Analysis of groundwater sufficienty for domestic and livestock requirements as an anticipation to sea water intrusion in Kebumen coast

Ignasius Loyola Setyawan Purnama[1*], *Salsabiila* Bayu Nugrahaeni[1], *La Ode* Saleh Isa[1] and *Vincentia* Anindha Primacintya[2]

[1]Faculty of Geography, Universitas Gadjah Mada, Indonesia
[2]Accounting Programme, Master of Science and Doctoral, Faculty of Economics and Business, Universitas Gadjah Mada, Indonesia

Abstract. This study has three objectives, i.e calculating the availability of groundwater in the study area, calculating water demand for domestic and livestock and evaluating the safe yield of groundwater extraction. To achieve these three objectives, groundwater availability, safe yield and actual utilization are calculated. Groundwater availability is calculated based on the multiplication of the area, aquifer thickness and the specific yield. Water demand for domestic is determined base on the number of population and the amount of water demand of each person in each day. Water demand for livestock is calculated based on the number of livestock and water consumption for each livestock in each day, while the safe yield is calculated based on the multiplication of area, annual groundwater level fluctuation and specific yield. The results of research showed that the availability of groundwater in the study area reached 440,517,770 m^3/year, while the safe yield for its extraction was 76,641,600 m^3/year. Because the water demand for domestic and livestock is 6,495,100 m^3/year, so that the availability of groundwater in the study area is still sufficient to support water demand for these sectors. The water demand of the two sectors still have not exceeded the safe yield water extraction, so it will not cause decreasing of groundwater pressure which can cause to sea water intrusion.

Keywords: groundwater, sea water intrusion, Kebumen coast

1 Introduction

Even though water is only composed of two atoms, namely H and O, however water is the main source of life needed for all human activities such as domestic, agricultural, livestock and industrial requirement [1]. It can be said that water is a blessing because its existence affects the quality of life of each human being [2]. According to [3], the increasing requirement for water related to population growth has led to awareness from the community to manage the existence of limited water resources.

One source of water that is very important in supporting everyday human life is groundwater. Until now groundwater is still the main source of water in various regions, especially for non-agricultural activities such as for domestic, industrial and livestock needs [4-5].

The high exploitation of groundwater, if it does not cause land subsidence, can also cause sea water intrusion. This second impact is more frequent, so it has become a serious problem in cities located in coastal areas [6-12]. Therefore, groundwater extraction must not exceed the safe yield. According to [11,13], it is incorrect to assume that the safe yield is equivalent to the amount of groundwater recharge because the safe yield is only part of the increase in groundwater. Some of the other water will be lost from aquifers in various ways.

An interesting phenomenon is that in fact the existence of interfaces is not only detected in densely populated urban areas, but also in rural areas where the population is scarce, such as in the coastal area of Kebumen. The results of the geoelectric sounding carried out by [14] in the area, show that there are interfaces in three geoelectric sounding route, i.e. (1) the route Salak-Petanahan-Munggu-Gadung-Petanahan coast, (2) the route of Tambakrejo-Jeblok-Prajuritan-Adikarto-Kebumen coast and (3) the route of Sinungrejo-Sidoluhur-Bener-Kaibon-Ambal and Kutowinangun coast. Base on data from geoelectric sounding, the detection of interfaces in the coastal area of Kebumen is because groundwater sources in this area only come from rainwater that falls in the beach ridge, so the fresh water is not strong enough to push sea water. In addition, the back swamp area in this area also often enters sea water at high tide.

The research of [15] did not detect any interfaces again in these three geoelectric sounding route. It was said that the undetected interfaces in the study area were caused by the deeper position of the interfaces due to the increasingly strong pressure of fresh groundwater. The increasing strength of this fresh water pressure is due to the increasing number due to the intensive accumulation of rainwater infiltration into groundwater and the intense flushing of sea water by fresh water. In addition, the back swamp area in this area may no longer enter sea water at high tide

According to [16], the Kebumen coast is part of the Southern Mountains of Java, which has been submerged and then covered by alluvium material. The alluvial plains which are the research locations are mostly composed of sand deposits, silty sand and clay

*Corresponding author : Setyapurna@geo.ugm.ac.id

sand. Generally, these alluvial plains can be divided into sand dune, beach ridges and ex backswamp route.

The sand dune is a route directly adjacent to the coastline composed of unconsolidated sand. The width of this route is not always the same but depending on the availability of sand and the strength of the wind. The beach ridge consists of sand material which has begun to develop into soil. This route can be either single or multiple beach ridge. For the coast to the east of the Karangbolong Mountains to Parangtritis Beach, generally there is only one beach ridge route, so that in the study area there is only one beach ridge route.

The lagoon is generally an area that lies lower than the surrounding area. At present, this area is either a rice field area or is still a permanently inundated swamp. In this lagoon route, it often experiences problems related to inundation of the area during the rainy season and intrusion of sea water from the river estuary at high tide. In addition, because it is an ex swamp, the quality of groundwater is also not good because it is often found water with a strong odor.

Based on this background, this study aims to calculate groundwater availability, to calculate water demand for domestic and livestock and to analyze the safe yield of groundwater extraction in the study area so that seawater intrusion does not occur.

2 Methodology

2.1 Calculation of water availability

Groundwater availability is calculated using a static approach using the formula:

$$Vat = Sy \ x \ Vak$$

where Vat is the volume of groundwater that can be extracted from the aquifer, Sy is the specific yield or percentage of water that can be released from the aquifer and Vak is the volume of the aquifer, which is the area of the district multiplied by the thickness of the aquifer. The value of Sy is determined using the Sy table based on the type of aquifer material from the results of the geoelectric sounding carried out by [15]. Likewise, the thickness of the aquifer is also determined based on the geoelectric sounding, whose location is shown in Figure 1.

Fig. 1. The route of geoelectric sounding [15]

2.2 Calculation of safe yield

In unconfined aquifers, the safe yield of groundwater can be indicated by the fluctuation of groundwater, the area of the aquifer and the specific yield, and is calculated by the equation:

$$Safe \ yield = F. \ A. \ Sy$$

where F is the groundwater level fluctuation obtained through interviews with residents, and A is the area of aquifer obtained from administrative area data.

2.3 Determination of water demand

In this study, the water demand that is calculated is the requirement of water that sourced from groundwater i.e domestic and livestock. The water demand for domestic is determined according to the number of the population and the amount of water demand of each person/day. According to Mangku Sitepoe [in 17], water demand in big cities is generally > 150 liters/person/day, in medium cities 80-150 liters/person/day, districts 60-80 liters/person/days and villages ranging from 30-60 liters/person/day. Based on these criteria, because the research area is a district with a fairly dense population, the water requirement of 100 liters/person/day is determined.

Water demand for livestock is calculated based on the number of livestock and water consumption of each livestock/day, where the types of livestock that are taken into account for water demand are cattle-buffalo-horses (big livestock), sheep (small livestock) and poultry. The standard of water requirement for big livestock is 40 liters/livestock/day, small livestock is 5 liters/livestock/day and poultry is 0.6 liter/livestock/day [18].

3 Result and discussion

3.1 Location, boundary and area

Administratively, the research location is located in coastal area of Kebumen Regency, covering Petanahan, Klirong and Bulupesantren Districts. Judging from its boundaries, in the west it is bordered by Puring District, in the east by Ambal District, in the south by the Indian Ocean and in the north by Sruweng, Pejagoan and Kebumen Districts. The research area has an area of 136.86 km^2

3.2 Climate

The coastal area of Kebumen has an annual rainfall amount of 2,500 to 5,000 mm/year, with the average of 2.647 mm/year. Base on its number, the rainfall of Kebumen coastal area is classified as high rainfall. For monthly rainfall, the highest average monthly rainfall occurs in November at 426 mm, and the lowest rainfall occurs in August at 18 mm.

Regarding climatic conditions, the climate on the coast of Kebumen cannot be separated from the overall climatic conditions of Java Island which are influenced by monsoon. During the months of October to April when the sun is located in the southern hemisphere,

mainland Australia is a center of low pressure so that the winds blow from mainland Asia which is the center of high pressure. When passing through the equator, this wind is deflected from the east of the ocean to the west of the ocean. When passing through Java, this wet monsoon winds into the west wind so it is often called the wet west monsoon. During this period, Java Island in general and the Kebumen coast in particular experienced the rainy season. On the other hand, from May to October, mainland Asia became a center of low pressure and Australia became a center of high pressure. The monsoon winds blow from Australia and do not carry water vapor, so that parts of Java Island experience the dry season.

Koppen divides climate types based on the amount of rainfall and air temperature into type A or tropical rain climate, type B or dry climate, type C or warm climate, type D or cold snow forest climate and type E or polar climate. To show the characteristics of climate types in more detail, Koppen subdivides the main climate types by adding lowercase letters f, s, w, m and a. The letter f indicates constant humidity or rain that occurs every month is sufficient, the letter s shows the dry period in summer, the letter w shows the dry period in winter, the letter m shows the monsoon rains with one dry season and the letter a shows the average the temperature in the hot month is greater than 22°C.

Specifically for Climate Type A, it can be divided in more detail by calculating the amount of rain in the dry month in a year and the amount of annual rainfall. A dry month is a month with less than 60 mm of rainfall. It is called a humid month when the rainfall ranges from 60-100 mm, and it is called a wet month when the rainfall is more than 100 mm.

As a result of this division, the types Af, Am and Aw were known. Af is a lower tropical climate or tropical rainforest climate. Climate Af has no dry season, because all months have rainfall greater than 60 mm. Type Am is a monsoon tropical rainforest climate. This type of climate has one or more dry months, however the rain that occurs can still compensate for the dry season, so that the existing vegetation is not so affected by this short dry period. Type Aw is a tropical, savanna rainy climate. This type of climate is characterized by the presence of dry months for 4-8 months, so that the rain that occurs in the wet period cannot compensate for the dry period.

Based on the division of climate types from Koppen, the climate type on the coast of Kebumen is Am. As previously explained, in the Am type, the amount of rainfall that falls in the wet month can compensate for the short dry season. So even though the Am climate has one or two dry months, the rainfall

in other months is quite high, so that the vegetation is not so affected by the short dry period.

3.3 Geology and geohydrology

The main rock material constituent of the Kebumen coast is alluvium. In the western part, the existence of this material is cut off by the limestone karst area in the Karangbolong area. As is well known, Karangbolong is part of the southern mountains that does not experience drowning. The lower part of this karst area consists of old andesite breccias that are inconsistent with a layer of limestone. In the northern part of this area, limestone is obtained from the Sentolo Formation and old andesite breccias with tuff layers inserted.

Base on its geohydrological conditions, the coast of Kebumen is included in the Kebumen-Purworejo groundwater basin. In the eastern part, this groundwater basin is bordered by Wates groundwater basin, in the west by the Banyumudal groundwater basin, in the south by the Indian Ocean and in the north by non-aquifer areas. The Kebumen-Purworejo groundwater basin has only one aquifer layer in the form of a unconfined aquifer with a discharge of around 130 million m^3/year [19]. Determining the existence of an area in groundwater basin is the initial stage in groundwater management. By assuming a groundwater basin as a natural underground reservoir, the utilization of groundwater on the coast of Kebumen will affect the overall condition of groundwater in this Kebumen-Purworejo groundwater basin.

3.4 Groundwater availability

Groundwater availability in the study area is obtained based on the analysis of aquifer units. Based on this analysis, the availability of groundwater in each district is determined, by multiplying of the aquifer thickness, the specific yield and the area of each district. The safe yied of groundwater extraction is the result of the multiplication of the area, the specific yield and the fluctuation of groundwater. The calculation results of these parameters are shown in Table 1.

Based on Table 1, it can be seen that the highest groundwater availability is in Petanahan District, followed by Klirong and the lowest is in Bulupesantren. Petanahan District has groundwater availability of 502,208,000 m^3/year, Klirong of 363,300,000 m^3/year and Bulupesantren of 341,390,000 m^3/year. The difference in groundwater availability is due to the different area and thickness of the aquifer.

Table 1. Groundwater availability of each district in the study area

No.	District	Area (m^2)	Sy (%)	Aquifer Thickness (m)	Groundwater Fluctuation (m)	Groundwater Availability (m^3/year)	Safe Yield (m^3/year)
1.	Petanahan	44,840,000	28	40	2	502,208,000	25,110,400
2.	Klirong	43,250,000	28	30	2	363,300,000	24,220,000

| 3. | Bulupesantren | 48,770,000 | 28 | 25 | 2 | 341,390,000 | 27,311,200 |

Source : Petanahan, Klirong, Bulupesantern District in Number 2020 and calculation result

3.5 Utilization of groundwater resources

Observing Table 2, the amount of water demand for domestic in the study area is 16,308,200 liters/day. In terms of each district, Klirong District has the largest domestic water demand, namely 5,512,400 liters/day, Petanahan District 5,451,000 liters/day and Bulupesantren District has the smallest domestic water demand, namely 5,344,800 liters/day.

In the study area there are many livestock businesses, both large livestock, small livestock and poultry. The types of big livestock cultivated by the population include dairy cows, beef cattle, buffalo and horses, while small livestock types are cultivated by goats, sheep and rabbits. For poultry, several types of poultry that are cultivated are purebred chickens, broilers, ducks, manila ducks, quails and geese. For big livestock, the water requirement is 711,920 liters/day, small livestock 349,235 liters/day and poultry 425,430 liters/day..

Table 2. The water demand of domestic and livestock in the study area in 2019

No.	District	Domestic		Livestock			
		Population (person)	Water Demand (liters/day)	Big	Small	Poultry	Water Demand (liters/day)
1.	Petanahan	54,510	5,451,000	3,804	36,568	327,852	531,711
2.	Klirong	55,124	5,512,400	5,703	5,481	172,877	359,251
3.	Bulupesantren	53,448	5,344,800	8,291	27,798	208,336	595,632

Source : Petanahan, Klirong, Bulupesantern District in Number 2020 dan calculation result

3.6 Evaluation of groundwater availability and safe yield

The results of the calculation show that the amount of water demand in the study area is 6,495,100 m³/year, while the safe yield of groundwater extraction is 76,641,600 m³/year (Table 3). Petanahan District has the highest water demand of 2,183,689 m³/year, followed by Bulupesantren District of 2,168,258 m³/year and the lowest water demand is in Klirong District of 2,143,153 m³/year. Based on this data, it can be seen that the water demand in the three sub-districts are not much different.

Table 3. Water demand and safe yield of groundwater extraction

No.	District	Water Demand (m³/year)	Safe Yield (m³/year)
1.	Petanahan	2,183,689	25,110,400
2.	Klirong	2,143,153	24,220,000
3.	Bulupesantren	2,168,258	27,311,200
	Total	6,495,100	76,641,600

For safe yield, the highest safe yield was in Bulupesantren District at 76,641,600 m³/year, followed by Petanahan District at 25,110,400 m³/year and the lowest was in Klirong District at 24,220,000 m³/year. The difference in safe yield values in the three sub-districts is more influenced by the different areas.

Based on this data, it can be said that the groundwater extraction that has been carried out by residents has not endangered the availability of groundwater, so there is no decrease in groundwater pressure which can cause sea water intrusion.

However, because the strong pressure of fresh groundwater into sea water is not always due to its small extraction, it must always be maintained so that rainwater as input is always stored in the beach ridge and lagoon. In addition, the back swamp in this area must also be maintained so that sea water does not enter at high tide.

4 Conclusion

1) Availability of groundwater in the study area 440,517,770 m³/year, with the safe yield of groundwater extraction is 76,641,600 m³/year
2) The groundwater demand in the study area was 6,495,100 m³/year
3) The extraction of groundwater that has been carried out by residents has not endangered the availability of groundwater, so there is no decrease in groundwater pressure which can lead to seawater intrusion.

Acknowledgement

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