Analysis of Groundwater Reserved in Dusun Ngantru Sekaran Village East Java

N H Pandjaitan[1], R S B Waspodo[1], T U Karunia[1] and N Mustikasari[2]

[1] Department of Civil and Environmental Engineering, Bogor Agricultural University. Indonesia
[2] Department of Soil Science and Land Resources, Bogor Agricultural University. Indonesia

E-mail: norahp@apps.ipb.ac.id.

Abstract. Limited capacity of fresh water in some areas in Indonesia made some regions had drought problem or lack of surface water. One of the solutions was increasing ground water used. This research aimed to identify aquifer and the pattern of ground water flow and also to determine potential of groundwater reserved in Dusun Ngantru. The result would be use to find the right location to be used as groundwater wells. The method used in this research was geoelectric method. This method was used to determine the condition of aquifer and rocks under the soil and to define hydrogeological condition of Dusun Ngantru.The analysis results can be used as a reference of where and what kind of groundwater runs underneath, in order to be optimally utilized. The results of hydrogeological studies and the distribution of aquifer showed that there were unconfined and semi aquifers. The direction of the groundwater flow in the study site varied greatly as the lithologic arrangement varied just as much. In the study locations there were Ledok formation, Mundu formation, and Lidah formation. Groundwater potential ware predicted of 55.33 m^3/day or 0.64 lt/s. Based on water quality standard in Indonesia, the water quality of wells were classified as first class quality.

1. Introduction

Water is an abundant natural resource on earth, but was distributed not equally according to place and time. Fresh water are found in the soils, rivers and lakes. Water sources that can be utilized to meet domestic, agricultural and industrial needs are surface water and groundwater. In addition to the economic growth, water demand are increasing, both in quantity and quality. This condition caused problem in water resources distribution. The limitation of raw water was caused, among others, by the development and changes in land use, which often does not consider the conservation of the ecosystems[9].

Aquifer is a layer, formation, or compactness of a permeable, consolidated geological unit (sand) with water-saturated conditions and has a hydraulic conductivity value (K), that can describe the soil ability to pass water. The value of hydraulic conductivity (K) is strongly influenced by soil characteristics. The aquifer store large amounts of groundwater. Confined aquifer is a water-saturated aquifer bounded on the top and bottom layers by aquiclude and the water pressure is greater than atmospheric pressure. Unconfined aquifer is a water saturated aquifer (saturated), and generally the limiting layer at the bottom is aquitard but there are no aquitard borders on the top. The spatial prediction of groundwater potential using the standard method is important for groundwater resources management[6].

Groundwater being a hidden subsurface treasures resource not easily seen with the naked eyes are very difficult to quantify potentially. Subsequently, planners and hydrological engineers have resolved to engage the efficacy of the predictive standard methods in groundwater potentiality mapping[5]. To analyse soil layers several subterranean methods of inquiry can be undertaken, including geological methods, gravity methods, magnetic methods, seismic methods, and geoelectric methods. Of these methods, the geoelectric method is a widely used method and the result is reliable. The difference between these methods lies in the methods and tools of the ground surface investigation. In seismic methods, artificial mechanical waves are used to investigate underground layer, while magnetic methods used the direction of the magnetic poles that are pressed on igneous rocks as well as the electromagnetic waves. This geoelectric estimation is intended to obtain an overview of subsoil and the presence of groundwater and minerals at a certain depth. The geoelectrical method is based on the fact that different materials will have different types of resistance when electrified. Groundwater has a lower type resistance than mineral rocks[11].

This study aimed to (1) identify aquifer in the form of position, typology, distribution, and thickness, (2) to know the pattern of groundwater flow and its distribution and (3) to determine potential of groundwater reserved and finding the right location to be used as groundwater wells .

2. Methods

This research was conducted in Dusun Ngantru, Sekaran Village, Kasiman Sub-district, Bojonengoro District (figure 1). Dusun Ngantru located in 7.2195° S and 111.7466° E. The data used in this study were primary data and secondary data. Primary data consisted of discharge measurements at monitored wells, measurement of rock type resistance and an existing hydrogeological data inventory. Secondary data consisted of geological map, hydrogeology map topography map and regulation according to water quality standard in Indonesia.

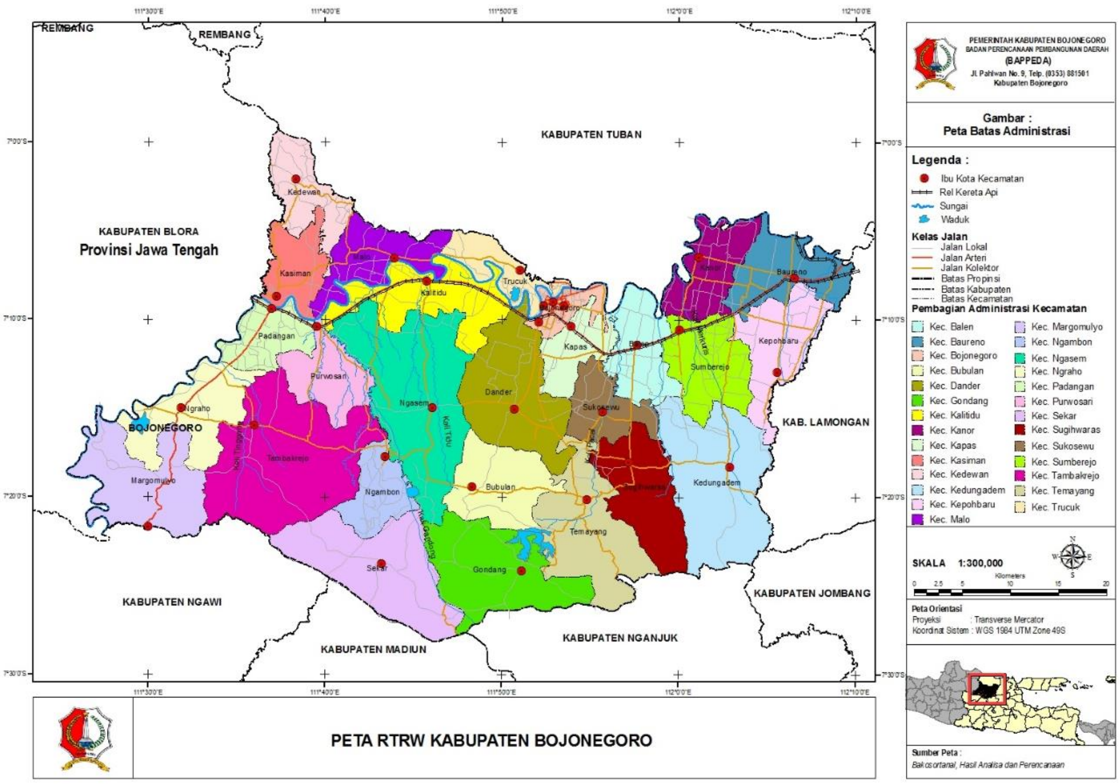

Figure 1. Bojonegoro District [1]

2.1. Groundwater Level Measurement
The groundwater level was measured from 5 monitored existing wells. Measurements are done manually, i.e. measuring the distance between the groundwater surface in the well monitor with the ground surface where the monitor well site was located.

2.2. Measurement of Resistance Type
The primary data collection required was the measurement of the type of aquifer, thickness of aquifer using geoelectric equipment. The general resistance measurement was done by injecting the current into the ground through two current electrodes (A and B), and measuring the potential difference generated at 2 potential electrodes (M and N). From the current (I) and potential (V) values data the apparent resistance value could be calculated using the Schlumberger configuration formula. Data analysis includes analysis of determination of geometry factor by using equation as follows:

$$\rho = \left[\pi \times \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \times \frac{\Delta V}{I} \tag{1}$$

Where AM, AN, BM and BN are the electrode distances in the Wenner-Schlumberger configuration with the unit length (m).From the parameters that have been obtained, the false resistance value (ρa) could be calculated in Ωm unit. The calculated resistance value was not an actual subsurface resistance value, but was an apparent value which was a resistance of a homogeneous earth that provided the same resistance value for the same electrode arrangement. To determine the actual subsurface resistance value required inversion or forward calculation process using computer assistance (software progress version 3.0).

After resistance value was calculated, the type of soil composing layer can be determined based on the typical ranges of electrical resitivity for selected earth materials in Palacky [4]. The geoelectric data acquisition in this study used the Wenner-Schlumberger configuration with the fixed-electrode potential and current electrode to obtain variation in the direction of depth (sounding). The analysis of geoelectric data were done using Progress Version 3.0 software with respect to the resistance value of type, the distance between electrode then in-inverse modeling to get error value or RMSmin.

2.3. Water quality test
Water quality test aimed to determine the feasibili ty of surface water in Dusun Ngantru. Water quality test was conducted based on Regulation of the Ministry of Health number 416/MENKES/X/PER/1990 (Permenkes 416/1990) about drinking water quality[7]. There are 3 parameters used as the quality standrad in this reglation such as physic, chemical and microbiology[8].Water quality test was done for 5 samples which were took from several water sources, located from upstream to downstream in Dusun Ngantru.

3. Result And discussion
Dusun Ngantru Desa Sekaran is one of the villages in Kasiman, Bojonegoro Regency, East Java. It has a surface of 5,423,000 m^2 with 3,000 inhabitants. Almost 60% of its population works as farmer and owns cows as livestock. Local economics are far from being advanced due to the low income that is barely enough to cover daily necessity. One of the factors that contribute to the situation is the location of the village. Dusun Ngantru is rather remote with poor infrastructure to support proper transportation and enhance trading. Other factors that may indirectly influence the economics are the limited school available in the area. The village only have elementary school, whereas to earn higher education the kids have to go as far as 12 km to the nearest junior high school, with 3 km of it is only accessible by foot.

In agriculture and farming, local people make use of the reserved rainwater in sadang and kali Bayangan water springs. For cows living in communal farm, they use water from the 3 available wells.

The water supply from those wells are not sufficient for all the necessity, especially for green areas irrigation for cows food. The people of Dusun Ngantru have tried to make drilled well as a new water resource by using ground water. The drilling process resulted in producing oil instead of water due to its location being above the layers of oil-producing soil. Next to Dusun Ngantru is Desa Wonocolo, which is one of the oil-producing location in Indonesia. Apparently the oil supply seeps into Dusun Ngantru area. The circumstances have forced people in Dusun Ngantru to fully rely on rainwater and make use of the available surface water sources.

In 2017 the cow farming in Dusun Ngantru increased up to 600 cows, and need the formation of local cooperative as business platform. This trend seemed to be parallel with the increased water demand for green areas irrigation of 2-3 acres. One of the strategies that can be done to fulfill water demand is to use ground water. In order to make a drilled well, a hydrogeology analysis is needed to identify potential spots with enough soil water and does not contain oil. According to this condition, geoelectric analysis was used in this research in finding the right drilling spots. This research aimed to give the information to Dusun Ngantru villagers in locating the right drilling spots. Geoelectrical analysis and wells identification is a part of research activities with the endpoint of creating a module of pipe hydraulics design criteria in water supply system using ground water. This paper presented the analysis result of the first year of the total 2 years research.

3.1. Potential of Water Source

The water source found in Dusun Ngatru is a well (sumur) that has a depth of about 5-10 m below the soil surface and there is an inundated water source called a *sadang*. There are 2 *sadang* used daily for household needs. In addition, water from Kali Bayangan is also used by residents for daily household needs. The need for water for animal feed is still very little and the water requirement is closely related to the requirement of animal feed. Cattle feed require 50 kg for 1 tail per day, so it requires a lot of greening area. Residents of Ngantru still have problems to meet the water requirements for reforestation areas.

Dusun Ngantru also had 2 water springs : Kali Bayangan at 133 m above mean sea level and Kerincing at 120 m above mean sea level. The water of Kali Bayangan came from the village located above Ngantru so the water were used for daily household needs, but not as drinking water. On the other side the water from Kerincing spring have the potential to be utilized for drinking water, and has not been utilized yet by local people.

3.2. Geoelectric and Pump Test Measurements

Measurements were carried out in areas representing Ngantru which became the research area. The purpose of this measurement was to know the condition of the subsurface by looking at the nature of the flow of electricity in the rocks beneath the earth's surface. Resistance of rocks was very sensitive to water content, so with this geoelectric measurement the existence of groundwater could be detected. The location is about 10 km at the north of Bengawan Solo River. The height of the place is between 80-130 m above mean sea level with the slope of the steep terrain.

Tabel 1. Measurement results of water level in Ngantru

No	Well location	Elevation (m)	Water level of well (m)	Groundwater level (m)
1	SUMUR 1	109,31	8,28	101,03
2	SUMUR 2	107,42	9	98,42
5	SUMUR 3	91,41	1,3	90,11
6	SUMUR 4	90,34	1,3	89,04
7	SUMUR 5	89,61	2,6	87,01
8	SUMUR 7	108,96	1,4	107,56
9	SUMUR 8	117,52	7	110,52
10	SUMUR 9	119,11	7,4	111,71
11	SUMUR 10	113,71	4,6	109,11
12	SUMUR 11	110,85	2	108,85
13	SUMUR 12	108,67	3,8	104,87
14	SUMUR 13	100,27	1,2	99,07
15	SUMUR 14	106,72	3,1	103,62
16	SUMUR 15	103,10	2,7	100,40
17	SUMUR 16	109,46	4,6	104,86
18	SUMUR 17	110,50	7,6	102,90
19	SUMUR 18	110,77	6,3	104,47
20	SUMUR 19	105,90	2,6	103,30
21	SUMUR 20	104,56	1,6	102,96
22	SUMUR 21	92,80	5,6	87,20
23	SUMUR 22	89,81	5,6	84,21
24	SUMUR 23	87,52	2,3	85,22
25	SUMUR 24	107,74	4,3	103,44
26	SUMUR 25	102,31	0,5	101,81

3.3. Physiographic Conditions

Physiographic location of the study included in sub section of Mandala Geological Rembang consisting of Ledok Formation (TML) in North, Mundu Formation (Tpm) in the middle, and Lidah Formation (OTI) in the South. Physiography of Rembang Geology Mandala was an area with a landscape of plains to hills. The north of the study site was composed of calcarenzite, sandstone and napal. While in the middle was the arrangement of napal. As for the southern part was composed of clay, sandstone and limestone. The slope of land was between 15% - 70%.

Regionally, members of Dander of Lidah Formation ware included in the Mandala Geological Rembang. In general, the stratigraphic sequence from old to young ware Ngimbang Formation, Prupuh Formation, Tuban Formation, Tawun Formation, Bulu Formation, Wonocolo Formation and Ledok Formation, Mundu Formation and Lidah Formation. Lidah Formation had three members namely Tambakromo Members, Turi Members and Malo/Dander Members[10].

3.4. Groundwater Basin

Based on the groundwater basin map of the Directorate of Geological Environment and Mining Areas, Department of Energy and Mineral Resources Sheet VII, the study area including Rembang groundwater basin composed by: quartz sandstone and limestone. Location of 11 geoelectric measurements was showed in figure 2 and the results were showed in table 2.

Table 2. Position of Aquifer at Geoelectric Assessment Location

No	Measurement Point			Level of Aquifer (m)			Information
	Name	Coordinat	Elevation (masl)	Unconfined	Semi Confined	Confined	
1	GLB-1	07°03'51.0"S-111°40'07.1"E	144	0.5-2	-	-	
2	GLB-2	07°03'53.8"S-111°40'12.5"E	148	2.1-6.8	-	-	
3	GLB-3	07°03'55.6"S-111°40'05.7"E	129	0.5-2	21-39.1	-	
4	GLB-4	07°04'18.6"S-111°39'38.0"E	105	0.5-1.5	22.2-40	-	drilling recommendation
5	GLB-5	07°04'13.2"S-111°39'36.0"E	118	0.3-5	66-98	-	
6	GLB-6	07°04'19.0"S-111°39'33.3"E	113	1-17.3	-	-	
7	GLB-7	07°04'24.3"S-111°39'54.3"E	107	0.2-9	33.6-50	-	drilling recommendation
8	GLB-8	07°05'09.1"S-111°39'34.6"E	85	1.0-8.0	-	-	
9	GLB-9	07°05'09.4"S-111°39'31.2"E	79	0.7-3.9	6.0-14	-	
10	GLB-10	07°04'50.8"S-111°39'41.1"E	87	0.4-5.5	69-110	-	drilling recommendation
11	GLB-11	07°04'19.0"S-111°39'33.3"E	113	2.2-6.1	10-28.9	-	drilling recommendation

Based on its physiography and morphological form, the study area was included in the Mandala groundwater with groudwater flow net in the north and very few groundwater in the center and south. Dusun Ngantru area is composed of various rock types, consisting of clay and napal stones incorporated in Ledok Formation in the north, Mundu in the middle and Lidah in the south and generally very low-grade. In terms of hydrogeology, based on the type of rock and its magnitude, aquifer lithology in the study area was typology of aquifer with flow through cracks or nests and rare groundwater.

Based on geoelectric assessment location and borehole data, the study area had two types of aquifer with various depths of unconfined aquifer and semi-confined aquifer. As an example figure 3 shown the interpreted borehole data on GLB-4. Unconfined aquifer was found less than 10 m below soil surface, and a semi-confined aquifer is found between 10 to 30 m below soil surface. Unconfined aquifers were found in some places.

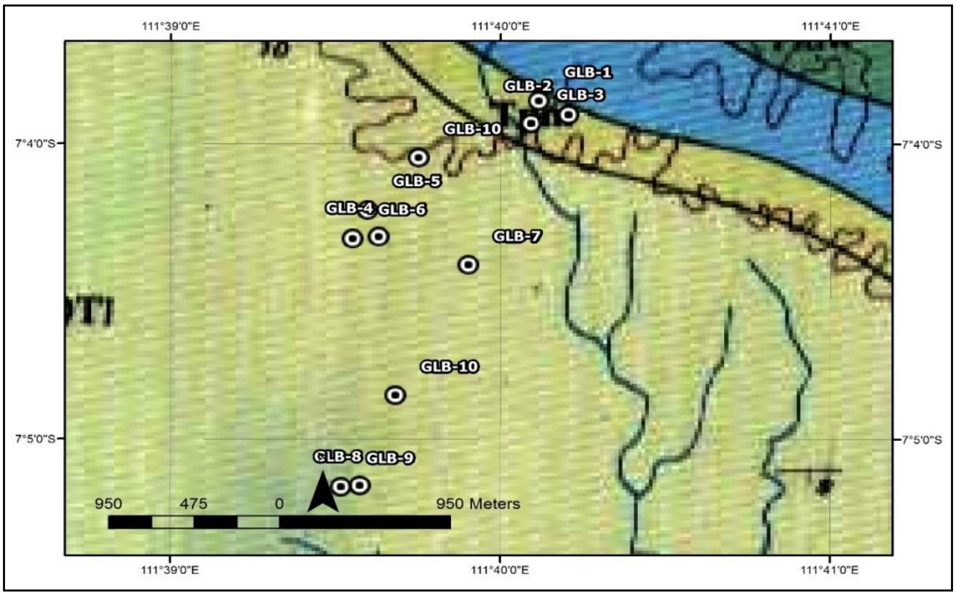

Figure 2. Geological map of geoelectric assessment location

TABLE OF INTERPRETED DATA

No.	Spacing (m)	Observed Data (Ohm-m)	Calculated Data (Ohm-m)	Error (%)
1	1.50	7.970	7.677	-3.6815
2	3.00	5.090	5.034	-1.1052
3	4.00	4.640	4.188	-9.7403
4	6.00	4.810	3.562	-25.9365
5	8.00	2.290	3.375	47.3828
6	10.00	3.620	3.289	-9.1333
7	12.00	5.300	3.232	-39.0195
8	20.00	4.760	3.043	-36.0709
9	25.00	4.540	2.934	-35.3730
10	30.00	3.180	2.849	-10.4062
11	40.00	2.120	2.795	31.8570
12	50.00	3.265	2.901	-11.1687
13	60.00	2.622	3.119	18.9772
14	100.00	5.868	4.326	-26.2832
15	125.00	5.177	5.042	-2.6001
16	150.00	5.641	5.681	0.7194
17	175.00	8.764	6.250	-28.6853
18	200.00	5.650	6.758	19.6103
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				

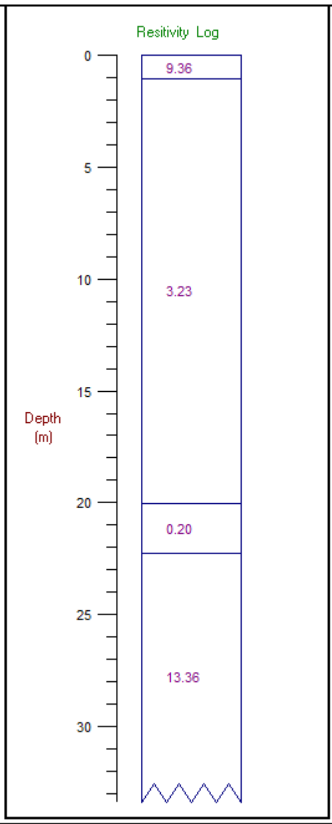

Figure 3. Interpreted borehole data on GLB-4

3.5. Prediction of Groundwater Potential

The resistivity parameter of the weathered formation (aquiferous unit) and the delineated overburden unit thickness have been successfully evaluated for groundwater potential rating in an area[3].The parameters K and TR (transverse resistance) on the other hand, have been established as the major driver of groundwater discharge in an area and determined the variability of groundwater potential from place to place[2]. Dusun Ngantru area was investigated using 1:25000 scale of hydrogeology map. Potential of groundwater was measured by darcy equation. Based on Darcy's law, groundwater discharge is directly proportional to hydraulic gradient (*i*) of aquifer and hydraulic conductivity (K). Darcy equation can be noted as follows:

$$Q = -K \times A \times \frac{\delta h}{\delta L} \tag{2}$$

Where:
A = area of the aquifer cross section (m^2)
K = hydraulic conductivity (m/day)
δh / δL = hydraulic gradient of aquifer
Q = groundwater discharge (m^3/day)

Dusun Ngantru had soil that contain sandstone (fine-grained) with a hydraulic conductivity value of 0.2 m / day. The area of aquifer cross section was 20750 m^2, and the potential of groundwater discharge was 55.33 m^3/day or equal to 0.64 lt/s (table 3).

Table 3. Prediction of groundwater's potential

Parameter	Volume	Unit
K	0.2	m/day
h1	93	m
h0	68	m
δh	-25	m
L	1875	m
δh/L	-0.013	
Length (l)	2075	m
Width (W)	10	m
Area (A)	20750	m^2
Discharge (Q)	55.333	m^3/day
	55333.333	l/day
	0.640	l/s

3.6. Pump Test

Test pump can only be done in shallow ground water wells. This is looking at the condition of the study sites that have no deep groundwater wells. Recovery of groundwater wells shall reach steady state after 47 minutes with very little water discharge, approximately 27 ml/s. This small water discharge recovery occurs due to the lithology of clay and napal clay and the location of the study that has the characteristics of apertured apertures and nesting. However, the condition is very diverse. So the groundwater exploration is needed in the semi-confined aquifer layer (10-30 m depth below the soil surface by adjusting the geoelectric survey results). The test pump results also indicate that the recommended pumps used for shallow wells are regular water pumps or maximum jet pump. As for deep ground water wells can use submergible pump.

3.7. Water Quality Test

Water samples were taken from 5 wells in Dusun Ngantru. These five wells were assumed can represent the water quality from upstream to downstream in Dusun Ngantru. Based on physical, chemical and microbiology parameter standard on Regulation of the Ministry of Health Republic of Indonesia number 416/MENKES/X/PER/1990 (Permenkes 416/1990), the water in Dusun Ngantru were classified in the first class water quality. The result of water quality test were shown on table 4.

Table 4. The result of water quality in one of well-point

No	Paramater	Unit	Standard *)	Analysis result	Method
Microbiology					
1	Total of Coliform	AMP100ml	0	0	MPN
2	E. Coli	AMP100ml	-	0	APHA ed. 22nd 9222 D, 2012
Chemical					
1	pH **)	-	6.5-9.0	7.02	APHA ed. 22nd 4500-H^+ B, 2012
2	Clorida (Cl^-)	mg/l	600	108	APHA ed. 22nd 4500-Cl^- B, 2012
3	Hardness as $CaCO_3$ **)	mg/l	500	81.14	APHA ed. 22nd 2340 C, 2012
4	Ferro (Fe) **)	mg/l	1.0	<0.016	APHA ed. 22nd 3111 B, 2012
5	Mangan (Mn) **)	mg/l	0.5	<0.017	APHA ed. 22nd 3111 B, 2013
6	Nitrat (NO_3-N)	mg/l	10	0.153	APHA ed. 22nd 4500-NO_3 B, 2012
7	Nitrit (NO_2-N)	mg/l	1.0	0.006	APHA ed. 22nd 4500-NO_2 B, 2013
8	Sulfat (SO_4^{2-}) **)	mg/l	400	44	APHA ed. 22nd 4500-SO_4^{2+} E, 2014
9	Organic matter	mg/l	10.00	1	APHA ed. 22nd 4500-$KMnO_4$ B, 2015
10	BOD	mg/l	-	8	APHA ed. 22nd 5210 B, 2012
11	COD **)	mg/l	-	15	APHA ed. 22nd 5220 C, 2012
Physical					
1	Color	PtCo	50	13	APHA ed. 22nd 2120 C, 2012
2	Electrical Conductivity	Umhos/cm	-	1182	APHA ed. 22nd 2520 C, 2013
3	Turbidity	NTU	25	0	APHA ed. 22nd 2130 C, 2014
4	The amount of solids dissolves **)	mg/l	1.500	864	APHA ed. 22nd 2540 C, 2015

*) standard of raw water based on Regulation of the Ministry of Health Republic of Indonesia number 416/MENKES/X/PER/1990
**) Committee of the National Accreditation (KAN)
(source: Laboratory of Departement of Agroindustrial Technology)

4. Conclusions and suggestions

4.1. Conclusions

Based on the result analysis it can be concluded that Dusun Ngantru had potential ground water source, originating from Krincing springs, that can be utilized to fulfil irrigation requirement especially for green areas for cows food. Groundwater potential were predicted of 55.33 m³/day or 0.64 lt/s. Based on geoelectric measurements the result showed that:

- Unconfined aquifers were highly variable, whereas the semi-aquifers were only at 7 points of measurement (GLB-3, GLB-4, GLB-5, GLB-7, GLB-9, GLB-10, and GLB-11).
- Drilling Recommendation was on GLB-4, GLB-7, GLB-10, and GLB-11.

IOP Conf. Series: Earth and Environmental Science **147** (2018) 012039 doi:10.1088/1755-1315/147/1/012039

- The direction of groundwater flow in the study site varied greatly because the lithologic arrangement also varied. In one study location there were three formations, namely Ledok Formation, Mundu Formation and Lidah Formation.

4.2. Suggestions
From the results of geoelectric studies, it could be suggested that:
- Location of groundwater drilling would be decided according to the results of hydrogeological studies.
- Irrigation water distribution should use sprinkler system, because it was estimated more effective and efficient as well as because the lithology is very diverse.

Acknowledgements
The authors acknowledge the Ministry of Research, Technology and Higher Education of Indonesia for funding this research as university priority research in 2017 and 2018.

References
[1] BAPPEDA (Badan Perencanaan Pengembangan Daerah) Pemerintah Kabupaten Bojonegoro 2013 *Map of Administration* (in Indonesian) (Bojonegoro)
[2] Okogbue C O, Omonona O V 2013 Groundwater potential of the Egbe-Mopa basement area, central Nigeria *Hydrol. Sci. J.* **58**(4): 826–840
[3] Oyedele K F, Fatuna O T, Coker O J 2011 Geophysical assessment of subsurface coastal sediments and their engineering implications *Arab. J. Geosci* **4** 543– 550
[4] Palacky G J 1988 *Resistivity Characteristics of Geologic Targets, in Investiations in Geophysics vol. 3: Electromagnetic Method in Applied Geophysics-theory, vol 1, edited by M N* (Nabighian: Soc. Expl. Geophys) pp 53-129
[5] Pourghasemi H R, Beheshtirad M 2015 Assessment of a data-driven evidential belief function model and GIS for groundwater potential mapping in the Koohrang Watershed *Iran. Geocarto Int.* **30**(6), 662–685
[6] Rahmati O, Naser T, Farhad N, Saro L 2016 Spatial analysis of groundwater potential using weights-of-evidence and evidential belief function models and remote sensing *Arab. J. Geosci* **9** 79
[7] Regulation of the Ministry of Health number 416/MENKES/X/PER/1990
[8] Shofiani and Nur Endah 2003 *Recontruction of Indonesia's Drinking Water Utilities:Assessment and Stakeholder's Perspectives of Private Sector Participation in the Capital of Jakarta* (Stockholm: Royal Institute of Technology)
[9] Sosrodarsono S and Takeda K 1993 *Hydrology For Irrigation* (in Indonesian) (Jakarta: Pradnya Paramita)
[10] Srijatno 1980 *Applied Geophysics* (in Indonesian) (Bandung: Physic Department ITB)
[11] Todd D K 1995 *Groundwater Hydrology Second Edition* (Singapore: John Wiley & Sons)