Conservation of groundwater in Nglanggeran Area, Gunung Kidul District, Yogyakarta

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Abstract. As a fast growing tourism destination, Nglanggeran area needs a safe availability of groundwater. Nglanggeran area has been considered as a part of "non-groundwater basin" where the availability of groundwater is commonly limited. The limited groundwater resource in Nglanggeran area should be capable to fulfill the necessity of local people and tourists that are increasing every year. This is the main reason of the present study to propose a groundwater conservation in Nglanggeran area. The methods applied consist of geological and hydrogeological mapping, and statistical analysis as well. We find that Nglanggeran Area has a unique groundwater system consisting of unconfined aquifer model (called as "Kedung Kandang" model) and fractured aquifer model (called as "Bendo" model). Both models can be found in southwestern part of Nglanggeran area. Both groundwater models are proved to support water necessity of inhabitants. We also found similar systems in other parts of study area. The analysis of demographic data indicates that groundwater utilization surpasses groundwater reserve. Therefore, groundwater conservation in the study area is urgent to be implemented to maintain groundwater sustainability.

Keyword: conservation, groundwater, unconfined-, fractured-, aquifer

1. Introduction

Nglanggeran area is one of favorite geotourism destination in Yogyakarta that shows a positive trend of tourist visit. In 2007 reaching 1,440 persons and then increasing up to 255,917 person in 2015 (Bappeda Gunungkidul, 2015). This fast growing tourist visit has been causing an increasing groundwater necessity. The trend of groundwater demand shows a positive trend but groundwater availability is limited. Regionally the study area has been mapped as a "Non-groundwater basin" (Keppres 26/2011) in which the quantity of groundwater in Nglanggeran area is limited due to its location which is not part of a groundwater basin and has restricted recharge area. To avoid a groundwater deficit, we need to do a proper conservation and support groundwater sustainability.

The study area is situated in Nglanggeran and its surrounding area, Gunungkidul Regency, Yogyakarta (Figure 1). The study area can be reached one hour from Yogyakarta city, 20 km to the SE. The topography of study area is characterized by a wide, E-W trending gentle valley, and flanked by high areas in the west, east, and north parts.

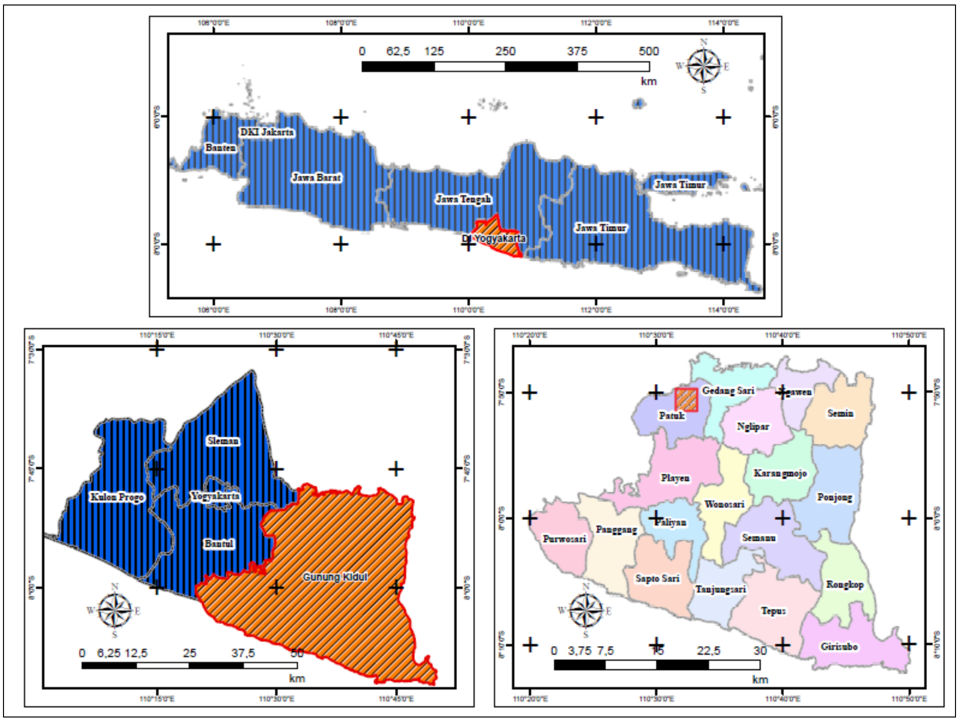

Figure 1. Location map of study area (red box).

2. Objective

The main objective of the present study is to understand geological, detailed structure and groundwater system as well as to deliniate groundwater conservation proposed area in Nglanggeran and its surrounding area.

3. Methods

Method applied in this study consists of geological, hydrogeological mapping, and statistical analysis. Field works are aimed to collect surface geological and hydrological data, while statistical analysis aims to analysis primary data and compilate the field result with secondary data. Geological mapping was carried out by collecting stratigraphy, and structural geology data. Hydrogeological mapping was performed by collecting groundwater table and water depth data, and also by observing spring types. Statistical analysis was conducted by collecting calculation of recharge and water consumption quantity.

4. Geology of Study Area

Stratigraphy of study area composed by ancient volcano lithology that was part of Old Andesite Formation (OAF) and product of ancient volcanic arc which is composed by Semilir and Nglanggeran Formations. The lithological variations of both formations consist of andesitic lava and breccia, volcanicsandstone, welded tuff, crystall tuff, shale, and lapili tuff. The stratigraphy shows homoclinal relation with dip toward south. Geological structures in this area shows complex relation and consist of sinistral fault, dextral fault, and normal fault with trend N-S, NE-SW, and NW-SE (Figure 2).

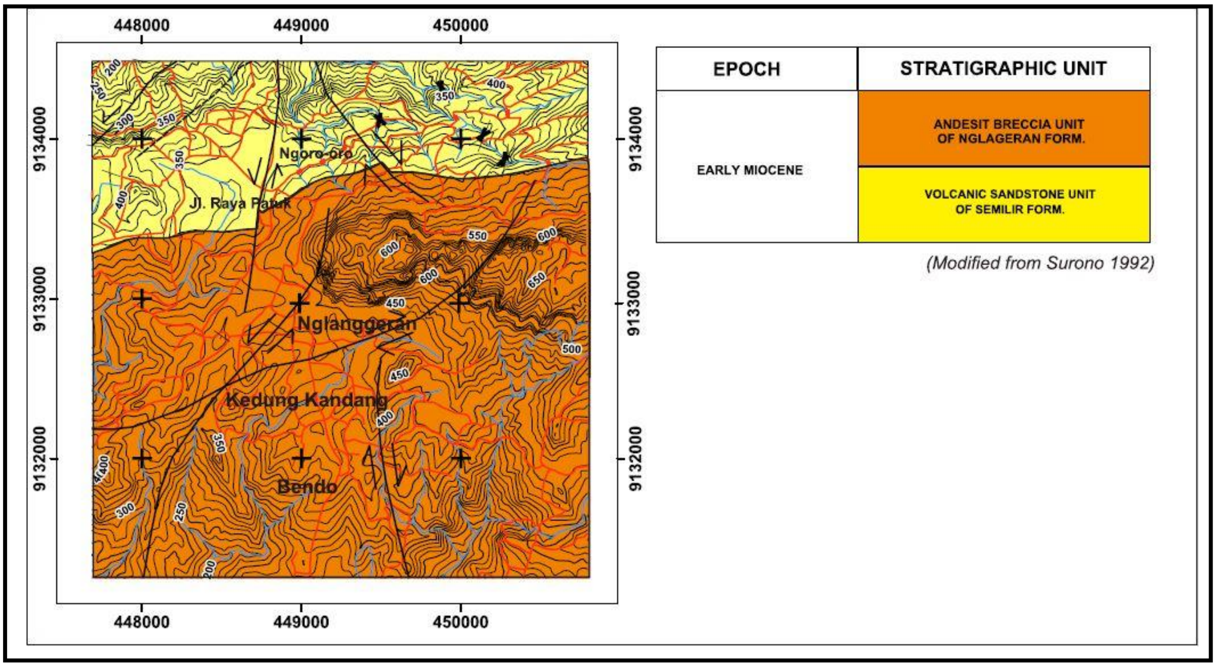

Figure 2. Geological map of study area.

5. Result of Field Study

5.1. Geological Structure

We found complex arrangement of the structure in this area. The their field indications are shown by the occurring fractures and faults which trend N-S, NE-SW, and NW-SE. The presence of some fault structures are shown by shear zone in the river, brecciated rock, shear fractures, gash fractures, slickenlines and fault planes. Shear and tension fractures are found as subsidiary structures in volcanic breccia, aglomerate, and volcanic sandstone. Shear fractures truncate rock fragment clearly, while tension fractures tend to follow the shape of rock fragments (Figure 3).

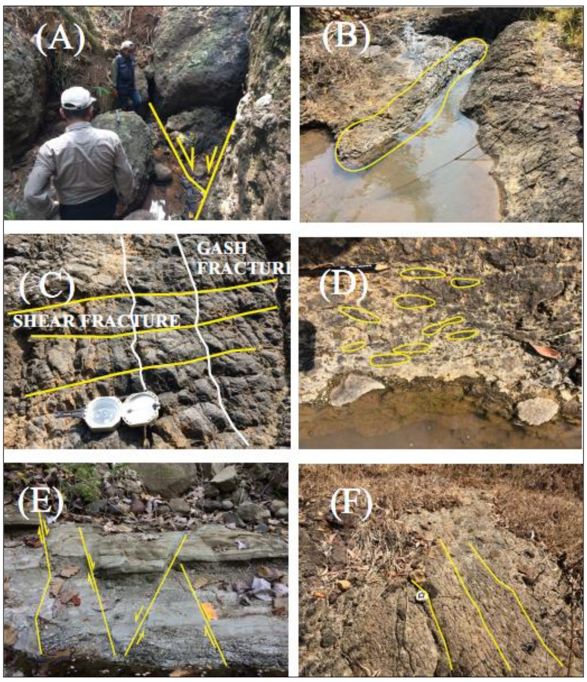

Figure 3. (A) Shear zone formed by sinistral and dextral fault, (B) A shear zone found in river bed. (C) Shear and gash fractures, (D) Brecciated fragments in a shear zone, (E) Conjugate normal fault in volcanic sandstone, (F) Tension fracture in pyroclastic breccia.

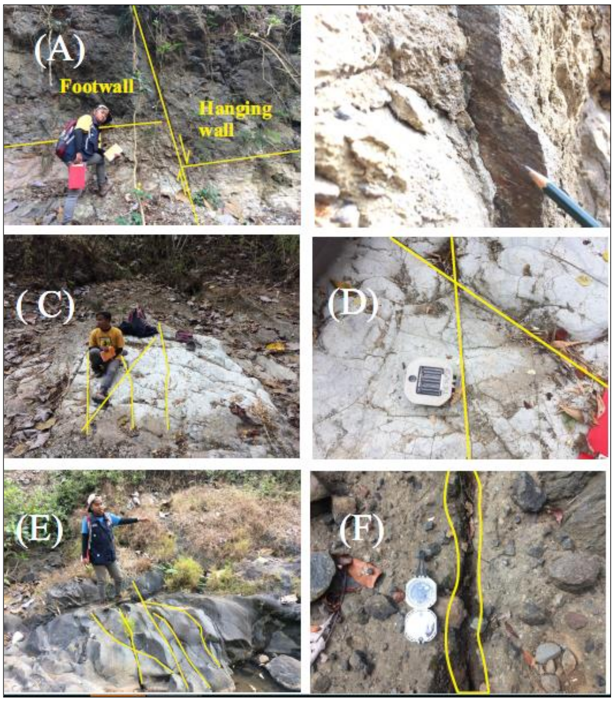

Figure 4. (A) Fault plane of normal fault found in volcanic breccia rock unit, (B). Slickenlines in the fault plane, (C) Tension fractures in volcanic sandstone unit . (D) Conjugate shear fractures in volcanic sandstone. (E) Tension fractures in lava. (F) Tension fractures in volcanic breccia.

In Kedung Kandang valley, we found a shear zone in andesitic breccia between two faults that crosscut each other. The attitude of dextral fault is N209E/72 and sinistral fault is N065E/68 (Figure 4.A). Another shear zone was observes in agglomeratic rock trending N200E (Figure 4.B). The attitude of shear fracture is N100E/68 and gash fracture is N195E/62 (Figure 4.C). In this shear zone, the fault breccias are clearly represented by elongated rock fragmen parallel to the fault lineament (Figure 4.D). In other outcrops, we found conjugate normal fault in volcanic sandstone with fault plane attitude N042E/78 and N275E/66. (Figure 4.E). Tension fractures found in ignimbritic breccia indicate attitude N205E/77 (Figure 4.F). Underneath the Ngoro-oro bridge, we found a normal fault with fault plane N330E/63 (Figure 5.A). We also found conjugate shear fractures and tension fractures with attitude N028E/82, N335E/86, and N115E/78. Similar pattern of tension fracture also found in lava and volcanic breccia.

5. 2 Groundwater Manifestation

Groundwater manifestations found in this area are in the form of springs and wells (Figure 5 and Figure 6). The springs found in volcanic breccia are located in soil areas as the product of the weathering of Nglanggeran and Semilir Formations. Local people use the water to fullfill household and agriculture neccessities and the water is distributed using pipes.The dug wells have water depth range from 2-3 meters with water column range from 1.4-3 meters. The wells are located in weathered volcanicbreccia and volcanic sandstone that act as unconfined aquifer. Water from the wells are also used by local people using pipe to fullfill daily household necessity. One well can be used to support about twenty households.

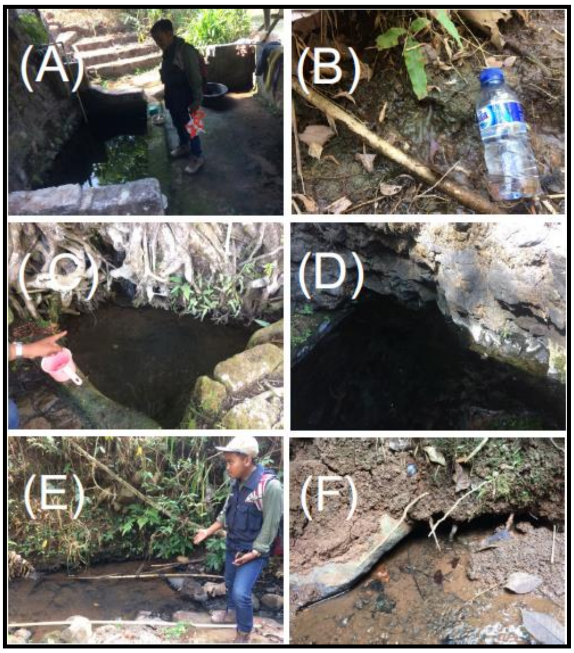

Figure 5. Topography-controlled spring in weathered volcanic breccia. (B) Fracture-controlled spring in weathered volcanic sandstone. (C) Topography-controlled spring in volcanic breccia. (D)(E)(F) Fracture-controlled springs in volcanic breccia.

Figure 6. (A)(B) Well in the soil of weathered volcanic sandstone, (C) and (D) Well in weathered volcanic breccia.

5.3 Type of aquifer

There are two kind of aquifers found in the study area, unconfined and fractured aquifers (Figure 7). Uncofined aquifer formed as the product of weathered bedrock that consists of volcanic breccias of Nglanggeran and volcanic sandstones of Semilir Formation. Unconfined aquifer is formed from grains relation of weathered bedrock that become highly porous while fractured aquifer is controlled by fractures which form secondary permeability and porosity in the bedrock and reserve water in its porous zone (Figure 9).

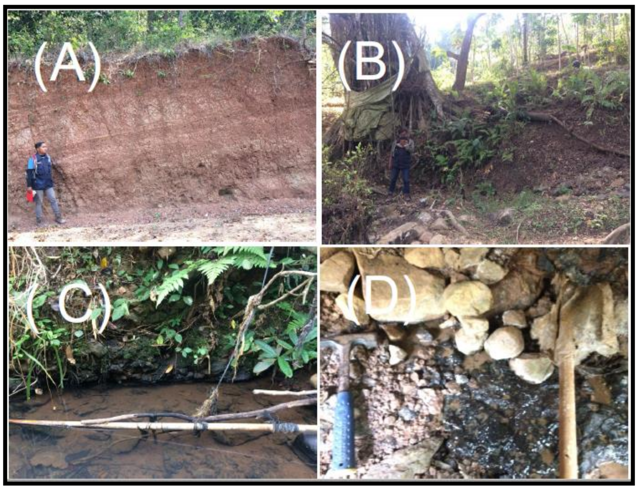

Figure 7. (A) and (B), uncofined aquifers of weathered volcanic breccias; (C) and (D), fractured aquifers in volcanic breccias.

6. Result of Analysis

6.1 Groundwater System

The flow direction of water table follows topographic relief of study area. In general, it flows to south area. Higher relief in east area is interpreted as part of Nglanggeran area and consists of pyroclastic breccia unit. There are some deflections that was caused by fault. (Figure 8.A)

There are two types of aquifer in study area; soil (unconfined) and fractured system. In soil system, aquifer is present as soil of pedogenesis product from volcanic rock. This system mostly is located in Nglanggeran area, where water table bounded by elevation of morphology. This condition results in springs as found in Kedung Kandang valley and we name it as "Kedung Kandang" system. Similar system has been identified and found scattered in this area. We use satelit image to help mapping distribution of this system. (Figure 8.B)

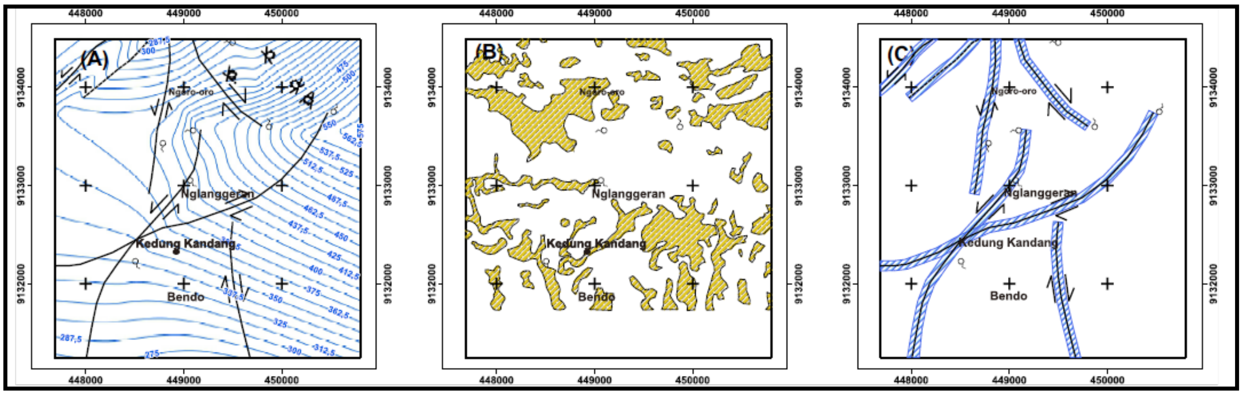

Figure 8. (A) Water table map. (B). Distribution of aquifer of "Kedung Kandang" system identified using satelite image. (C) Aquifer distribution of "Bendo" system.

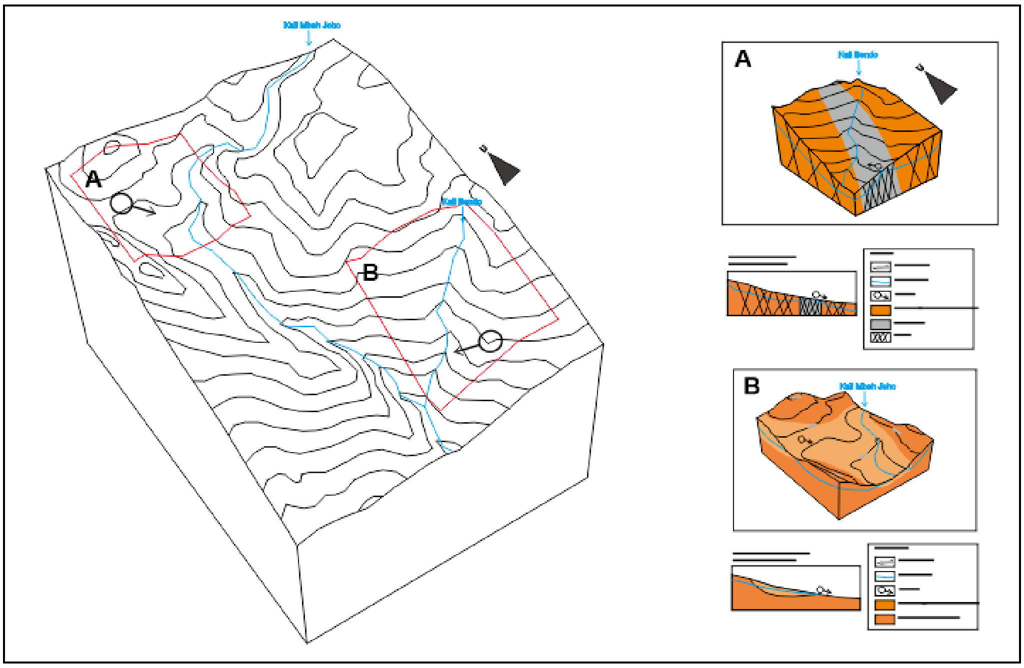

Figure 9. 3-D block model of groundwater systems found in study area. LEFT: A is “Kedung Kandang” system and B is “Bendo” system; RIGHT: A is fractured system (Bendo System); B is soil aquifer (Kedung Kandang System).

Another system found in the study area is fracture-controlled aquifer which lies in fractured volcanic bedrock in which the bedrocks have fractures that form secondary porosity and permeability with ability to reserve groundwater. The spring of this kind emerges from fracture zone of the bedrock in Kedung Kandang valley and we name it as “Bendo” system. The distributions of locality of fracture aquifer tend to follow structural pattern in this area. (Figure 8.C)

6.2 Groundwater Necessity

Groundwater necessity has been calculated using parameter: Total population and tourist, monthly rainfall, and evapotranspiration, and distribution of both aquifer. Distribution of both aquifer was aquired by analysis of the aquifer maps. The other parameter was aquired by using secondary data from BPS Gunung Kidul Regency. Based on calculation, we can get the following features: Total population of local villager and tourist is 340,535 people in 2014; domestic water necessity is 12,381,852,600 liter/year; distribution of “Mbah Joho” system is 2,350,325 m^2; distribution of “Bendo” system is 1,179,155 m^2; and calculation of potensial reserve from both systems is 2,205,926,016 liter/year (Table 1 and Table 2). Because of domestic water necessity quantity is more than potensial reserve from both sistem, there will be a threat of defisit in fullfilment of water necessity in study area.

Table 1. Calculation of water necessity based on population of Nglanggeran Area 2014 (www.gunungapinglanggeran.com and BPS Kab. Gunungkidul, 2017).

Area	Population and Tourism 2014	Monthly Domestic Water Necessity (liter/month)	Annual Domestic Water Necessity (liter/year)
Terbah	2,407	7,293,210	87,518,520
Ngoro-oro	3,442	10,429,260	125,151,120
Putat	4,016	12,168,480	146,021,760
Nglegi	2,927	8,868,810	106,425,720
Nglanggeran	2,489	7,541,670	90,500,040
Local tourist	324,827	984,225,810	11,810,709,720
International Toursit	427	1,293,810	15,525,720
Sum	**340,535**	**1,031,821,050**	**12,381,852,600**

Table 2. Calculation of monthly recharge in Nglanggeran Area based on 2014 data.

No	Month in 2014	Monthly Rainfall 2014 of Patuk (mm)	Monthly Evapo-transpiration Yogyakarta (mm)	Monthly Recharge Potential (mm)	Calculation of Monthly Recharge on Unconfined Aquifer (m3)	Calculation of Monthly Recharge on Fractured Aquifer (m3)	Calculation of Both Aquifer (m3)	Calculation of Both Aquifers (liter)
1	January	0.24	0.14	0.09	223,280.90	112,019.79	335,300.75	33,530,0754.50
2	Feruary	0.28	0.15	0.13	310,243.01	155,648.56	465,891.57	465,891,574.60
3	March	0.18	0.15	0.03	65,809.12	33,016.36	98,825.48	98,825,485.53
4	April	0.22	0.15	0.07	176,274.43	88,436.68	264,711.12	264,711,122.00
5	Mey	0.22	0.4	0.08	190,376.39	95,511.61	285,888.01	285,888,011.70
6	June	0.05	0.13	0	0	0	0	0
7	July	0.05	0.14	0	0	0	0	0
8	August	0	0	0	0	0	0	0
9	September	0	0	0	0	0	0	0
10	October	0	0	0	0	0	0	0
11	November	0.35	0.15	0.19	460,663.86	231,114.53	691,778.39	691,778,398.70
12	Desember	0.16	0.14	0.02	42,305.86	21,224.80	63,530.66	63,530,669.27
Sum								**2,205,926,016.00**

6.3 Conservation

Nglanggeran area, as part of non-groundwater basin area, has a good potency to reserve groundwater. Both of the aquifer systems proves to support water necessity for local people but limited and a threat of defisit of groundwater resources is able to give bad impact for the people and the developing tourism in the study area. Therefore, conservation of groundwater reserve system is need to be conducted starting from the present time. Conservation can be done in the proposed area (Figure 13), especially in thw Kedung Kandang valley as type location that has both of groundwater systems.

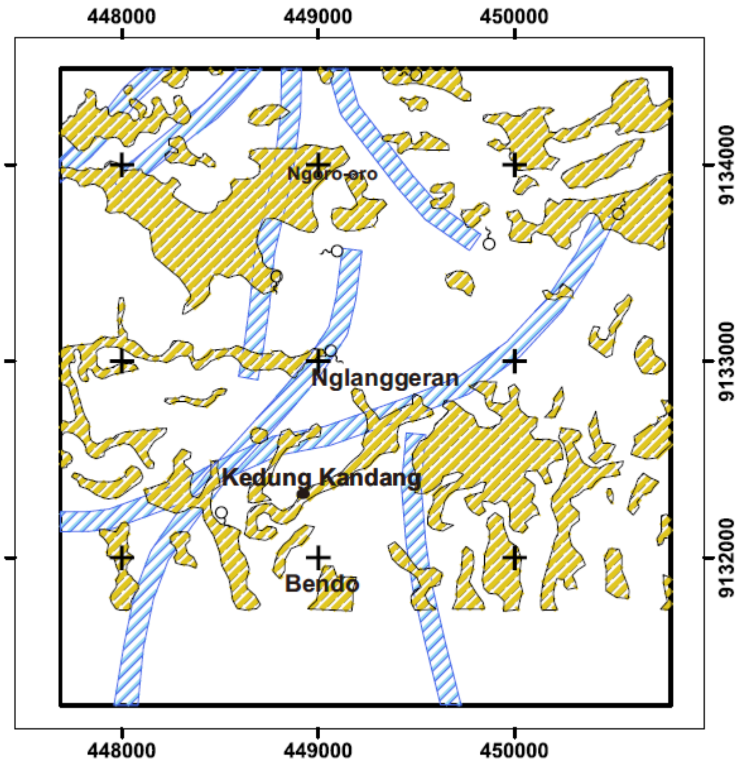

Figure 10. Map of proposed conservation area. Yellow color is soil aquifer (Kedung Kandang system), blue color is fracture aquifer (Bendo system).

7. Conclusion

Study area is a gentle valley located in non-groundwater basin in Nglanggeran area and composed lithologically of Old Andesit Formation products consisting of andesitic pyroclastic breccia of Nglanggeran Formation and volcanic sandstone and tuff unit of Semilir Formation.The trend of geological structures in this area is N-S, NE-SW, and NW-SE. Hydrogeology manifestations found in this area are dug wells and springa that are used by local people to fullfill daily household necessity. There area two groundwater systems: “Kedung Kandang” system in which the aquifer is controlled by pores between grains of weathered volcanic bedrock and “Bendo” system with the aquifer is controlled by fractures. Both of the systems have good potency to reserve groundwater. Statistical analysis shows the increase of groundwater need and causing the deficiency of groundwater supply. Therefore, it is urgent to do groundwater conservation in the proposed area, especially in Kedung Kandang valley area as type location that have both groundwater systems.(***)

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