

The Condition of Hydro-Geology in Mantewe, Tanah Bumbu Regency, South Kalimantan, Indonesia

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Abstract

The location of the research is in Sukadamai Village, Mantewe District, Tanah Bumbu Regency. There are a lot of open charcoal mining activities in this location. This mine will increase the potential of groundwater pollution due to the charcoal mining waste; acid mine water. Therefore, it is necessary to conduct a research in order to figure out the hydro-geological condition of the location so that the pollution potential can be depicted. The analysis used in this research includes geo-electric and hydro-geological analysis. Based on the analysis on all collected data, it is known that: a) Hydro-stratigraphy of the location, from the oldest to the latest, is composed from layered limestone aquifer, sandstone aquitard-aquifer, clay stone aquiclude, charcoal and stone chops intermittence aquitard plays a role as aquitard; b) The flow of groundwater in the location is highly controlled by the distribution of aquifer and geological structure in the form of syncline; c) Charcoal mining in the research location that produces acid mine water does not flow to the settlement.

Keywords: hydro-geology, acid mine water, aquifer

A. Introduction

The research location is in Sukadamai Village, Mantewe District, Tanah Bumbu Regency, Southern Borneo (Figure 1). There are a lot of charcoal mining activities in this region that use the open pit method that the potential of groundwater pollution due to acid mine water increases further. Therefore, in order to figure out the potential of groundwater pollution by acid mine water in this region, it is necessary to conduct a study about hydro-geological system. Based on the map of groundwater basin in Borneo Island (Murtianto [5]), the research location is in Pagatan and its small part is in non-groundwater basin location. In terms of regional hydro-geology [2], this research location is in the local productive aquifer zone (Figure 2). The groundwater

in this zone flows in cleavage and fracture with the groundwater surface that generally has great depth. This aquifer zone in this research location is divided into two kinds; the aquifer in limestone and aquifer in sandstone with clay stone intermittence. In the aquifer of limestone, marl and sandstone are intermittent, generally has low passing, the passing is in the fracture zone, cracks, and corrosion. In sand stone aquifer which is intermittent with clay stone, there is a insertion of chips, charcoal, limestone, and clay stone. This aquifer has middle to low passing.

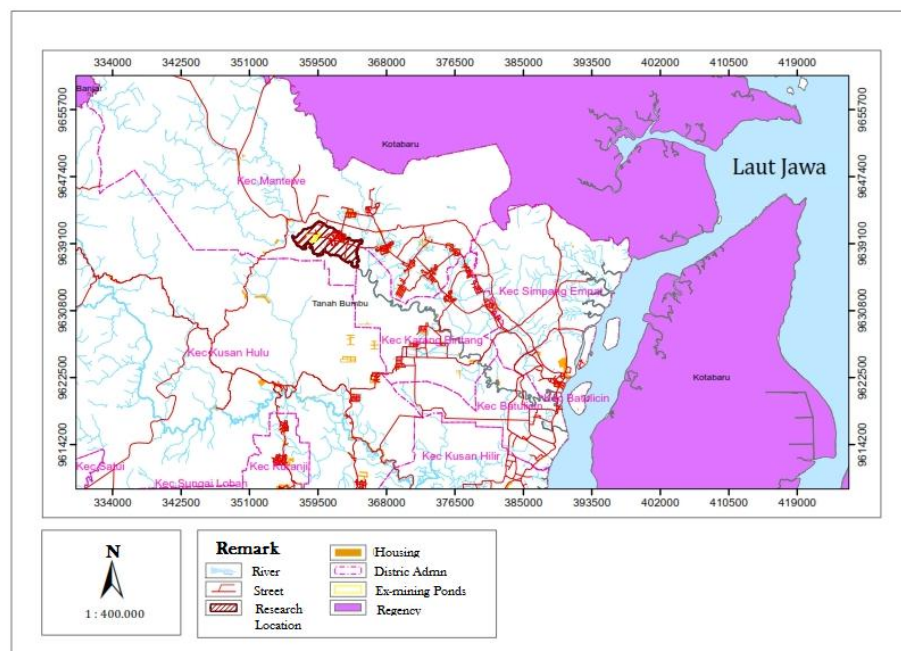


Figure 1. Map of Research location

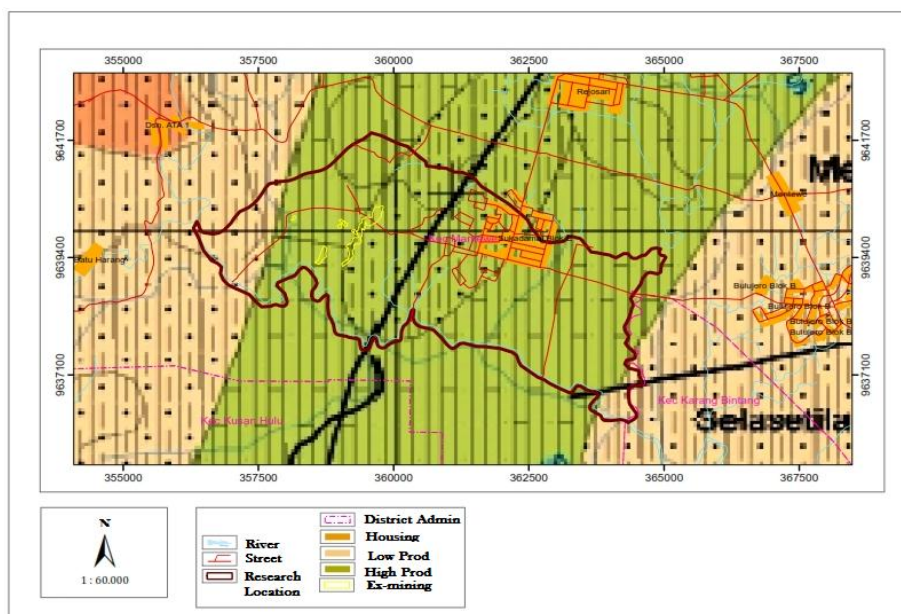


Figure 2. Map of Regional Hydro-geology of research location [4]

B. Research Methods

In order to figure out the hydro geological system of the research location, it is done by three approaches; field geological physical observation, geo-electrical measurement, and groundwater surface height measurement. The field geological physical observation is needed in order to figure out the hydro-stratigraphy of the research location. Geo-electrical measurement is needed to find out the distribution of aquifer. Shallow groundwater surface measurement is to figure out the shallow groundwater streamline [2].

In this research, the determination of hydraulics conductivity value is done by adjusting the type and condition of stones in the field by referring to the former researches. One of the references used in order to find out the hydraulics conductivity value from some stones is shown in Figure 3.

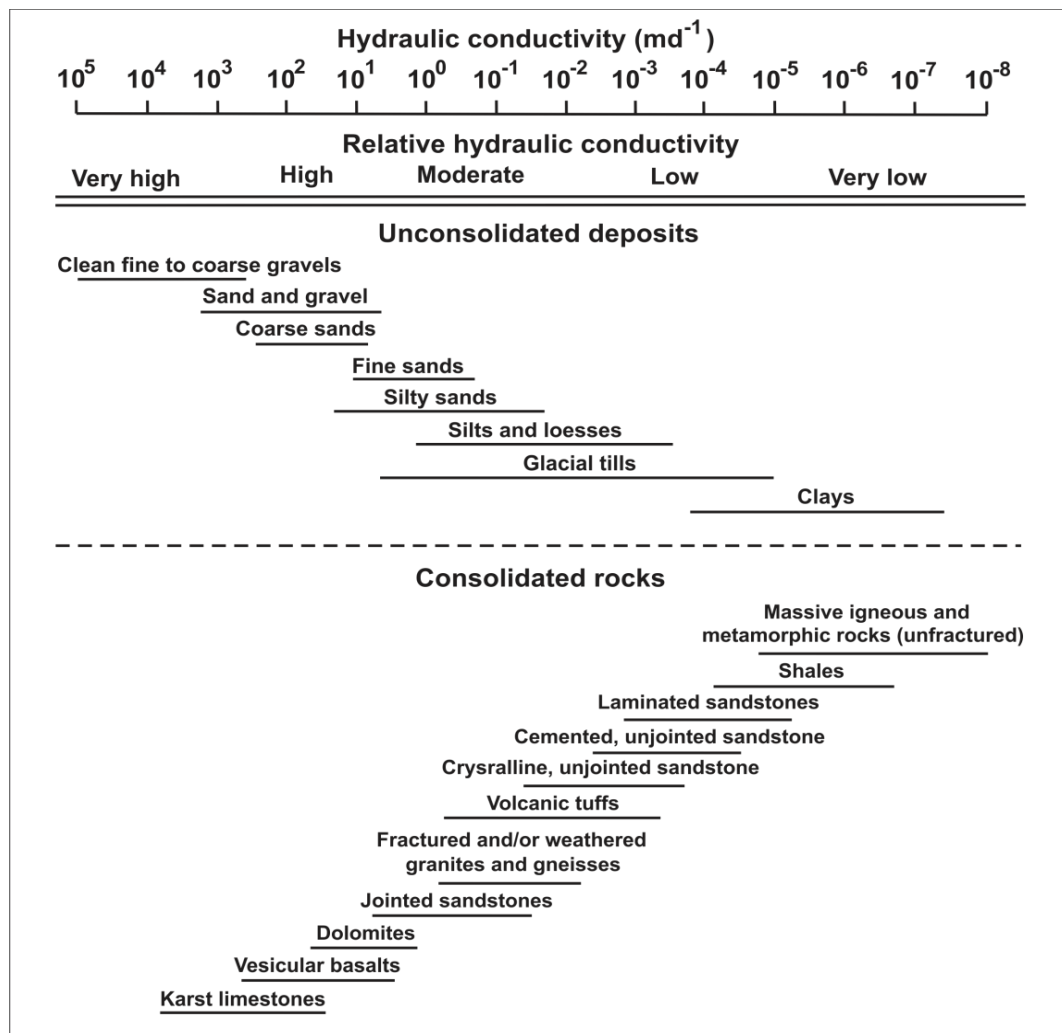


Figure 3. The range of stones and sediment conductivity value (Driscoll [1] and Todd [7] with modification).

In this research, the classification of stone types is based on the hydraulics conductivity value and their characteristics toward the groundwater, by using the classification according to Freeze and Chery [3] and Suharyadi [6], who divide stones into four types;

- (1) Aquifuge. Aquifuge is a layer which is relatively impermeable against water that it can neither deposit water nor pass the water. The hydraulics conductivity value of this material is 10^{-8} m/second. One of the examples is granite and massive andesite lava.
- (2) Aquiclude. Aquiclude is a layer which has quite big porosity despite its small permeability value, that this layer can deposit water but cannot be passed or flow water. The hydraulics conductivity value of this material is $<10^{-8}$ m/second. The difference between aquiclude and aquifuge lies on the types of stones and their porosity. Aquifuge belongs to massive crystalline stone that has very little pores, while aquiclude is a material with numerous separated pores, that both aquiclude and aquifuge are water-impermeable. One of the examples of this layer is clay.
- (3) Aquitard. Aquitard is a layer which has middle permeability value between aquifer and aquiclude, that this layer still can flow water even though in small number. The hydraulics conductivity value of this material is 10^{-8} - 5×10^{-5} m/second. The example of this layer is sand clay.
- (4) Aquifer. Aquifer is layer that passes water and can carry water in great amount. This layer has great porosity and permeability value that it can deposit and flow groundwater easily. The hydraulics conductivity value of this material is $>5 \times 10^{-5}$ m/second.

C. Result and Discussion

C1. Hydro-stratigraphy.

Based on the field geological observation, the lithology in the research location is divided into four denominations. Based on the stratigraphical order from old to new, there are layered limestone denomination, sand stone denomination, intermittence of clay stone and chips denomination, and intermittence of charcoal and chips denomination. Layered limestone denomination is found in the western end and in the eastern part of the research location. This denomination is composed from layered limestone, with the layer width ranges between 20-80 cm. Based on the field observation, the limestone has undergone dissolution that there is a cavity that can increase permeability. The cavity in this limestone, especially on the edge of the layering, becomes one of the weak zones in the type of clay stone. The existence of cavity in limestone shows that the limestone has undergone karstification process. According to Driscoll [1] and Todd [7], limestone in this condition has hydraulics conductivity value around 5.8×10^{-4} - 6.9×10^{-2} m/second that this denomination belongs to aquifer category.

Sand stone denomination is composed from sandstone layering with soft to medium powder size, and has cracks. The spreading of this denomination in the research location is quite wide. The location of settlement in this region often experiences difficulty in obtaining standard water resource, especially during long dry season. In such local region, there are water puddles that create natural wells and become the

standard water resources for the local people. According to Driscoll [1] and Todd [7], sandstone in this condition has hydraulics conductivity value around 10^{-4} - 10^{-6} m/second, that this denomination belongs to aquifer-aquitard.

Above the sand stone denomination, there is a denomination of intermittence of clay stone and chips, consistently. This denomination is composed from clay stone and chips with the layer width of 0.5-30 cm. The chips found in this research location generally create lamination. The outcrop of this stone is frequently found in the surface where there is water seepage in the edge of this denomination. According to Driscoll [1] and Todd [7], the stone in this condition has hydraulics conductivity value around 10^{-8} - 10^{-10} m/second that this denomination belongs to aquiclude category.



Figure 4. The cavity developing in limestone.



Figure 5. Natural water puddles in sand stone denomination that are used as standard water resources for the local people.

The newest denomination in the research location is the denomination of intermittence of charcoal and chips. Besides this denomination is composed from the intermittence of charcoal and chips, insertion of quartz sand stone, clay stone, and limestone is also found. The quartz sand stone insertion is around 50 cm. The charcoal in the research location is seen to have cracks which enable water to seep. With the cracked condition of charcoal and the insertion of quartz sand stone, this denomination can be categorized in aquitard.



Figure 6. The outcrop of clay stone in denomination of intermittence of clay stone and chips that plays a role as aquiclude.

From the explanation above, the hydro-stratigraphy of the research location, from the oldest to the newest, is composed from (Figure 7): Denomination of layered limestone which plays a role as aquifer; Denomination of sand stone which plays a role as aquitard-aquifer; Denomination of intermittence of clay stone and chips which plays a role as aquiclude/ non-aquifer; Denomination of intermittence of charcoal and chips which plays a role as aquitard.

Based on the overlay result between the map of hydro-geology and the location of settlement and the mine openings, it is known that the mine openings location is on the aquitard of intermittence of charcoal and chips. In this denomination there is an insertion of limestone. The settlement location based on overlay result lies on the denomination of sand stone aquifer-aquitard. On the cutlet of the map of hydro-geology, it is seen that the denomination of aquitard intermittence of charcoal and chips is separated by other denominations due to the denomination of non-aquitard/aquiclude intermittence of clay stone and chips.

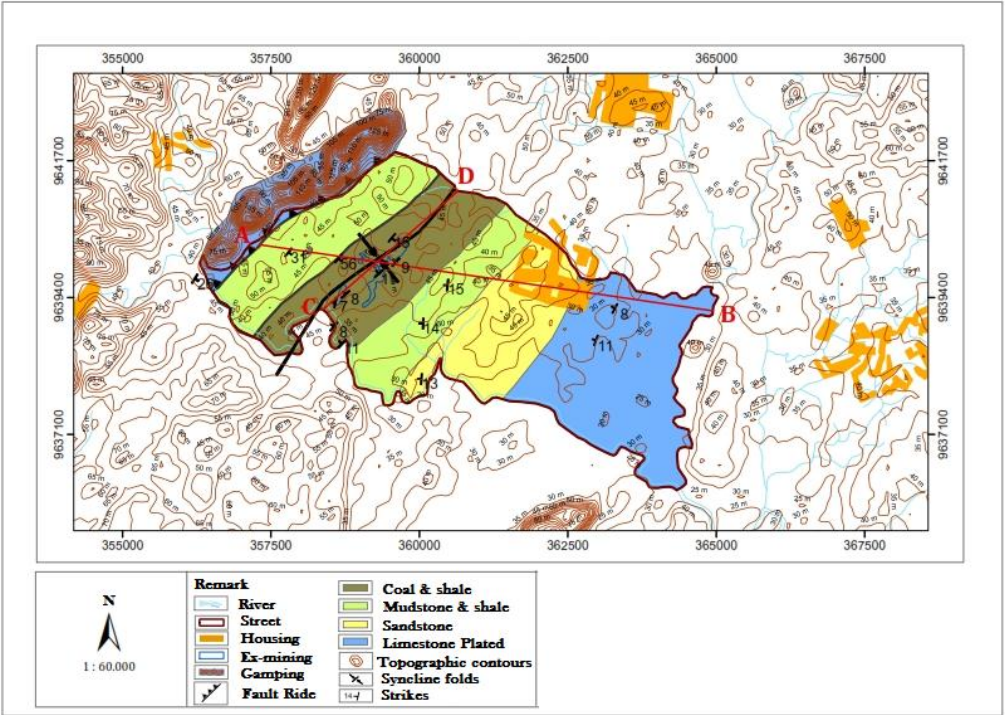


Figure 7. Map of hydro-geology of the research location.

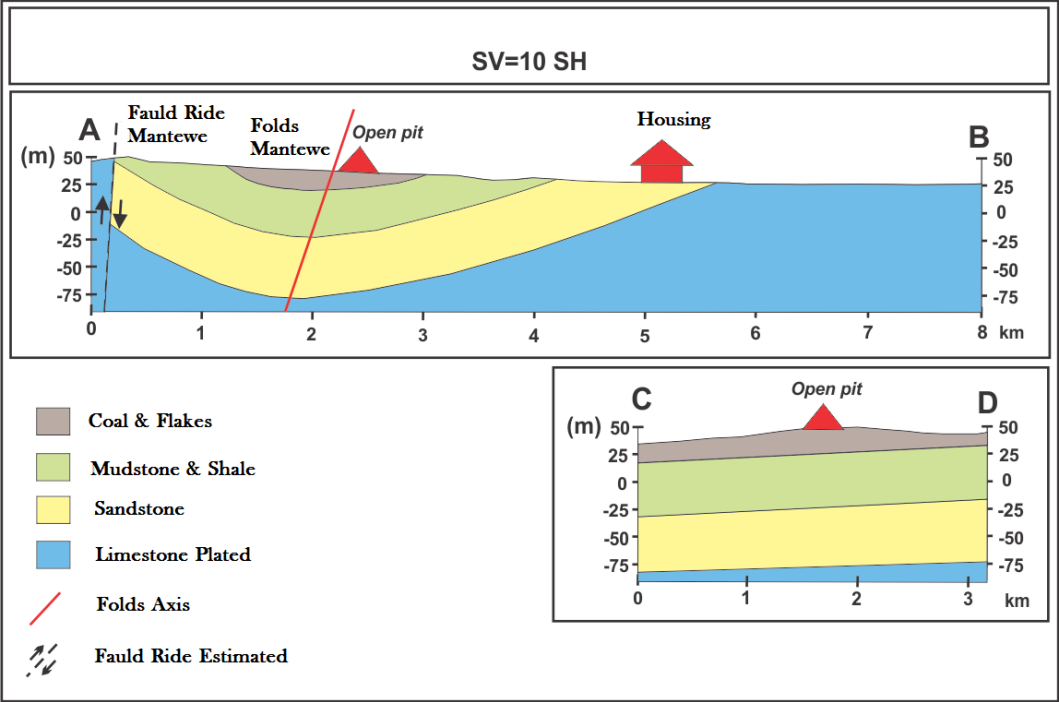


Figure 8. The profile of map of hydro-geology of the research location.

With the existence of this non-aquifer denomination, the aquitard intermittence of charcoal and chips where the open pit lies causes groundwater in this aquitard isolated merely in this denomination. The flow of groundwater from this denomination to the others is through regolith is also adequately small. It is due to the fact that based on the field observation, the width of the regolith in the research location only ranges from 1-1.5 meters, that the access for groundwater to be able to pass the aquiclude intermittence of clay stone and chips through the regolith is adequately small.

In order to figure out the distribution of hydro-geological denomination in more details, geo-electrical analysis is used. Around 28 spots of geo-electrical measurement are found (Figure 9). Based on the correlation of spot A-B in the geo-electrical measurement that contains station sk10, sk8, sk26, sk5, sk4, sk14, sk15, sk16, sk24, and sk23 (Figure 10) it can be seen that the spreading of hydro-geological denomination is not really different from the cutlet A-B in the map of hydro-geology. In the top part, there is a denomination of aquitard intermittence of charcoal and chips that also contains an insertion limestone. In the bottom part, there is an aquiclude of lampung stone that insulate the aquitard intermittence of charcoal and chips with aquifer-aquitard sand stone and limestone aquifer. All these denominations are folded and create syncline structure. Based on the correlation of spot E-F on geo-electrical measurement that contains station sk19, sk18, sk7, sk5, sk25, sk2, sk1 (Figure 10), it can be seen that the spreading of hydro-geological denomination in the direction of northeast-southwest. On this cutlet E-F, syncline can be seen and the spreading of hydro-geological denomination looks tilted towards south due to the syncline that subducts towards south around 8^0 .

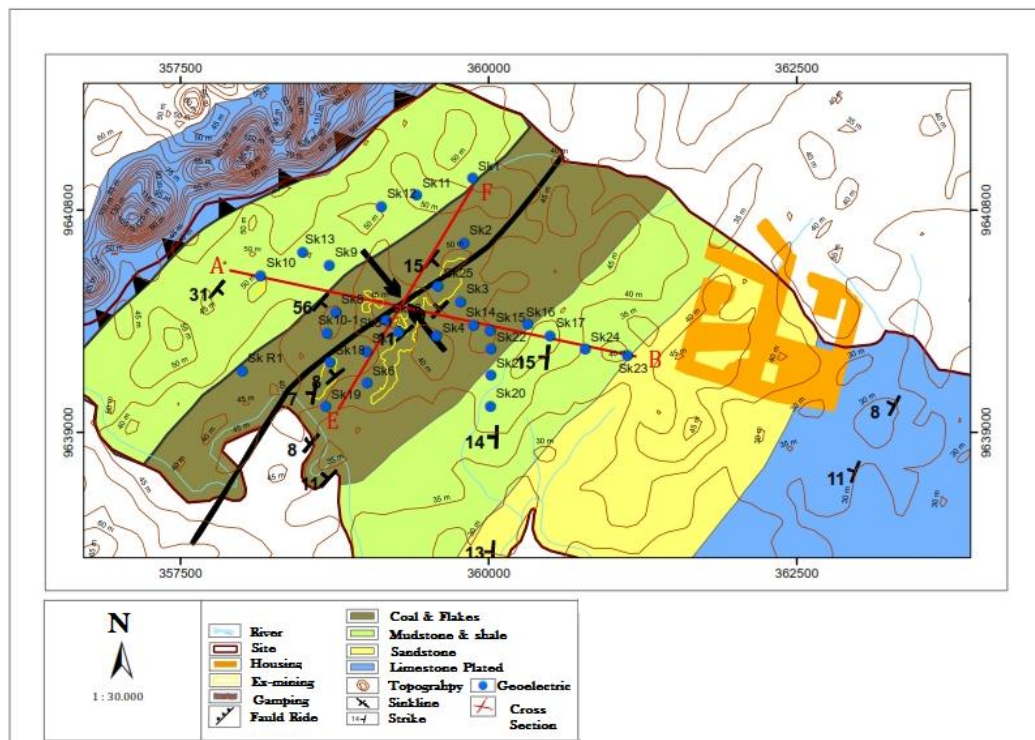


Figure 9. Map of Geo-electrical measurement.

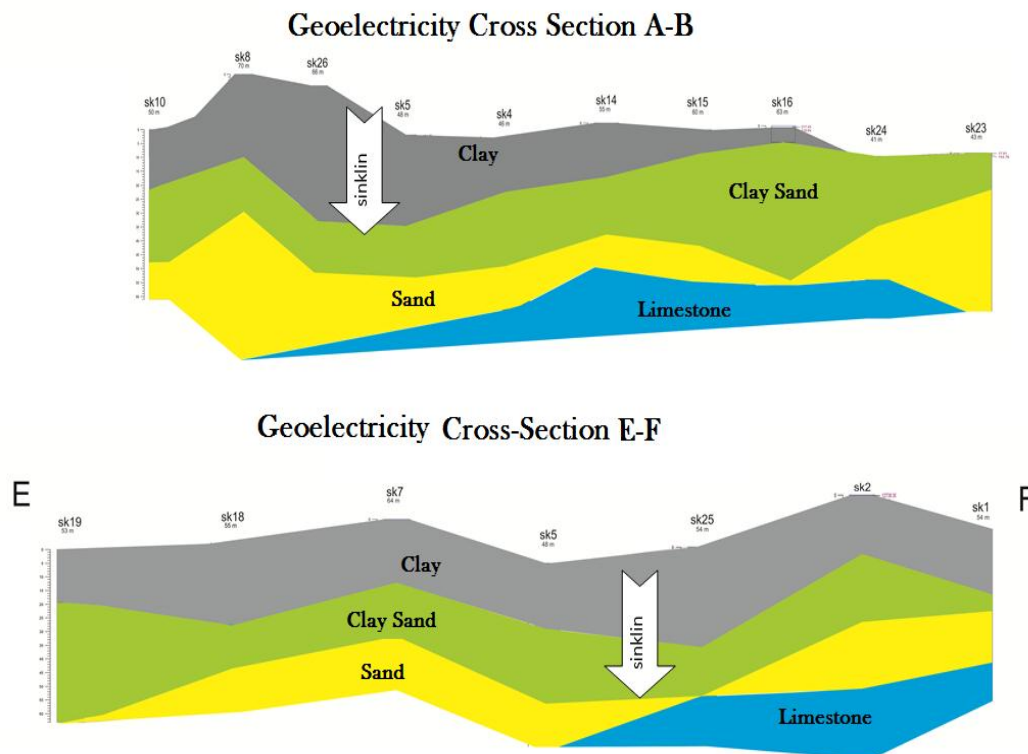


Figure 10. Cross section of geo-electrical A-B and E-F.

C2. Augmentation Area and Groundwater Streamline

Based on the hydro-geological map of the research location, it can be seen that the groundwater in the research location flows through 2 separated systems; first, through aquitard intermittence of charcoal and chips, second, through aquifer layered limestone and aquifer-aquitard sand stone. The augmentation area and groundwater streamline need to be found in each of the systems. There are several methods in determining the augmentation area. According to Danaryanto *et al.* [8], the determination of augmentation and detachment area can be done by methods: a. Buckling slope/ morphology; b. River stream pattern; c. The emergence of spring; d. Depth of groundwater surface; e. Natural isotope. Based on the field condition in the research location, the determination of the depth of groundwater surface is done based on morphology and the depth of groundwater surface.

Based on morphology method, the highest area will play a role as augmentation area. Therefore, each of the systems will have their own augmentation area. Based on the depth of groundwater surface method, the augmentation area will be characterized by the great depth of groundwater surface. In order to figure out the depth of groundwater surface, the measurement of depth of shallow groundwater surface is done on the mine void and people's wells. From this measurement, there are 11

location spots found. Not all of the stone lithology denomination has wells or mine openings of which the height of groundwater surface can be measured. The denomination that does not have the measurement data is the intermittence of clay stone and chips. The absence of the measurement data in this denomination is due to the fact that there is no well and the limited number of water resources in this location. Based on overlay of morphology method and depth of groundwater surface, the augmentation area on each hydro-geology system in the research location is obtained (Figure 11). In the figure, it can be seen that the augmentation area on the aquitard intermittence of charcoal and chips is on the middle and southern part, while the aquifer limestone and aquifer-aquitard sand stone are on the west part.

The data of the depth of shallow groundwater surface can also be used to find out the horizontal groundwater streamline in the research location. From the data of depth of groundwater surface, it can be known that the groundwater streamline on the aquitard intermittence of charcoal and chips is different from the groundwater streamline on the aquifer-aquitard sand stone and aquifer layered limestone.

In the research location, the groundwater streamline on the aquitard intermittence of charcoal and chips horizontally has dominant direction of NNW (north-north-west). Meanwhile, the groundwater streamline on the aquifer-aquitard sand stone and aquifer layered limestone are dominant to SSE (south-south-east) (Figure 11). On the northernmost part of the research location, there is a river that is possible to influence the groundwater streamline in the northernmost part of the research location. However, the data of height of groundwater surface to show this influence is not obtained.

The groundwater streamline above is the horizontal streamline based on the data of augmentation area and the height of groundwater surface. Besides the horizontal direction, groundwater streamline also has vertical direction component. On its vertical streamline, it is highly influenced by the model of surface bottom side, the distribution of aquifer, and the geological structure formed in the region.

In the research location, the configuration of the surface bottom side is highly controlled by the presence of folding structure in the form of Mantewe syncline. As the result of this syncline structure, the groundwater streamline also experiences the effect of the change. As the result of the syncline structure, the groundwater streamline in the denomination of aquitard intermittence of charcoal and chips and the insertion of sandstone and limestone will be isolated merely on the denomination. This is due to the fact that by the presence of syncline structure and aquiclude clay stone denomination, bulkhead will be created both on the side part and the bottom part of the denomination of aquitard intermittence of charcoal and chips with the insertion of sand stone and limestone.

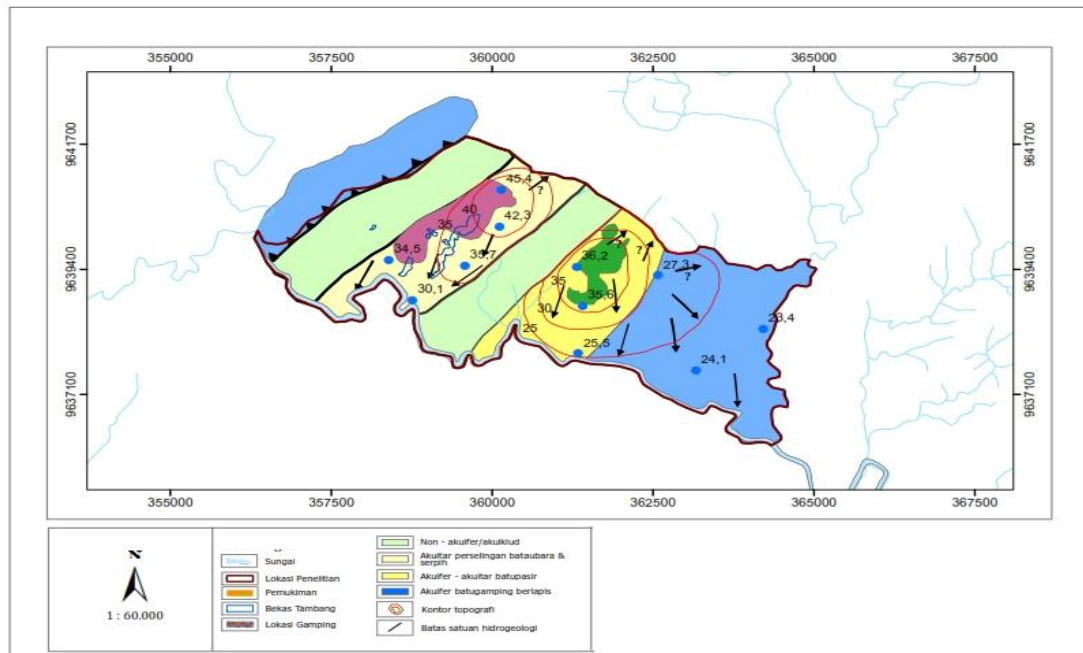


Figure 11. Map of groundwater streamline

As the result of syncline structure on the aquifer limestone and aquifer-aquitard sand stone, the groundwater streamline in this denomination will vertically flow against the topography. The vertical groundwater streamline in this denomination will head to the syncline center which lies on the area with greater height (Figure 12). By the Mantewe syncline configuration that creates turn to south around 8° , then the groundwater streamline will also have the component directing to south because of the tilt of the stones aquifer-aquitard to the south.

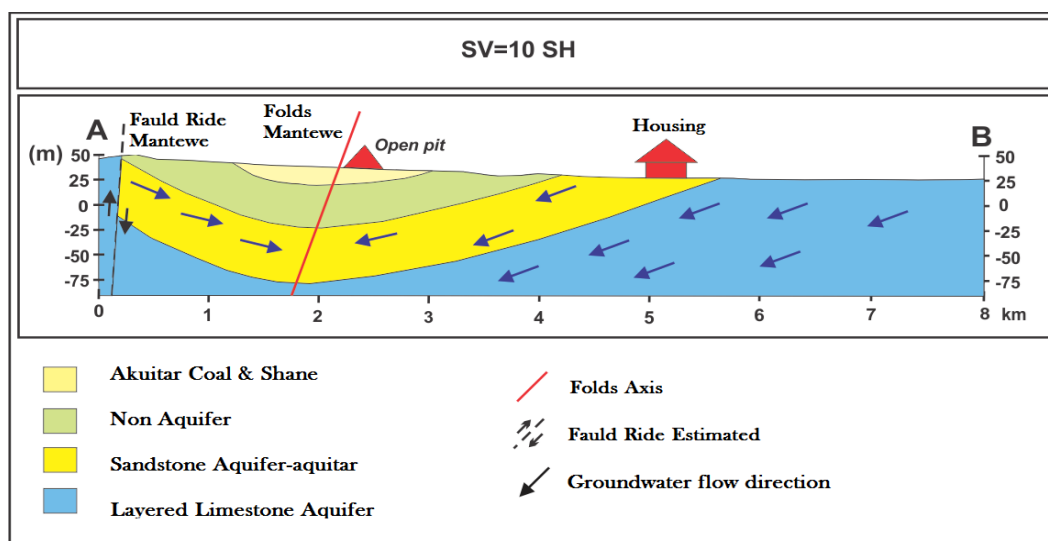


Figure 12. Scheme of groundwater streamline in vertical cross section.

C.3. Hydro-geology and Acid Mine Water.

As the result of charcoal mining in the research location, acid mine water will be produced as the waste of this activity. The acid mine water has great potential to pollute groundwater which becomes the standard water resources for mankind. In order to be able to figure out the potential of this pollution, hydro-geological investigation in the research location needs to be done. Therefore, void depth measurement is done from the open pit in order to be able to predict the dept of the permeable stone. Based on the data obtained, the depth of the void ranges between 5-10 meters. Based on this data, the correlation between pool depths by using the closest geo-electrical analysis is done in the research location. One of the pools with greatest depth of 10 meters is chosen. This pool lies on the relatively southern part of the research location. Subsequently, the correlation with geo-electrical spot sk7 in the profile of the pool depth is done (Figure 13).

Based on the result of this correlation, it is known that the layers of the penetrated charcoal lies on the denomination of aquitard intermittence of charcoal and chips with an insertion of limestone and sand stone. The charcoal is obtained in the depth of around 10-15 meters. Below the charcoal there is an insertion of limestone. Below this denomination there is a denomination of aquiclude clay stone. In the most bottom part there is aquifer-aquitard sand stone. Based on the analysis towards all the obtained data, it can be seen that charcoal mining in the research location that produces acid mine water does not flow towards the settlement. It is due to 2 things; (a) The presence of aquiclude bulkhead that isolates the acid mine water not to spread to other hydro-geological denominations; (b) The presence of geological structure in the form of syncline keeps the vertical groundwater streamline in the research location from flowing in the same direction with the topographical slope; however, the groundwater will stay flowing towards the syncline cernter that the acid mine water cannot flow as groundwater towards the settlement area.

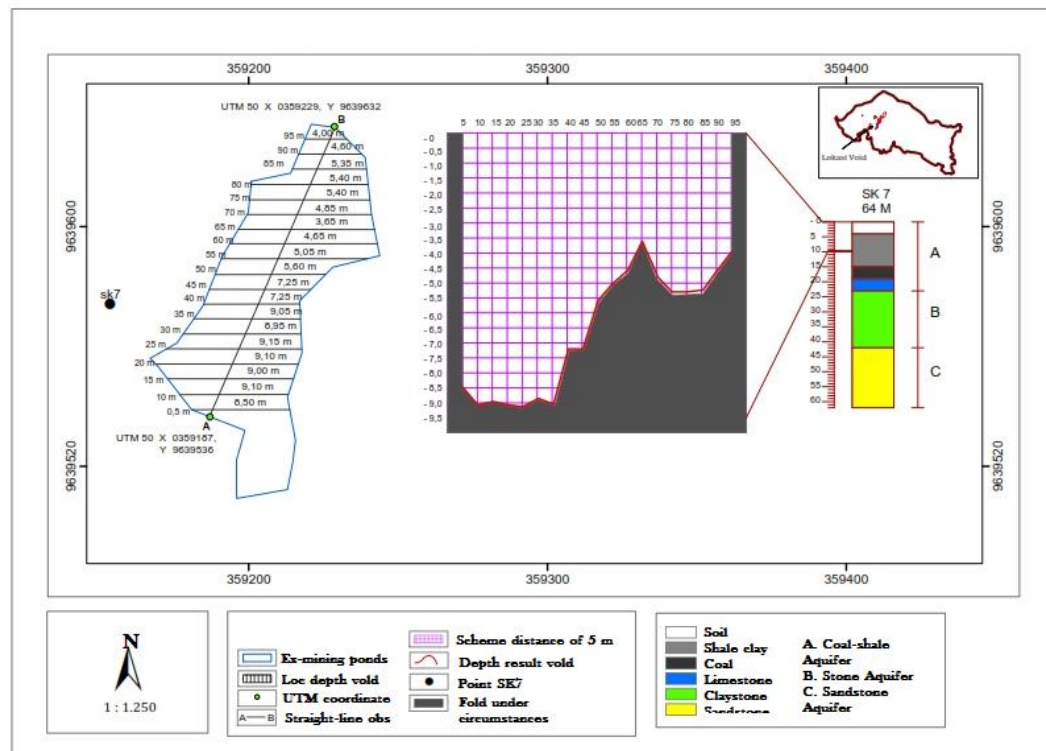


Figure 13. Correlation in Deep Void with Geoelectricity

D. Conclusion and Recommendation

Based on the result and discussion, it can be concluded

- Hydro-stratigraphy of the research location, from the oldest to the newest, is composed from: Denomination of layered limestone which plays a role as aquifer; Denomination of sand stone which plays a role as aquitard-aquifer; Denomination of clay stone and chips which plays a role as aquiclude/non-aquifer; Denomination of intermittence of charcoal and chips which plays a role as aquitard.
- Groundwater streamline in the research location is highly controlled by the distribution of aquifer and geological structure in the form of syncline.
- Charcoal mining in the research location that produces acid mine water does not flow towards the settlement. This is due to 2 things; The presence of aquiclude bulkhead that isolates acid mine water from flowing towards other hydro-geological denominations; The presence of geological structure in the form of syncline, keeps the groundwater streamline in the research location from flowing in the same direction with the topographical slope; however, the groundwater will stay flowing towards the syncline center that the acid mine water cannot flow as groundwater towards the settlement area.

Based on the conclusion above, the recommendation of this study are: (a) In order to strengthen the analysis in this research, the review of hydro-chemical and groundwater surface streamline in the research location needs to be done in order to figure out the level of water pollution by the acid mine water. Moreover, by the

presence of limestone insertion in the area of charcoal mining, there is a potential of self-purification towards the acid mine water in the research location. The potential of self-purification needs to be elaborated by hydro-chemical studies. (b) Recommendations for further research may consider factors that influence of hydro-geological characteristics in different location.

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