Recharge Zone of Shallow Groundwater at Southeastern of Kulon Progo District Area based on Groundwater Facies

by Listiyani Retno Astuti

Recharge Zone of Shallow Groundwater at Southeastern of Kulon Progo District Area based on Groundwater Facies

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Abstract: The Galur and Lendah areas are in the southeastern part of Kulon Progo Regency, Yogyakarta, Indonesia. This area has become a developing area because of the new airport in this district. Along with the development of this region, the need for groundwater is increasing so that more intensive research is needed. A study on groundwater is needed to support the development of this region. This time, a groundwater study was conducted to determine the potential for the recharge-discharge zone based on the chemical facies of the groundwater. The hydrogeological survey was carried out with groundwater sampling from 9 (nine) dug wells and 1 (one) spring for physical/chemical testing of groundwater in the laboratory. The results showed that groundwater in the study area generally flows south or northwest, with a radial pattern anomaly in the north. The shallow groundwater studied was bicarbonate type with Ca, Na, and Mg cations variations. The groundwater facies characterizes groundwater that is typical in the catchment area. Based on this fact, recharge zones can occur throughout the study area, with local to medium flow systems.

Key words: Groundwater, facies, hydrochemistry, recharge.

Introduction

Water is a vital and strategic need. Therefore water must be maintained in adequate quantities and of good quality. Hydrogeological research has been developed in various regions throughout Indonesia to assist communities in providing clean water.

One of the potential groundwater studies in an area can be done by knowing the position of the area in a groundwater basin. In addition, groundwater potential in an area needs to be supported by understanding the zoning of the recharge–discharge area. By knowing the recharge-discharge zone of an area, we can better protect groundwater and maintain its sustainability.

The delineation of the recharge-discharge zone needs to be supported by groundwater quality data, especially in terms of facies. Groundwater facies can explain the genetics of groundwater in an area (Geological Agency, 2011). Groundwater in the recharge zone is generally of the bicarbonate type, in line with the hydrochemical evolution developed by Chebotarev (1955, in Freeze and Cherry, 1979). Therefore, to ensure the recharge-discharge zoning of an area, hydrochemical methods need to be used to verify other data.Hydrochemical studies help to understand the zoning of the groundwater area of an area. Researchers have also conducted a hydrochemical study in the Kulon Progo area (Listyani et al, 2021), but with a different objective, namely to understand the groundwater flow system in the Kulon Progo Dome area. This time, the hydrochemical study aims to determine the recharge-discharge zone in the southeastern part of the Kulon Progo Regency.

This study was conducted in the Districts of Galur and Lendah, Kulon Progo Regency, Special Region of Yogyakarta (Fig. 1). This area is located at the end of the Kulon Progo Regency, close to the city of Yogyakarta, which is already quite developed. The research area is an area that is growing quite rapidly along with the opening of a new airport in the Kulon Progo Regency. Therefore, various necessities of life and infrastructure are increasingly needed along with the development of this region.

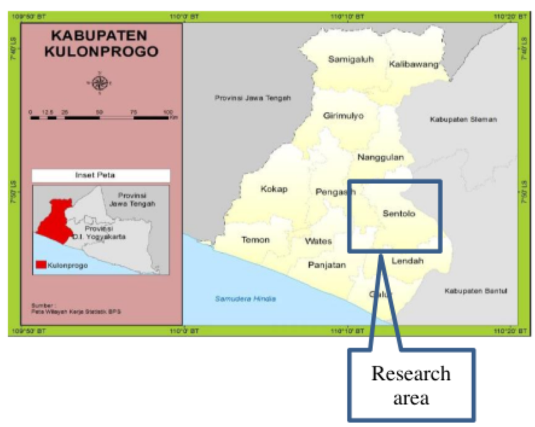

Fig. 1. Research locations on the Kulon Progo map (Central Bureau of Statistic of Kulon Progo Regency, 2021).

Materials and Methods

Geological and Hydrogeological Setting

Most of the research area is in the physiography of the Solo Zone (Van Bemmelen, 1949), which is composed of alluvial and coastal deposits, including sand, silt, and clay deposits (Rahardjo et al, 1977). A small part of the study area comprises compact rock from the Sentolo Formation and the Old Andesite Formation, where outcrops can be found in the northern and northeastern parts of the Lendah District.

The center of the study area is an alluvial plain. This morphology is spread lengthwise in the west-east direction. The dominant flow pattern is dendritic, indicating uniform rock resistance and a non-dominant structure (Srijono et al, 2011). The lithology that composes this morphology is alluvial deposits consisting of clay to gravel, produced by fluvial-volcanic processes (Santosa, 2020).

This alluvial/fluvial plain is a landscape that dominates the study area (Figure 2). This plain is formed by fluvial-volcanic material in fine sand to conglomerate sand. In addition, this plain also receives a reshuffle from the Sentolo Formation and the Old Andesite originating from the Kulon Progo hills to the north. The materials are the clay, silt, sand, tuffaceous sand, and limestone debris or andesite breccia. The Kulon Progo hills had undergone many tectonic processes, even neotectonic (Budiadi, 2008),. The existence of tectonic and exogenic processes causes many intensive geomorphic processes to produce rock debris that can be transported to lower areas, including in the central to the southern part of the study area.

The southern part of the research area forms a coastal plain morphology, spread along the southern coast. The rocks that make up this area are coastal alluvial deposits (fluvio-marin). As in the morphology of the alluvial plain, the drainage pattern in this area also develops dendritic. Meanwhile, the northern part of the study area develops as a high morphology part of the Kulon Progo Hills (Fig. 2).

The research area is included in the Pekalongan regional hydrogeological map sheet (Efendi, 1985) and is part of the eastern part of the Groundwater Wates Basin (Geological Agency, 2011). Furthermore, alluvium deposits of the Kulon Progo may be divided area into the Wates Formation and the Yogyakarta Formation (McDonald & Partners, 1984). The Yogyakarta Formation is composed of loose material resulting from volcanic activity, especially the acti[vity of Mount Merapi Muda. The Yogyakarta Formation in the study area is composed of loose material resulting from the fluvial activity, especially the Progo River. This formation is spread out in the central part of the research area to the south coast (Hendrayana, 2011; Yogyakarta Special Region Local Government Public Works and Housing Department Service – CV. Cita Prima Consultant. 2016).

Hydrogeological Survey

A hydrogeological survey was conducted to determine the position of the shallow groundwater table at 20 dug wells. The groundwater level in the study area is presented in Table 1. The lowest groundwater level is found at SG12 well in Sidorejo Hamlet, Banaran, Galur with a position of 2.1 m asl, while the highest position is at an elevation of 73.65 m asl in SL06 well in Dusun Tubin, Sidorejo, Lendah.

Fig. 2. Structural rolling morphology spread over the northern part of the study area (left); fluvial plain is the dominant landscape, spread over the northeast, middle to the south of the study area (right).

Tabel 1. The shallow groundwater table of the study area.

Location	Water Table (m asl)	Saturation Zone (m)	Location	Water Table (m asl)	Saturation Zone (m)
SG_01	13.57	1.4	SL_04	31.75	2.31
SG_02	10.66	2.13	SL_05	30.87	1.2
SG_03	17.62	2.8	SL_06	73.65	5
SG_04	18	3.8	SL_07	28.3	7.08
SG_05	14.5	1.1	SL_08	58.98	4.65
SG_06	10.5	1.1	SL_09	28.68	7.88
SG_07	13.1	8.3	SL_10	39.04	5.46
SG_08	10.37	2.1	SL_11	34.8	7.8
SG_09	9.64	2.4	SL_12	31.7	2.6
SG_10	10.57	0.8	SL_13	36	9.2
SG_11A	9.6	1.2	SL_14	44	7
SG_11B	8.12	0.62	SL_15	31.8	7
SG_12	2.1	1.3	SL_16	17.7	7.6
SG_13	14	1.5	SL_17	31.8	7.5
SG_14	9.8	1.5	SL_18	31.8	7.8
SG_15	14	1.3	SL_19	40.1	12
SG_16	5.9	0.6	SL_20	16	9.4
SL_01	31.65	8	SL_21	17.3	3.5
SL_02	31.7	4.1	SL_22	15	1.5
SL_03	42.2	4.8	SL_23	16.8	2.5

Field Sampling and Measurement of Groundwater Hydrochemistry

Results Field surveys indicated dug wells in several locations, but only one spring was found. One example of dug wells and springs is shown in Fig. 3. Groundwater conditions generally show clear, tasteless, odorless properties, low turbidity, and normal temperature.


Fig. 3. Groundwater sampling locations include dug wells (SG 01) in Galur and spring (MA 01) in Lendah.

Laboratory Analysis

Sample groundwater is then tested for physical/chemical properties in the laboratory, the results of which can be seen in Table 2. The data shows that the groundwater quality is quite good, with low turbidity (0.5 – 3.2 NTU).

Table 2. Results of groundwater physical/chemical tests from the laboratory.

No	Parameter	SL-02	SL-09	SL-20	SL-16	SL-23	MA-01	SG-01	SG-07	SG-10	SG-12
1	Ca^{2+}	155.2	79.2	115.2	54.4	48	136	46.4	65.6	44.4	24
2	Na^{+}	19	42	14	36	33	17	44	47	89	44
3	K^{+}	1	18	1	10	6	2	14	12	33	16
4	Mg^{2+}	22.36	22.36	23.33	23.33	25.27	15.55	32.08	40.34	31.1	27.22
5	Cl^{-}	23.8	43.4	17.9	21.3	18.9	13.4	5.5	22.8	54.1	32.3
6	HCO_3^{-}	549.3	319.4	408.8	306.6	319.4	479	357.7	427.9	447.1	191.6
7	SO_4^{2-}	14	29	7	25	39	13	17	27	43	38
8	Fe^{2+}	<0.0168	0.0248	<0.0168	0.0379	0.0639	0.035	0.1199	0.0282	0.0622	0.035
9	Mn^{2+}	<0.0066	0.011	<0.0078	<0.0066	0.5894	0.0078	0.0635	0.0651	1.2971	0.011
10	Zn^{2+}	<0.0381	<0.0381	<0.0381	<0.0381	<0.0381	<0.0381	<0.0381	<0.0381	<0.0381	<0.0381
11	PO_4^{2+}	0.122	0.371	0.046	0.989	0.521	0.12	0.991	3.244	1.219	6.034
12	NO_3^{-}	3.87	37.43	35.55	2.55	2.58	6.8	0.4	3.45	2.58	61.53
13	Turbidity	0.5	0.7	0.5	2.9	3.2	0.9	1	1.6	0.8	0.7

Note: All parameter unit in mg/L except turbidity (in NTU)

Results

Groundwater Flow Pattern

The results of groundwater-surface mapping are useful for knowing the flow pattern of groundwater in the research area. The groundwater level map is presented in Figure 4. From the figure, it can be seen that the high groundwater level is in the highlands to the north of the study area, namely in the district of Lendah. The groundwater level gradually gets lower towards the south towards the coastal plain. In general, the position of the groundwater table in the study area is in line with the relief of the ground surface. This is a common condition in an area, where the shallow groundwater level usually resembles local topographic conditions (Freeze and Cherry, 1979; Listyani, 2014).

Groundwater Facies

The results of groundwater chemistry testing in the laboratory are then analyzed to determine the shallow groundwater facies in the study area. The analysis results (Table 3) show that all the groundwater samples studied were of the bicarbonate type, with a variation of the Ca-HCO_3; Ca,Mg-HCO_3; Ca,Na,Mg-HCO_3; and Mg-HCO_3 facies. The groundwater type can be seen in the Piper diagram (Fig. 4). Groundwater is a type of freshwater that has not undergone a mixing process, so this groundwater does not yet have significant salinity.

Table 3. Determination of groundwater facies in the study area.

No	Parameter	SL-02	SL-09	SL-20	SL-16	SL-23	MA-01	SG-01	SG-07	SG-10	SG-12
Kation (epm)		10.11	7.65	8.07	5.99	5.58	8.59	6.69	8.32	8.49	5.26
1	Ca (%)	76.58	51.67	71.24	45.32	42.93	79.03	34.62	39.36	26.11	22.78
2	Na (%)	4.80	14.04	4.44	15.37	15.13	5.06	16.82	14.45	26.82	21.40
3	K (%)	0.43	10.24	0.54	7.26	4.68	1.01	9.10	6.28	16.92	13.24
4	Mg (%)	18.19	24.05	23.79	32.04	37.26	14.90	39.46	39.91	30.15	42.59
Anion (epm)		9.97	7.06	7.35	6.15	6.58	8.50	6.37	8.22	9.75	4.84
5	Cl (%)	6.74	17.33	6.87	9.78	8.10	4.45	2.44	7.83	15.65	18.82
6	HCO_3 (%)	90.34	74.12	91.15	81.76	79.56	92.37	92.01	85.33	75.16	64.85
7	SO_4 (%)	2.92	8.55	1.98	8.47	12.34	3.18	5.55	6.84	9.18	16.34

Note: The yellow shadow represents the major ion that gave the name of the groundwater facies

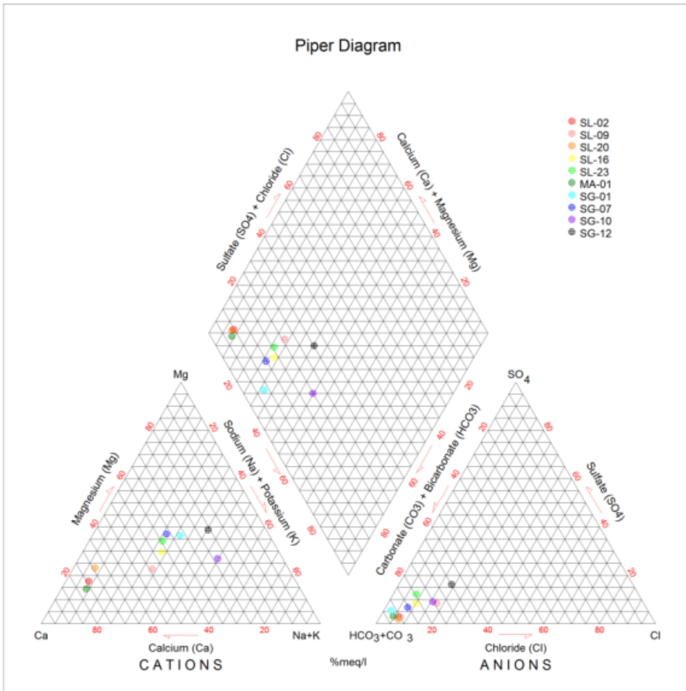

Fig 4. The plot of studied groundwater samples on the Piper diagram.

Discussion

The studied groundwater flows in shallow aquifers in the eastern Wates groundwater sub-basin. The general pattern of shallow groundwater flow in this area can be started from a relatively high area in the north and then spreads radially in adjacent areas and flows further south to the sea. Thus, shallow groundwater flow patterns in this area can be local to medium. By looking at the general direction of the groundwater flow pattern towards the south or southwest, there is a tendency for the northern area to be potentially a catchment area.

Local flow patterns occur in relatively close areas, which is likely to occur in the northern and northeastern regions with a radial pattern. This groundwater flow only reaches areas that are not too wide. Meanwhile, intermediate flow patterns can occur from north to south at a relatively long distance from the recharge zone to the South Sea. The recharge zone is in the northern part of the study area by looking at the flow pattern.

However, the potential of the catchment area can also be viewed from the hydrochemical facies of the groundwater. All groundwater samples studied showed a bicarbonate facies with the major cation Ca, except for groundwater from SG12, which was of Mg-bicarbonate type.

The bicarbonate facies are the groundwater type in the early stages of the evolution process. Evolution is also one of the causes of salinity in groundwater (Listyani et al, 2019). Chebotarev (1955, in Freeze & Cherry, 1979) suggests the changes in groundwater facies along the drainage process are as follows:

$HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^-$.

Groundwater with bicarbonate facies is generally young groundwater, recently seeped below the surface. Changes in facies according to groundwater evolution are also influenced by the flow distance. The longer the drainage process or the longer the drainage distance, the groundwater facies will resemble seawater.

The Ca-bicarbonate groundwater facies indicate that the study area's shallow groundwater is groundwater type in the catchment area. The groundwater of this type resembles rainwater, which means that the groundwater understudy is groundwater that has not yet traveled far in its subsurface drainage system. Therefore, the entire research area has the potential as a catchment zone.

Based on the shallow groundwater table in the study area, it can be interpreted that the groundwater flow pattern has an intermediate pattern in most areas, as well as a local radial flow in the northern part. Thus, the entire research area can function as a recharge zone based on its hydrochemical facies. The consequence of this can then be interpreted that in the lowlands (alluvial plains) to the coastal plains, it is also possible for groundwater to infiltrate, which means that local groundwater flows are also developing (Fig. 5).

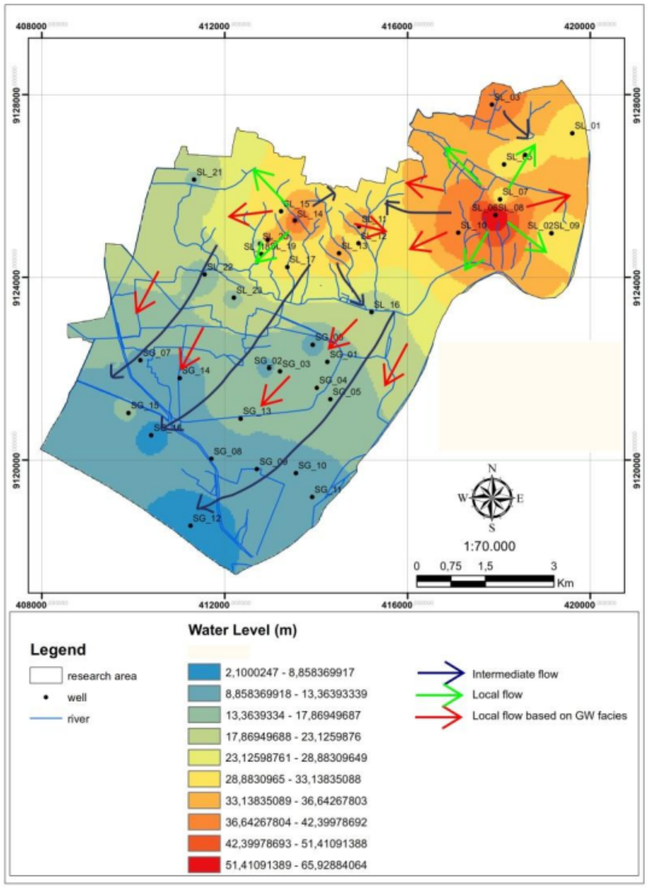

Fig. 5. Groundwater table map of the research area.

Groundwater facies can also help understand the delineation of the recharge-discharge zone. However, understanding the recharge-discharge zone needs to be supported by other aspects, such as land use, land cover, and rock hydrogeological conditions, especially permeability.

Conclusion

The Galur and Lendah areas are dominated by plain morphology, with a slight elevation in the north. Shallow groundwater in this area can be obtained through several dug wells and one spring. In general, groundwater flows from north to south/northwest (intermediate flow system), with some radial anomalies in the northern part of the study area (local flow system).

Groundwater throughout this area develops with bicarbonate facies, with variations in Ca, Na, and Mg cations. Therefore, shallow groundwater in the study area can be categorized as young groundwater, typical for the catchment zone. Thus, the entire study area can function as a catchment zone with a local groundwater flow system based on the groundwater facies.

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