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LINEAMENT CONTROL ON SPRING CHARACTERISTICS AT CENTRAL WEST PROGO HILLS, INDONESIA

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ABSTRACT: The research area is located at the central of West Progo Hills, in Yogyakarta and Central Java Province, Indonesia. It is hard water area, but there are some springs appearing from Jonggrangan and Old Andesite Formations. These formations consist of hard, compacted Tertiary rocks which have dissected by some lineaments of structure or morphology. The lineaments may control to springs characteristics, involve their appearance, frequency and discharge. Field observation has been done to collect springs data. The small discharge has been measured by water gauge and stopwatch directly, while the big ones have been measured by river channeling measurements. On the other hands, lineaments were determined from Landsat image, SRTM and topographic map as well as from field. The result shows that lineaments in Old Andesite Formation develop in many directions followed by spring appearance, in random location. Springs in Jonggrangan Formation mainly appear in NE-SW direction in accordance with the azimuth of lineaments almost in SW-NE direction. The springs of both formations usually appear controlled by individual lineaments, indicated by coefficient correlation of 84% for the relationship between distance of spring – lineament and the numbers of springs. The density of lineaments also control of springs appearance (r = 62% for cross dots of fractures and r = 51% for length). The distance between lineament and spring to discharge rate of springs seems no influence indicated by r^2 = 0.0495. It means that lineaments influence to spring occurrence in their density and distance characteristics.

Keywords: Spring, lineament, fracture, discharge

1. INTRODUCTION

Research area is located at central of West Progo Hills which is included in Yogyakarta and Central Java Provinces, Indonesia (Fig. 1). This area is limited geographically by 07o43’00” – 07o48’00” S latitude and 110o5’00” – 110o08’00” E longitude coordinates.

West Progo Hills is a poor groundwater region with a moderate to steep slope morphology. In this area, groundwater is difficult to be obtained in sufficient quantities. Because of the lack of groundwater, the area is not interesting for many researchers. The hydrogeology researches seldom carried out in this non groundwater basin. Study of groundwater potential just a little done in this area. Nevertheless, the author interested to know about groundwater especially in relation with the lineament of fracture or morphology.

Geologically, the research area consists of Tertiary rocks which usually have hard and compacted petrophysics. It is consists of Jonggrangan and Old Andesite Formations. The rocks of these formations are complex tectonically, therefore many fractures can be found. The fractures usually make lineaments in whole area. The lineaments also indicated by some steep topography which sometimes indicated by spring appearance.

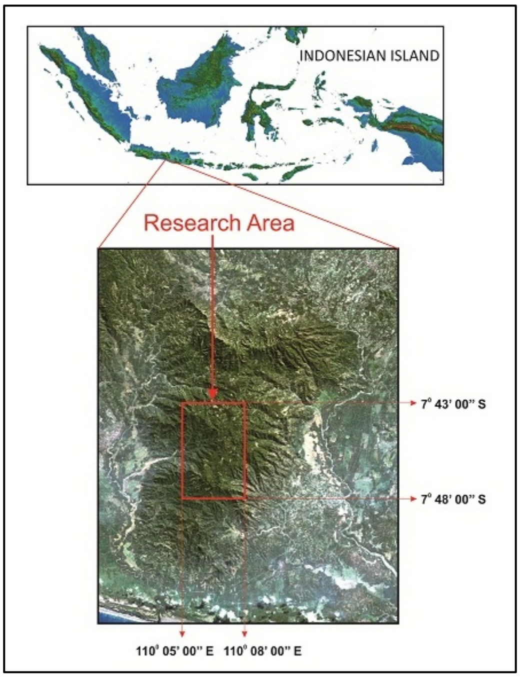


Fig.1. Research area in the central part of West Progo Hills showed from Landsat image band 321 [1].

The small potential of groundwater in this area may encourage the author to understand about its local groundwater system. The groundwater system can be known by understanding of groundwater appearance as springs. This paper wants to discuss about groundwater potential, especially on springs at this hard water area.

Knowing about groundwater potential can be done from many points of view. In this paper, the research will focus on spring appearance in the field in relation with lineaments of fracture or morphology. This research has been done to know about one of hydrogeological aspects of central West Progo Hills.

This study is purposed as a field hydrogeological research to observe springs characteristics. Hydrogeological data collecting in the field has been done to determine the appearance and discharge rate of springs. Some secondary data were also collected to complete the analysis. Goal of the study is to know the relation of lineaments and springs characteristics in the research area.

Study of hard water area is important for understanding its groundwater potential in order to know about its management and planning of water resources. For example, propose supply of surface water to deficient regions by linking river basin therefore it will reduce pressure on groundwater and then facilitate recharge and raise water table [2]. Understanding of groundwater in hard water area also can be generated from its occurrence.

Understanding about groundwater potential is important to know its storage. Global estimate of groundwater storage changes due to land subsidence can be used to estimate the groundwater depletion trends at any region throughout the world [3]. Apart from land subsidence problem, climate change can also be used to predict groundwater storage.

2. METHOD

Field survey has been done as mapping of springs in the study area, use some standard geological equipment (hammer, compass and loupe). This hydrogeological survey has been carried out to collect morphological, lithological and structural data as well as springs data. The springs data in the field took to get numbers and discharge quantity. All primary data has been taken in the field on May – June, 2017. The climate in that month was in dry season with very little precipitation.

Discharge of springs has been measured by two kinds of methods, depends on the volume of water discharge. The discharge of small springs were measured directly by water gauge and stopwatch with the formula as follows [4].

$$Q = V / t \tag{1}$$

Where : Q = water discharge (l/s)
V = volume (l)
t = time (s)

Whereas, the medium - big springs have been measured their water discharge by measuring of stream which water out from springs, use its formula as follows [4].

$$Q = v \times A \tag{2}$$

Where : v = velocity of water stream flow (m/s)
A = area of stream section (m2)

On the other hand, lineament data has been collected from secondary and primary data. The secondary data was taken from interpretation of remote sensing and Landsat image band 321 [1], while primary data was interpreted from SRTM. Both data have been analyzed to get lineaments of fracture or morphology in study area.

Lineaments which have been identified then analyzed by GIS, rose diagrams as well as regression graphic. GIS method used in this research by ArcGIS software. GIS is useful for representation of spatial variability, and suitable for hard rock terrain [5]. In this study, GIS is used especially for helping of springs and lineaments mapping.

3. REGIONAL GEOLOGY

Based on physiographic zone division, the research area is included in Dome and Hills in Central Depression Zone [6]. West Progo Hills is dome like area. It has NNE – SSW long axe as long as 32 km, where short axe in WNW – ESE direction as long as 15 – 20 km. Core of this dome was built by three ancient andesitic volcanoes (Oligocene – Miocene) which has advanced erosional, i.e. Gajah, Ijo and Menoreh volcanoes. These volcanoes have yielded Old Andesite Formations rocks.

West Progo Hills consist of rocks from old to young successively are Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations and Alluvial sediments [7]. The formations which outcropped in study area are Old Andesite and Jonggrangan Formations. Old andesite Formation consists of andesite breccia, tuff, lapilli tuff, tuffaceous sandstone, agglomerate and intercalation of andesite lava which sometimes intruded by andesite or dacite. Whereas, Jonggrangan Formation mainly composed by coral or bedded limestone, otherwise tuffaceous marl, conglomerate, and calcareous sandstone.

4. RESULT AND DISCUSSION

The study area can be considered as core of West Progo Dome physiography. This area has variable morphology, mainly composed of high dissected, steep slope morphology. This morphology is located at elevation of 187.5 until 850 m asl, with slope developed from 5% (undulating) until more than 100% (very steep). Some lineaments of escarpments can be seen at many places as shown in block diagram (Fig. 2).

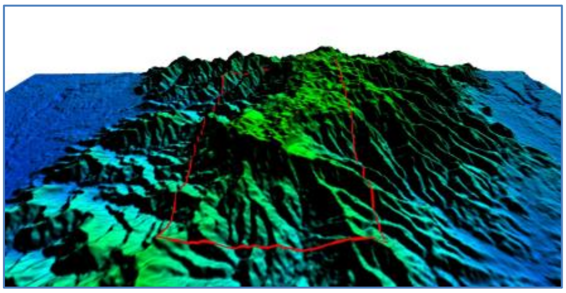


Fig 2. Morphology feature of study area looked from southern side.

The study area is a hard rock terrain, which contains many kinds of rocks. The rocks in this area generally consist of sedimentary and igneous rocks with high compaction and hardness. This petrophysic characteristics show lower porosity and permeability.

In central part of study area there are Jonggrangan plateau composed by limestone and other carbonate rocks of Jonggrangan Formation. Whereas, at western and eastern part, the study area mainly built by volcanic andesitic rocks of Old Andesite Formation. Both formations usually build coarse relief in the area.

Old Andesite Formation composed by siliciclastic rocks, such as epiclastic and pyroclastic andesite breccia. This breccia rocks usually are black color in fresh outcrop or brownish black when they have weathered, massive or jointed structures, composed of andesite fragment dominantly. Tuff and tuffaceous sandstone sometimes are found at some locations. The rocks usually white to brownish white in color, massive or bedded structure, and composed of tuff, and any other siliciclastic minerals. Dacite and andesite intrusion rocks are combined into Old Andesite Formation included in the analysis of this research.

Limestone of Jonggrangan Formation commonly have white to creamy white in color, clastic or non clastic (reef) texture, with massive or bedded structure, composed by some carbonate minerals and are often found some fossils. The fossils in limestone involve foraminifera, coral or algae and sometimes mollusk can be found. The rocks both of Old Andesite and Jonggrangan Formations have been jointed.

More than 160 lineaments have been identified by Landsat band 321 [1] and SRTM resolution 30 m both of Old Andesite and Jonggrangan Formations (Fig. 3). From Landsat image, the lineaments can be identified as long, regionally lineaments. The analysis of SRTM shows some short to medium length of lineaments. Those lineaments can be yielded from structural geology or morphology as well as drainage pattern.

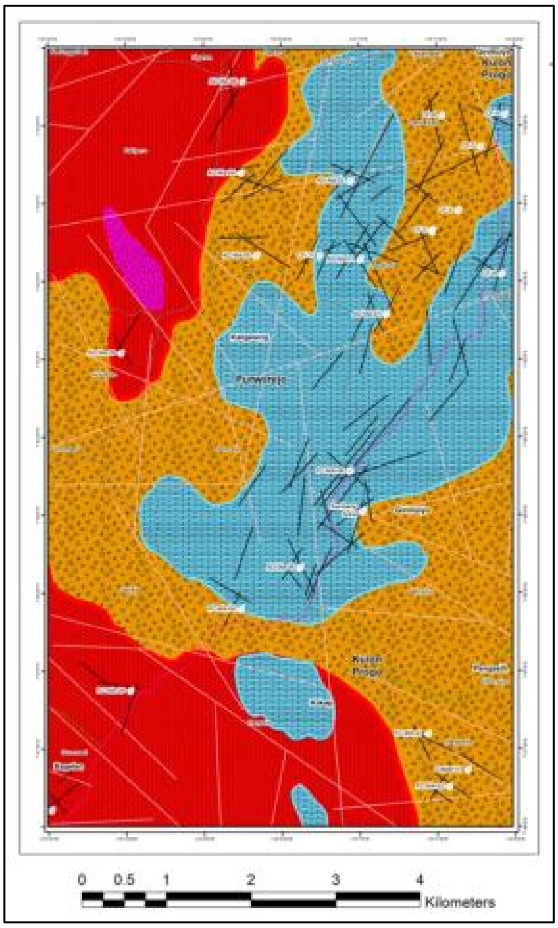


Fig. 3. The lineaments are shown in geological map of study area. Black lineaments analyzed from SRTM resolution 30 m. Red lineaments identified from Landsat band 321 [1]; geological map [7].

Legend:
- Dacite intrusion
- Andesite intrusion
- Jonggrangan Formation
- Old Andesite Formation

Table 2 below show some location of springs in research area and their discharge rate. Those springs can be classified into class 3 – 7 of magnitude based on Meinzer classification. It shows that there are many spring which small discharge, and small numbers of big discharge springs. The biggest one can be found at Mudal Park, Girimulyo Sub-district.

Table 2. Location and discharge rate of springs in research area.

No. of Spring	Location	Q (l/s)	M*)
1	Pandanrejo	0.10	6
2	Telogoguwo	0.15	6
3	Telogoguwo	0.50	6
4	Telogoguwo	1.00	5
5	TukSongo	0.10	6
6	TukSongo	0.10	6
7	Anjani Cave	32.74	4
8	Telogoguwo	0.06	7
9	Telogoguwo	0.07	7
10	Telogoguwo	0.08	7
11	Pagertengah	0.10	6
12	Telogoguwo	1.50	5
13	Sikantong Cave	56.98	4
14	Purwosari	10.30	4
15	Kalilo	0.10	6
16	Hulosobo	0.01	7
17	Mudal River Park	236.77	3
18	Jaran	1.20	5
19	Kembang Soka	1.00	5
20	Seplawan Cave	15	4
21	Teganing Dua	0.60	6
22	Jatirejo	0.34	6
23	Hargowilis	0.40	6
24	Clapar 1	1.20	5
25	Clapar 2	0.90	6
26	Dermosari	1.10	5

*) Magnitude of spring based on discharge rate of Meinzer classification [8].

There are 86 lineaments can be identified from Old Andesite and 75 lineaments from Jonggrangan Formation. Analysis of these lineaments in each formation result some major azimuth of lineaments as shown at Fig. 4. Lineaments in Old Andesite Formation show many directions trending, whereas those in Jonggrangan Formation have dominant trend in NE-SW direction. This major pattern of lineaments seems conformably with spring exposure, which random in Old Andesite Formation and SE-NW trending in Jonggrangan Formation.

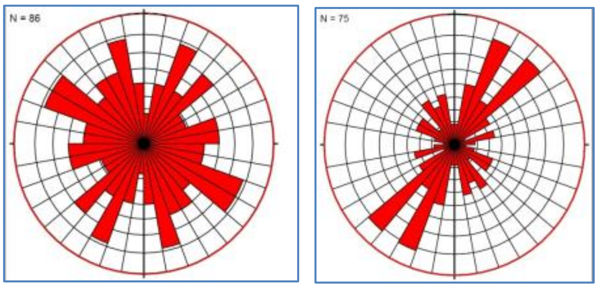


Fig. 4. Rose diagrams of numbers of lineament plot in their azimuth of Old Andesite Formation (left) and Jonggrangan Formation (right).

The trending of lineaments can be analyzed from their length as shown at Fig. 5 below. At that figure it shows that lineament of Old Andesite Formation developed until 9 km length at N80ºE – N90ºE or East-West dominantly. Whereas, there are lineaments of 12 km length can be found at Jonggrangan Formation in N40ºE - N-50ºE direction.

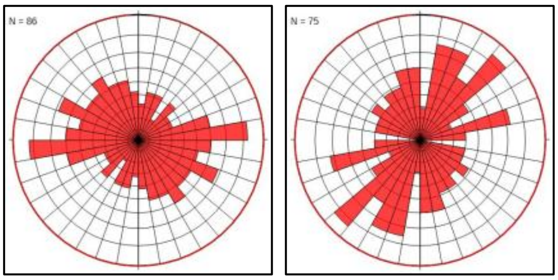


Fig. 5. Rose diagrams of lineament's length plot in their azimuth of Old Andesite Formation (left) and Jonggrangan Formation (right).

There are some lineaments made of fracture or morphology can be seen directly in the field. For examples, there is long escarpment of hills can be found in a NE-SW direction at east slope of Jonggrangan Hills (Fig. 6).

Springs exposure in the field sometimes indicate conformable with lineaments. For example, Fig. 7 shows that there are at least three springs expose at Clapar Village which parallel in fractures made of sheeting joints in the lava of Old Andesite Formation (OAF).

Map of lineament density has been drawn to explain the density characteristic of fracture in research area based on numbers of a cross dot of lineaments (Fig. 8) as well as based on length of lineaments (Fig. 9). Both two maps will explain the area and their lineaments density, especially around spring exposure.

Fig. 6. Morphology feature show escarpments in many location of study area.

Notes:

a. Mt. Ijo and surrounding area at West Progo Hills looked from Hargotirto Village (N140ºE) (top).

b. Escarpment at Mudal River Park area (bottom left)

c. Escarpment at Mt. Gajah, Kaligesing area (bottom right).

Fig. 7. Sheeting joints in lava OAF (left). Two springs at Clapar 2 Village expose from the lava parallel to sheeting joints (right).

Relationship between lineament and springs exposure can be analyzed by some graphic based on some variables (Fig. 10 – 13). This analysis was done to understand about influence of lineaments/fracture characteristics to the existing of springs. The variables using for this analysis include density of lineaments, numbers of spring, as well as their discharge rate.

5.1 Relationship between density of lineament (cross dots) and numbers of springs

Sometimes it can be found lineaments which cross the other, then they met in cross dot of their direction. The numbers of their cross dots can be calculated in term of density of lineaments. Fig. 10 shows that there is strong correlation enough between density of lineaments and numbers of springs with correlation coefficient of 62% (r^2 = 0.3831). It means that density of lineaments has strong influence to the springs. There should be any springs exist in the area with enough numbers of lineaments which interconnected. The lineaments which are interconnected each other may become the ways for springs occurrence.

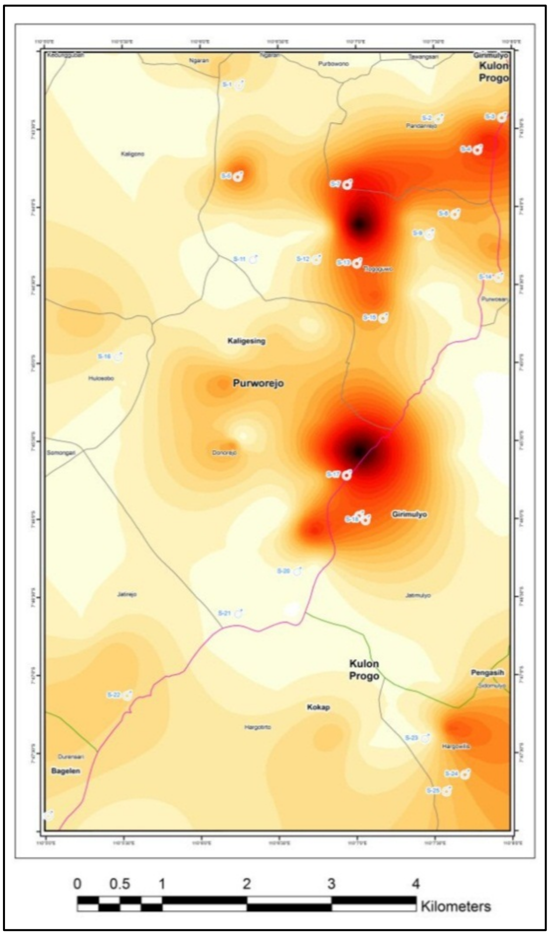


Fig. 8. Density map of lineaments in research area, calculated based on numbers of cross dot of lineaments.

Legend:

- 0 – 8 dots/km^2
- 8 – 16 dots/km^2
- 16 – 24 dots/km^2
- 24 – 32 dots/km^2
- > 32 dots/km^2
- Spring

5.2 Relationship between density of lineament (length of fracture) and numbers of spring

Density of lineaments is also can be

determined from their length. There are some lineaments show short or long distance. Furthermore, the relationship of density based on length of lineaments has moderate correlation only with correlation coefficient of 51% (r^2 = 0.2635) (Fig. 11).

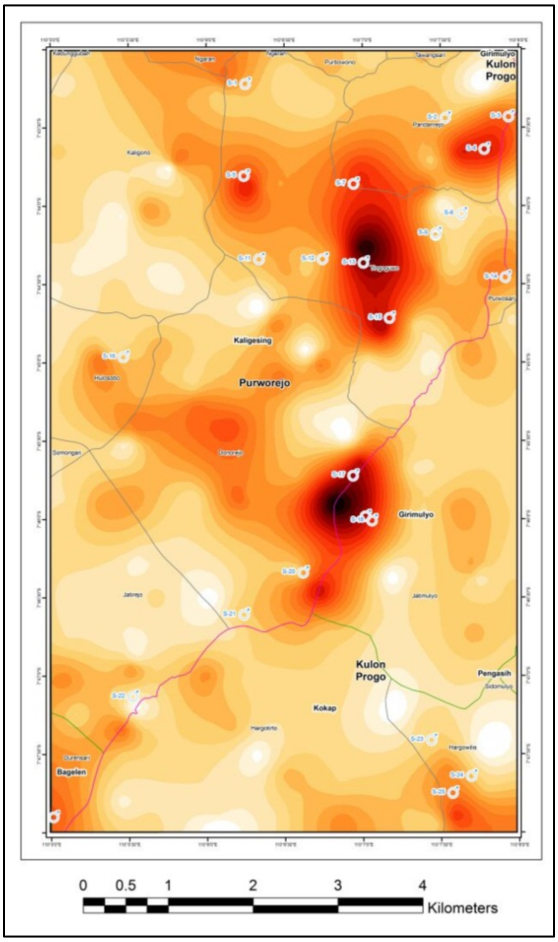
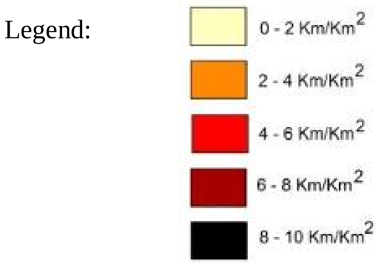


Fig. 9. Density map of lineaments in research area, calculated based on length of lineaments.



Figs. 10 and 11 show that the occurrence of spring in the study area has influence of lineaments. The correlation indicated by moderate to the strong correlation coefficient. It means that the numbers or length of lineaments in such area may be followed by the existence of spring. The high density of lineaments would always be followed by big numbers of springs.

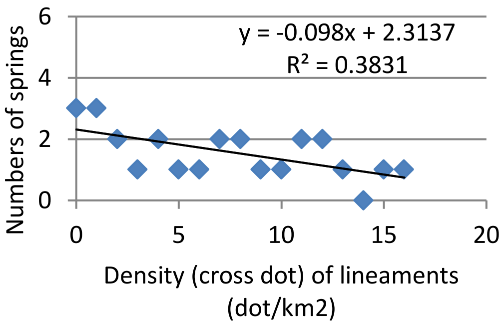


Fig. 10. Relationship between density of lineament (based on numbers of cross dot) versus numbers of springs in study area.

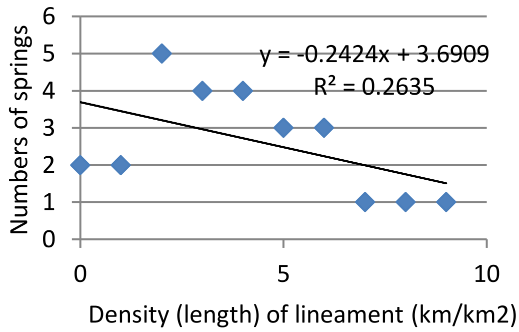


Fig. 11. Relationship between density of lineament (based on length of lineament) versus numbers of springs in study area.

5.3 Relationship between distance of springs to nearest lineaments and the numbers of spring

Some springs are usually found near lineaments which were made of fracture and indicated by steep of morphology both of high or low delta height. The perpendicular distance of spring to the nearest lineament can be calculated to analyze their influence. The result of the analysis shows that relationship between spring distance to lineament shows a strong correlation as shown in Fig. 12. The very strong coefficient correlation of 84% (r^2 = 0.7104) proves that many springs exist at or near the lineaments. It means that many springs expose controlled by certain lineament It also means that spring usually controlled by individual lineament.

5.4. Relationship between distance of springs to nearest lineaments and discharge rate of spring

The relationship between distance of spring to lineament versus their discharge rate show very low correlation coefficient (r^2 = 0.0495; Fig. 13). It means that there is no correlation between them.

The discharge of spring does not influenced by their distance to lineaments.

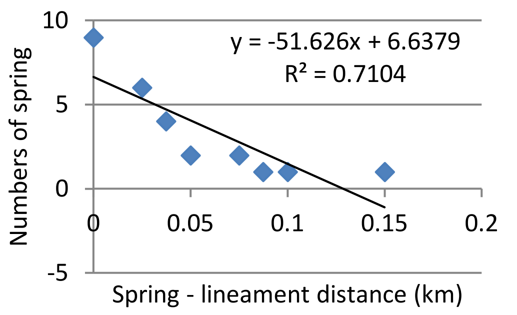


Fig. 12. Relationship between perpendicular distance of spring to nearest lineament versus the numbers of springs.

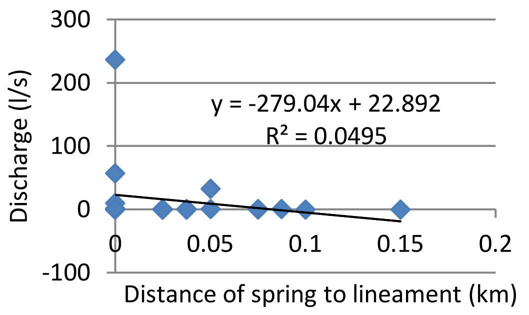


Fig. 13. Relationship between perpendicular distance of spring to lineament versus the discharge rates of springs.

Fig. 13 above show poor relationship between distance of spring to lineaments and its discharge rate. That figure seems any anomalous point with very high discharge rate coms from Mudal spring. Mudal is a big spring in Girimulyo with very high discharge rate in rainy season but it will decrease much in dry season. In rainy season, its discharge rate reaches more than twice of its discharge when it is dry season. It seems that groundwater from Mudal spring is strong influenced precipitation or season. Thus, recharge rate is not only influenced by its distance to lineaments. Effect of season usually has strong influence to unconfined aquifer, because this aquifer system due to its dynamic condition and also affected by fluctuation of the seasons [9]. A short hydrologic cycle generates a groundwater flow mechanism which is easily changed.

Again, groundwater discharge rate may be influence of other aspects, such as lithology or weathering process. It needs other analysis of many aspects. Sometimes, lithology will be related with geological structure. However, in India for example, there was no significant influence of lithology in distribution patterns along the longitudinal profiles [10]. The study also reveals that presently the state of tectonic activity is not uniform within the same regional structure. According to this example, it is possible that some aspects can influence the lineaments or discharge rate in certain area.

On the other hand, most productive bore wells and least productive ones in India drilled along lineaments but different orientation [11]. It means that lineaments can trigger discharge rate or not. Refer to that researchers, it seems that variable discharge rates of springs in central West Progo Hills are logical although springs are near to lineaments.

By means of some graphics before it can be understand that lineaments usually control the occurrence of spring because many springs are found located near or at the lineaments. It may be interpreted that some springs exist to the surface through fracture. Moreover, the influence of lineaments to spring exposure also depend on their densities. Unfortunately, the discharge rate seems no relationship with the lineaments. It means that the characteristics of lineaments just depend on spring from their distance and densities.

The study area is hard water area with compact, Tertiary rocks. The rocks in study area are usually difficult to be aquifers. These rocks can be a basement of Wates basin which has a very low permeability [12]. Even, the study area is a boundary condition of Wates basin therefore it is set as a no flow boundary.

Old Andesite Formation consists of volcanic sediments and intrusion rocks which hard properties, therefore springs are seldom found, moreover in big discharge rate. The springs may occur under lineament control, and usually depends on their distance to lineaments. These lineaments usually made from many geological structures, especially as fractures or joints.

Jonggrangan Formation mainly composed of limestone which can be aquifer because of its fracture or solution porosities. The lineaments usually came from its fractures or steep topography which made of joints. Some springs are often found in the bottom of steep morphology or break of slope. They are controlled by distance of lineament to spring then often expose at or near the lineaments.

Groundwater is stored in many kinds of rocks. It can be stored in shallow or deep aquifers. The most important source of water supply is groundwater that stored in deep seated sedimentary aquifers [13]. However, groundwater in research area may be stored both in shallow and the deep (medium) aquifers, but it may difficult to take it from very deep zone. Groundwater in research area flow in limestone aquifer of Jonggrangan

Formation as well as andesite breccia and andesite lava aquifers of Old Andesite Formation. These aquifers may be shallow or deep aquifers. It seems that groundwater develops in shallow and deep aquifers.

5. CONCLUSION

The hydrological survey has been carried out to get a mapping of lineaments and the existing of springs. Some lineaments have been measured of their azimuth, length, as well as their density by identifying from Landsat and SRTM, while springs have been measured their discharge rate in the field directly. The analysis show that existing of springs occur through the lineaments or fractures. The most influencing of lineament characteristic to spring occurrence is their distance, with coefficient correlation 84% (very strong correlation). Whereas, the other characteristics of lineaments such as their density seem have medium to strong correlation. Unfortunately, the distance between spring and lineaments do not have any correlation to discharge rate of springs.

6. ACKNOWLEDGEMENTS

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