location of the spring and discharge of the spring, the quality of the spring is also very important to know. To find out the quality of springs we have taken 7 samples of springs randomly in the study area and measured the quality of water through laboratory tests. The springs which are sampled include the springs of Randusari, Kemirikebo I, Kemirikebo II, Kemirikebo III, Karangnongko, Umbul Temanten, and Sendang Pancuran. There are 8 parameters tested including physical, chemical and biological parameters. Laboratory test results from 7 spring samples which were then matched with water quality criteria according to Minister of Health Regulation No. 32 of 2017 indicate that spring water quality generally matches the criteria for drinking water. There are only 2 parameters that exceed the limit of quality standards, namely detergent from the group of chemical parameters and total coliform from the group of biological parameters. The results of this analysis indicate that springs can be used for drinking water consumption in disaster emergency situations, but it needs good processing to overcome two parameters that exceed the compliance threshold.
Table 2. Springs in the Research Area

| No. | Springs Name   | Debit (l/s) | Debit Class | Management |
|-----|----------------|-------------|-------------|------------|
| 1.  | Kemirikebo     | 0.35        | VI          | Not yet    |
| 2.  | Kemirikebo II  | 0.15        | VI          | Not yet    |
| 3.  | Randusari      | 0.21        | VI          | Not yet    |
| 4.  | Karangnongko   | 5           | V           | Not yet    |
| 5.  | Kemirikebo III | 0.10        | VII         | Not yet    |
| 6.  | Umbul Temanten | 1           | V           | Not yet    |
| 7.  | Sendang Pancuran | 0.1      | VI          | Already    |
| 8.  | Tunggul Arum   | 1           | V           | Already    |
| 9.  | MertiBumi      | 0.64        | VI          | Not yet    |
| 10. | Benteng Celeng | 0.30        | VI          | Already    |
| 11. | Kedung Cuwo    | 2           | V           | Already    |
| 12. | Bendung Suro   | 0.8         | VI          | Already    |
| 13. | Goa Lawa       | 1.2         | V           | Already    |
| 14. | Ledok Lempong  | 0.7         | VI          | Already    |
| 15. | Sendang Jambon | 3           | V           | Not yet    |
| 16. | Ledok Ipik     | 0.6         | VI          | Not yet    |
| 17. | Jobin          | 0.2         | VI          | Not yet    |
| 18. | Ledok Mincon   | 0.4         | VI          | Not yet    |
| 19. | Sumber Andong  | 3.1         | V           | Not yet    |
| 20. | Sumber Pucung  | 2.1         | V           | Not yet    |
| 21. | Sumber Cuwo    | 1.9         | V           | Not yet    |
| 22. | Umbul Candi    | 0.8         | VI          | Not yet    |
| 23. | Kletak         | 0.24        | VI          | Not yet    |
| 24. | Madoan         | 0.7         | VI          | Not yet    |
| 25. | Kratuan        | 0.9         | VI          | Not yet    |
| 26. | Tawang rejo    | 1           | V           | Not yet    |
| 27. | Kemiri         | 0.3         | VI          | Not yet    |
| 28. | Guwa Lava      | 1.6         | V           | Not yet    |
| 29. | Bebeng         | 1.1         | V           | Not yet    |
| 30. | Gambiran       | 0.45        | VI          | Not yet    |
| 31. | Pakem          | 0.9         | VI          | Not yet    |

Source: Ratih et al [7]

Two parameters that exceed the quality standard also show that it is necessary to manage spring catchments to protect the quantity and quality of water. Efforts to prevent coliform bacteria by protecting rainwater catchments from agricultural and livestock activities are one example of efforts that need to be made. This condition is based on the possibility of high coli bacteria caused by the use of manure as fertilizer so that the water that seeps into the soil is contaminated by coli bacteria. The 2015 land use map (Figure 3) and analysis of birdview imagery on google earth show that agricultural activities such as moor and mixed gardens are mostly carried out in the catchment area so that it can influence the increase in coli content. However, further research is needed to accurately determine the causes of high detergent and coli content in springs in the study area. Table 2 shows the results of analysis of water quality in the study area.
Table 3. Water Quality Laboratory Test Results

| No | Spring name       | TDS (mg/l) | Alkalinity (mg/l) | Nitrit (mg/l) | Fe (mg/l) | Detergent (mg/l) | pH  | Temperature (°C) | Coliform MPN/100ml |
|----|-------------------|------------|-------------------|--------------|-----------|------------------|-----|------------------|-------------------|
| 1  | Randusari         | 122        | 57.14             | 0.016        | 0.214     | 0.246*           | 6.8 | 24.15            | 1600*             |
| 2  | Kemirikebo        | 105        | 57.14             | 0.004        | 0.146     | 0.165*           | 7.34| 23.52            | 46                |
| 3  | Kemirikebo II     | 114        | 61.22             | 0.003        | 0.186     | 0.049            | 6.95| 26.55            | 1600*             |
| 4  | Kemirikebo III    | 115        | 60                | 0.048        | 0.073     | 0.189*           | 6.95| 23.47            | 350*              |
| 5  | Karangnongko      | 133        | 64                | 0.034        | 0.074     | 0.161*           | 7.02| 23.36            | 1.8               |
| 6  | Umbul Temanten    | 302        | 104               | 0.032        | 0.156     | 0.132*           | 6.88| 21.39            | 7.8               |
| 7  | Sendang Pancuran  | 159.7      | 60                | 0.034        | 0.174     | 0.058*           | 7.02| 22.84            | 1600*             |
|    | **Baku mutu**     | **1000**   | **500**           | **1**        | **1**     | **0.05**         | **6.5-8.5**   | **22.32-28.32**   | **50**            |

Source: Analysis of laboratory tests in 2018

Note: * Exceeding the quality standard

4.3. Spatial Distribution of Springs Distribution in Disaster Prone Areas in the South Slope of Merapi Volcano

The Merapi Volcanic Landscape, besides having the potential for disaster in the form of eruptions, on the other hand also has high natural resource potential, one of which is water resources. Sutikno et al. [12] explained that the potential of water resources high in the southern slopes of Merapi Volcano was indicated by the presence of potential aquifers with wide distribution, relatively shallow groundwater, discharge reaching 10 liters / second, and good water quality. The high potential of water resources on the South Slope of the Merapi Volcano is also indicated by the number of springs. The emergence of springs is inseparable from geomorphological conditions which are in the form of young volcanic cone morphology with a break of slope. These morphological characteristics besides influencing the appearance of springs also affect their distribution, which is a circular pattern called the volcanic spring belt [13].

This study has identified 31 springs locations in the southern slope of Merapi Volcano. The distribution of springs in the study area turned out to follow the pattern of a volcanic spring belt that is circular in shape on the break of the slope of the intermediate shape of the land. Regarding this pattern of distribution, Ratih et al. [7] have explained that the patterned springs distribution groups in the slope bending zone with a Z-score of -3.66. Based on the map plotting the location of the springs it appears that this clustering pattern forms a longitudinal path that indicates the pattern of the springs belt. There are two units of landforms that are part of the springs belt system, which are the volcanic landforms and volcanic foot plains. When viewed from each unit of land, springs on volcanic leg are spread evenly throughout the region with a value of Z-Score 1.965059, whereas in the landforms of the volcanic foot plate the distribution pattern of springs tends to cluster on the west side with a Z-Score -2.436591.

Furthermore, based on the results of the analysis of springs distribution, Ruth et al. [7] showed that the clustering pattern forming the springs belt is still clearly visible as a feature of young vulcanization. This condition was found to have similarities with the distribution of springs on the eastern slope of Vulkan Sindoro which was studied by Ashari [19] but different from that in Vulkan Lawu Tua which was studied by Santosa [13]. There is an interesting comparison between the results of the study on the southern slopes of Mount Merapi and the western slopes conducted by Aurita and Purwantara [18]. Although the springs in the two study locations were part of the same volcanic area, it turned out that the development of different shapes between the southern and western parts had an effect on differences in the pattern of springs belts. Geomorphological conditions in the form of landforms and geomorphological processes greatly influence the distribution of springs on the
southern slopes of Merapi Volcano. One interesting finding is spring anomalies that do not appear on the east side, whereas in the same landform unit there are clusters of springs on the west side. The Merapi Volcanic Eruption in 2010 allegedly affected the loss of many springs on the east side due to being covered by volcanic material. This eastern part is a directly affected area of eruption in 2010 [7].

In relation to efforts to use springs for handling disaster emergencies, an analysis of the spatial distribution of springs in disaster-prone areas also needs to be done. There are 31 springs located in units of volcanic landforms and volcanic foot plains. The area based on the potential for eruption hazards is divided into disaster prone areas I, II, and III. Disaster prone areas III have the highest eruption hazard level. Disaster prone areas II cover the most extensive areas with the most population. The results of the geographic information system analysis using the average nearest neighbour method show that the distribution of springs in disaster prone areas III is patterned dispered with a Z-score of 486.74 (Figure 3a). Springs are spread evenly in various parts of the region including disaster prone areas III.

In KRB II the spreading pattern of the springs was clustered on the west side of this region with a Z-score of -3.080 (Figure 3b). The east side of the southern slope of Merapi Volcano is not much spring after the 2010 eruption. Ratih et al. [7] suggested that the 2010 eruption material hoarded many springs in the east. Based on the map of disaster-prone areas and areas affected by the 2010 eruption [5] it is known that the east side of the southern slope of the volcano Merapi in Cangkringan sub-district is an area of direct impact of the 2010 eruption which was buried by thick erupted material. Because the thickness of this material influences the appearance of springs as explained by Santosa [13] that springs appear in generally very thin soil layers. Meanwhile in the combined area between KRB II and III the distribution of patterned springs was dispersed with a z-score of 890.72.
4.4. Springs Spatial Modeling as Optimization of Hydrological Potential

The results of this study have found 31 spring locations on the southern slopes of Merapi Volcano. These springs are generally included in class VI and VII. Although it has a debit that is not too large, but because the amount is quite large, the springs are very potential to be utilized in fulfilling the needs of the community, especially in emergency situations of eruption disasters. With a population of 47,347 people living in villages whose territory is included in the Vulkan Merapi disaster-prone area, the standard for meeting the needs of water per capita for refugees is 20 liters as has been done in handling Mount Agung refugees in 2017 [24], then it takes 946,940 liters of water per day. This amount can certainly be fulfilled by springs found on the southern slopes of Mount Merapi (Table 1). Meanwhile from the aspect of quality, springs in this region also have good water quality. There are two parameters that exceed the threshold but if processed further it can still be used optimally.

To manage the spring well, planning for the selected springs is needed to fulfill the needs in a particular village refugee camp. Springs management planning to be effective needs to be done by taking into account the distance of the spring from the refugee camp as well as the closest route to drainage from the spring to the refugee camp. In this study we tried to make an example of some design of spring selection according to the distance of the spring from the refugee camp and the closest route between the spring and the camp. The selection of springs in addition to considering
distance also considers other aspects, namely accessibility, barrack capacity and spring discharge. The chosen springs are springs that have easy accessibility and large enough discharge to meet the needs of refugees who are accommodated in refugee camps. If some springs are found that meet these criteria, then the springs are located closest to the refugee camp.

We have tried to make springs utilization routes for Wonokerto barracks, Sendanglegi barracks, Umbulharjo barracks, Pagerjurang barracks, Glagaharjo barracks, Jiwan barracks, Candibinangun barracks, and Kuwang barracks. The Wonokerto Barracks can utilize the Sendang Jambon spring with a flow of 3 l/s, the closest route from the spring to the refugee barracks is 1.96 km. Barak Sendanglegi can utilize the Sumber Pucung spring with a discharge of 2.1 l/s, the closest route from the spring to the refugee barracks is 3.1 km. Barak Pagerjurang can use the Umbul Temanten spring with a debit of 1 l/s, the closest route from the spring to the refugee barracks is 4.17 km. Barak Glagaharjo can use the spring of the Bebeng with a flow of 1.1 l/s, the closest route from the spring to the refugee barracks is 2.02 km. Baracks Jiwan can take advantage of the Bebeng spring with a flow of 1.1 l/s, the closest route from the spring to the refugee barracks is 1.34 km. Barak Candibinangun can use the Pakem spring with a flow of 900 ml/s, the closest route from the spring to the refugee barracks is 3.7 km. While Kuwang Barracks can use Bebeng spring with a flow of 1.1 l/s, the closest route from the spring to the refugee barracks is 3.98 km.
Figure 4. Nearest Springs Access Route from the Refugee Barracks
5. Conclusion

Volcanic landscapes such as Merapi Volcano have very high potential springs. One of the potentials of water resources is indicated by the presence of springs. On the volcanic landscape springs are spread in a circle forming a springs belt in the transitional area of the landform or slope bending zone. The young volcanic landscape has a more regular springs belt pattern than old volcanic threads. The volcanic south slope of Merapi has many springs that form the pattern of the springs belt. There are two springs belt systems, namely at the slope buckling in the intermediate region between the shape of the volcanic slope and the slope of the slope in the transitional area between the volcanic footsteps and the volcanic foot plains. In areas directly affected by eruptions such as the southern slopes of the Merapi volcano, there is a possibility that the springs will be lost due to the eruption of material so that anomalies occur in the springs belt. The distribution of springs on the southern slopes of the Merapi volcano is seen as geomorphologically clustered. Whereas seen from areas included in disaster-prone areas, springs in disaster prone areas II have clustered patterns while in disaster prone areas III are patterned dispersed. In general, the distribution of springs to community settlements in disaster-prone areas is patterned dispersed. The pattern of distribution of springs combined with information on the quality and quantity of water can be a consideration in determining the direction of springs utilization. Losses due to the disaster of the Merapi eruption can be minimized by increasing community capacity by providing information on the location of springs along with the data on quality, discharge and the nearest route in utilizing water, so that scarcity of clean water after the eruption can be overcome. There are several things that need to be done further research, among others, regarding the factors that affect water quality on the southern slopes of the Merapi volcano.

6. Acknowledgement

The author would like to thank the Republic of Indonesia Ministry of Research, Technology and Higher Education for funding this research through the 2017 Exact Research Student Creativity Program grant. The author also thanked various parties who have helped in the research process including the Disaster Management Agency Sleman Regency; staff of the Turi, Pakem, and Cangkringan Sub-District Offices in Sleman Regency, as well as village office staff and the entire community in the research area.

References

[1] Badan Geologi, “G. Merapi - Sejarah Letusan,” Data Dasar Gunungapi, 2014. [Online]. Available: http://www.vsi.esdm.go.id/index.php/gunungapi/data-dasar-gunungapi/542-g-merapi?start=1. [Accessed: 20-Mar-2018].

[2] H. Murwanto, D. A. Siregar, and A. Purwoarminta, “Jejak erupsi Gunung Merapi di Kabupaten Magelang Provinsi Jawa Tengah Traces of Merapi Volcano eruption in Magelang District Province of Central Java,” J. Lingkung. dan Bencana Geol., vol. 4, no. 2, pp. 135–147, 2013.

[3] S. D. Andreastuti, C. Newhall, and J. Dwiyatno, “Menelusuri kebenaran letusan Gunung Merapi 1006,” J. Geol. Indones., vol. 1, no. 4, pp. 201–207, 2006.

[4] BNPB, “Dampak Letusan Gunung Merapi Mencapai Rp 3,56 Trilyun,” Majalah GEMA BNPB, Ketangguhan Bangsa dalam Menghadapi Bencana, pp. 17–20, 2011.

[5] Badan Geologi, “Peta Kawasan Rawan Bencana Gunung Merapi dan Area Terdampak Letusan 2010.” Badan Geologi Kementerian Energi dan Sumberdaya Mineral, 2011.

[6] BPPTKG Badan Geologi Kementerian Energi dan Sumberdaya Mineral Republik Indonesia, “Status Merapi: Waspada,” 2018. [Online]. Available: http://merapi.bgl.esdm.go.id/. [Accessed: 08-Sep-2018].

[7] S. Ratih, H. N. Awanda, A. C. Saputra, and A. Ashari, “Hidrogeomorfologi mataair kaki Vulkan Merapi bagian selatan,” Geomaina, Maj. Ilm. dan Inf. Kegeografian, vol. 16, no. 1, pp. 25–36, 2018.
[8] BPS Kabupaten Sleman, *Kecamatan Turi Dalam Angka 2017*. Sleman: BPS Kabupaten Sleman, 2017.

[9] BPS Kabupaten Sleman, *Kecamatan Pakem Dalam Angka 2017*. Sleman: BPS Kabupaten Sleman, 2017.

[10] BPS Kabupaten Sleman, *Kecamatan Cangkringan Dalam Angka 2017*. Sleman: BPS Kabupaten Sleman, 2017.

[11] H.A. Sudibyakto, *Manajemen Bencana Indonesia Ke Mana?* Yogyakarta: Gadjah Mada University Press, 2011.

[12] Sutikno, L. W. Santosa, Widyianto, A. Kurniawan, and T. H. Purwanto, “*Kerajaan Merapi*, *Sumberdaya Alam dan Daya Dukungnya*. Yogyakarta: BPFG UGM, 2007.

[13] L. W. Santosa, “Kajian hidrogeomorfologi mataair di sebagian lereng barat Gunungapi Lawu,” *Forum Geogr.*, vol. 20, no. 1, pp. 68–85, 2006.

[14] S. Purnama, *Hidrologi Air Tanah*. Yogyakarta: Kanisius, 2010.

[15] A. E. Springer *et al.*, “A comprehensive springs classification system: Integrating geomorphic, hydrogeochemical, and ecological criteria,” in *Aridland Springs in North America, Ecology and Conservation*, L. E. Stevens and V. J. Meretsky, Eds. Tucson: UAP Press, 2008, pp. 1–31.

[16] D. Glazier, “Springs,” in *Encyclopedia of Inland Waters*, G. E. Likens, Ed. Academic Press, 2009, pp. 734–755.

[17] A. E. Springer and L. E. Stevens, “Spheres of discharge of springs,” *Hydrogeol. J.*, vol. 17, no. 83, 2009.

[18] R. P. Aurita and S. Purwantara, “Karakteristik Mataair Kaki Lereng Gunung Merapi dan Pemanfaatannya di Kecamatan Dukun Kabupaten Magelang,” *Geomedia*, vol. 15, no. 1, pp. 75–85, 2017.

[19] A. Ashari, “Distribusi Spasial Mataair Kaitannya dengan Keberadaan Situs Arkeologi di Kaki Lereng Timur Gunungapi Sindoro antara Parakan dan Ngadirejo Kabupaten Temanggung,” in *Mega Seminar: Geografi Untukmu Negeri*, 2014, pp. 169–179.

[20] H. T. Verstappen, *Garis Besar Geomorfologi Indonesia*, 1st ed. Yogyakarta: Gadjah Mada University Press, 2013.

[21] S. Simoen, “Sistem Akuifer di Lereng Gunungapi Merapi Bagian Timur dan Tenggara, Studi Kasus di Kompleks Mataair Sungasang Boyolali Jawa Tengah,” vol. 15, no. 1, pp. 1–16, 2001.

[22] E. Kurniati, N. Vikriyah, and N. Ardana, *Nice Tutorial SIG Lanjut: Sistem Informasi Geografis Tingkat Lanjut*. Yogyakarta: Bilion Technology, 2016.

[23] W. Raharjo, Sukandarrumidi, and H. M. D. Rosidi, “Peta Geologi Lembar Yogyakarta, Jawa,” Bandung, 1995.

[24] Direktorat Jenderal Cipta Karya Kementerian Pekerjaan Umum dan Perumahan Rakyat, “Cipta Karya Pemenuhi Kebutuhan Air Bersih dan Sanitasi di Pos Pengungsian Erupsi Gunung Agung,” *Berita*, 2017. [Online]. Available: http://ciptakarya.pu.go.id/v3/news.php?id=7273. [Accessed: 10-Sep-2018].