ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0890 (Print)
ISSN: 2521-0491 (Online)
CODEN: GBEEB6

Geological Behavior (GBR)

DOI: http://doi.org/10.26480/gbr.02.2022.57.60

RESEARCH ARTICLE

GEOPHYSICAL APPLICATION FOR GROUNDWATER POTENTIAL AND WATER QUALITY ANALYSIS OF MELANGKAP AREA, KOTA BELUD, SABAH

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ARTICLE DETAILS

Article History:

Received 14 February 2022
Accepted 29 March 2022
Available online 01 April 2022

ABSTRACT

The study area is located at Melangkap area of Kota Belud, Sabah, Malaysia which comprises of Crocker Formation aged Late Eocene to Early Miocene and Quaternary alluvium deposits. This study focuses on groundwater potential using electrical resistivity method and water quality analysis of the study area. Schlumberger array using ABEM Terrameter LS instrument and Res2DINC software is used for data acquisition. Three survey lines were conducted in Kg. Melangkap, Kg. Kebayau dan Kg. Tambatuon. Water samples from existing boreholes from these locations were analysed based on Drinking Water Standard by Malaysian Department of Environment. Subsurface interpretation showed the layer of shale with resistivity value of 20 - 40 ohm-m, fractured sandstone with 20 -175 ohm-m, interbedding of shale and sandstones with 60 – 500 ohm-m, saturated sandstones with 40 – 1000 ohm-m, thick sandstones with 500 – 1000 ohm-m and gravel deposits with 175 - 1000 ohm-m. Each survey line showed 3 zones of different materials. Kg Kebayau shows the best potential for groundwater supply than Kg Melangkap and Kg Tambatuon, due to existence of 12 m thickness of sandstone aquifer. Water quality analysis shows the heavy metals concentration for all samples are within permitted range for drinking water consumption. However, water sample from Kg Kebayau borehole has the lowest value of electrical conductivity, total dissolved solids, chloride content and heavy metals concentration made it the cleanest among all samples, which is widely used by the villagers of Kg Kebayau for drinking and external purposes.

KEYWORDS

Electrical resistivity, groundwater potential, water quality, Schlumberger array, ABEM Terrameter LS

1. INTRODUCTION

Groundwater is a part of the dynamic hydrologic cycle. It can be defined as the science of the occurrence, distribution and movement of water which is below the surface of the earth. Groundwater, in average of 30% of world's fresh water, is a very important natural resource readily available to humans and agriculture purpose (Clark and Briar, 2001). Therefore, the objectives of this study are to determine the groundwater potential in the study area by using geophysical application (electrical resistivity) and to analyse the water quality based on the standard index of Malaysian Department of Environment (2019).

There are various geophysical methods used to locate groundwater sources, but electrical resistivity is vastly conducted due to the depth and location of the aquifer can be directly determined during the survey (Young et al., 1998). The electrical resistivity value of earth materials has larger range for different materials; made this method is very suitable for the purpose (Loke, 2001). Reliance on geophysical method in groundwater source exploration has increased recently with the progression of computer software and field data (Musa et al., 2014). Furthermore, electrical resistivity method is a non-destructive method of underground survey with easy operation on field (Mohd Sazaly and Sanudin, 2017). The study of groundwater quality is essential to ensure the safety before consumption Geological factors and human activities can contribute to the groundwater chemical concentration (Majid et al., 1996).

The study area is located at Melangkap, Kota Belud district, in the Northwestern part of Sabah which is bounded by latitude of 6° 12'N to 6° 05'N and longitude of 116° 23'E to 116° 30'E (Figure 1). The study area consists of Crocker Formation aged Late Eocene to Early Miocene and Quaternary Alluvium deposits. Crocker Formation comprises of thick sandstones unit, interbedded of sandstone and shale unit and shale unit. Alluvium deposition has overlain the Crocker Formation and widely distributed on a lower and flat elevation.

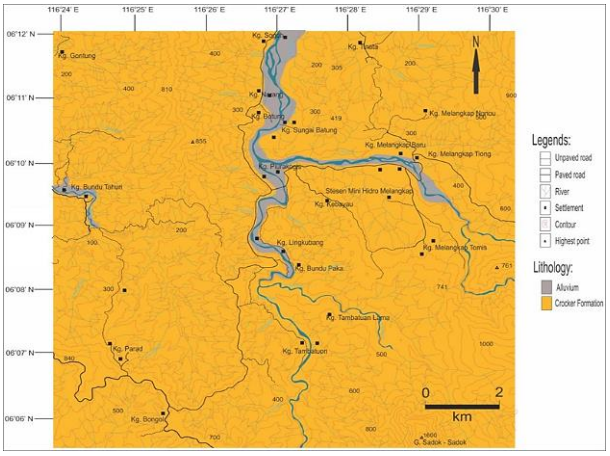

Figure 1: Geological map of the study area

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2. Materials and Methodology

Preliminary study has been conducted including the literature reviews and geological map production for fieldwork purpose. Geological mapping includes observation on the lithology of the rock units in the study area. Three geophysical survey lines of 100 or 200 meters each were set in Kg Melangkap, Kg Kebayau and Kg Tambatuon, respectively (Figure 2). The survey is conducted using electrical resistivity method with Schlumberger arrangement (Figure 3) and detected with ABEM Terrameter LS instrument. Schlumberger protocol is chosen due to vertical geological structures and provide 10% more coverage of the survey area (Loke, 2000). Field data obtained is later processed with Res2DInv software to invert the data to produce 2D pseudo-section which exhibits the value of resistivity (in ohm-m) of each depth of materials. Borehole data of the survey location from previous researcher also used for comparison. The correlation of earth materials and the resistivity value is referred to Loke (2000), Giocoli et al. (2008), Rosli Saad et al. (2012), Mahmoud Khaki et al. (2016) and Aziman Madun et al. (2018) (Figure 4).

Figure 2: Survey lines conducted at Kg. Melangkap, Kg. Kebayau and Kg. Tambatuon, respectively.

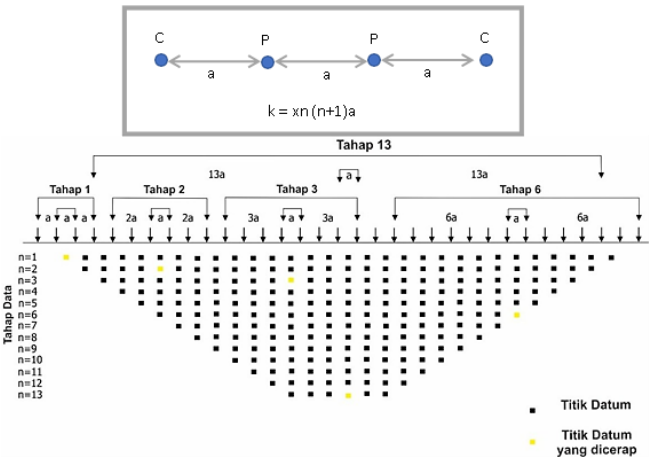

Figure 3: Schlumberger arrangement protocol

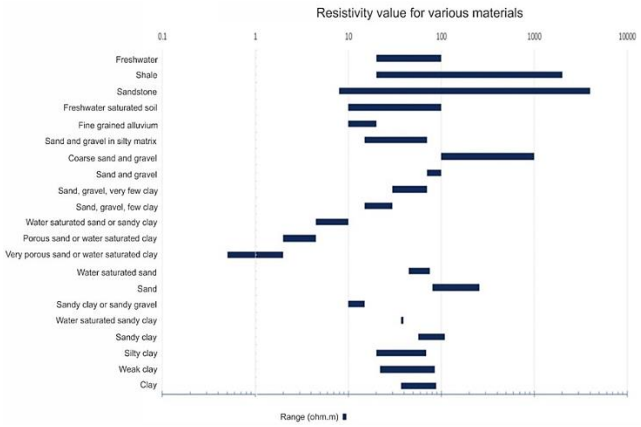

Figure 4: Resistivity value for various earth materials

Survey line is adjacent to the available pump well which the water sample is collected from pump well of each location for water quality analysis. Several parameters such as pH value, electrical conductivity, alkalinity, chloride content and heavy metals concentration are to be compared with the Malaysian Department of Environment of drinking water standard (2019) (Table 1) for safe water consumption. All standard parameters in Table 1 were meet minimum value for Class II of National Water Quality Index which is good water quality and suitable for drinking with conventional treatment.

Table 1: Malaysia Groundwater Quality Standards for Conventional Raw Water Treatment for Drinking Water (Malaysian Department of Environment, 2019

Parameters	Standard (mg/l)
pH	5.5 – 9.0
Electrical Conductivity	1000 µS/cm
Total Dissolved Solids	1500
Chloride (Cl)	250
Alkalinity	500
Iron (Fe)	1.0
Mangan (Mn)	0.2
Cadmium (Cd)	0.003
Arsenic (As)	0.01
Lead (Pb)	0.05
Chromium (Cr)	0.05
Copper (Cu)	1.0
Zinc (Zn)	3.0
Natrium (Na)	200
Magnesium (Mg)	150
Nickel (Ni)	0.05

*All standards meet minimum value for Class II of National Water Quality Index

3. Results and Discussion

3.1 *Resistivity Data Interpretation*

3.1.1 Kg. Melangkap

200 meters of survey line has been set in Kg Melangkap and has produced a cross-section of earth materials resistivity up to 35-meter depth (Figure 5). Three zones were interpreted, where Zone A has resistivity value of 20 to 40 ohm-m with 50 mS of chargeability which indicates the existence of shale. Zone B has the highest value of resistivity ranges from 250 to 1000 ohm-m which interpreted as saturated sandstones, while Zone C is interpreted as saturated layer due to low value of resistivity and chargeability which is less than 60 ohm-m and 1 mS, respectively. It can be concluded that the survey line area is comprises of interbedding between thick sandstones and shale with 4 meters depth of water table based on the borehole data. The groundwater potential is in Crocker Formation thick sandstones which contained as unconfined aquifer.

3.1.2 Kg. Kebayau

100 meters of survey line has been set in open area of SK Kebayau and has produced a cross-section of earth materials resistivity up to 18.9-meter depth (Figure 6). Three major zones were identified. Zone A consists of 175 to 2000 ohm-m and interpreted as gravel deposits which also shown in borehole data. Zone B is interpreted as fractured sandstones with low resistivity value of 20 to 175 ohm-m. Borehole log indicated the presence of fractures in sandstones in Kg. Kebayau compared to intact sandstones in borehole log of Kg. Melangkap. Zone C referred to saturated zone with the lowest resistivity value of less than 60 ohm-m. It can be concluded that the area consists of more porosity due to the layer of gravels on top and fractured sandstones which also became unconfined aquifer for groundwater potential with 8 meters depth of water table.

3.1.3 Kg. Tambatuon

The 100 meters survey line is located along the main road which consists of Crocker Formation thick sandstones. The cross section for 18.9-meter depth of earth materials resistivity is shown in Figure 7 which indicated three major zones. Results from this line is a control data to compare the precision of results obtained for two previous survey lines. Zone A has the highest resistivity value up to 1000 oh- m which interpreted as topsoil with gravels. Zone B and Zone C showed the presence of sandstones with 500 to 1000 ohm-m which indicated thick sandstones and 60 to 500 ohm-m which indicated interbedding between sandstones and shale, respectively.

3.2 Water Quality Analysis

All water samples were compared based on Malaysia Groundwater Quality Standards for Conventional Raw Water Treatment for Drinking Water (Malaysian Department of Environment, 2019). Table 2 below shows the water quality results which include the analysis of pH, conductivity, total dissolved solids, chloride, alkalinity, and concentration of several heavy metals.

Based on Table 2, most of the result is within the range of value permitted. All samples show pH value between 6.01 to 6.69 which is still within permitted standard. Electrical conductivity for groundwater normally between 300 to 800 µS/cm (Rusyadi, 2018), however result showed much lower value (65.16 to 158.02 µS/cm) due to probability of rainwater presence with value of 5 to 50 µS/cm. Total dissolved solids, chloride and alkali concentration analysis indicated low value for every water sample. Heavy metals usually low concentrated in earth's crust (Clark, 2015) and may accumulated due to human's activities. Certain heavy metals exhibited concentration value higher than permitted standard. Iron (Fe) content in BH1 (14.63 mg/l) may be due to the oxidation or reduction process of ferum oxide minerals in groundwater. This also can be seen in concentration of Mangan (Mn) in BH1 (4.09 mg/l) which is dominant in reduction setting (Clark, 2015). Weathered shale may become the source for Mn in groundwater (Boggs, 2006) which is supported with the presence of shale layer in BH1 (Kg. Melangkap). Natrium (Na) is also higher in BH1 exceed the permitted standard may be retrieved from alkali feldspar minerals which is abundance in thick sandstones of Crocker Formation.

BH2 and BH3 showed permitted range of heavy metals concentration except for Zinc (Zn) due to its slightly acidic environment and Arsenic (As) which may be slightly accumulated through fractures in rocks from further source (Murcott, 2012), respectively. Concentrations of Lead (Pb), Chromium (Cr), Copper (Cu) and Nickel (Ni) for all water samples were within permitted range or below detection due to the parent rocks of the study area mainly consists of sedimentary rock.

Table 2: Water quality data for samples in the study area

Parameter	Standard (mg/l)	BH1/Kg. Melangkap	BH2/Kg. Kebayau	BH3/ Kg. Tambatuon
pH	5.5 – 9.0	6.69	6.01	6.52
Conductivity	1000 µS/cm	158.02	65.16	128.81
TDS	1500	86.91	35.84	70.85
Chloride	250	0.35	-	1.77
Alkalinity	500	82	88	88
Fe	1.0	14.63	0.005	0.045
Mn	0.2	4.09	0.005	0.06
Cd	0.003	bdl	bdl	bdl
As	0.01	bdl	bdl	bdl
Pb	0.05	0.03	0.04	0.005
Cr	0.05	bdl	bdl	bdl
Cu	1.0	bdl	bdl	bdl
Zn	3.0	0.05	7.90	2.98
Na	200	291.16	89	147.57
Ni	0.05	bdl	bdl	bdl

4. Conclusion

The resistivity interpretation is conducted using Schlumberger array protocol and ABEM Terrameter LS at three survey stations, namely Kg. Melangkap, Kg. Kebayau and Kg. Tambatuon. Each station exhibited three major zones of earth materials resistivity. General subsurface interpretation showed the layer of shale with resistivity value of 20 - 40 ohm-m, fractured sandstone with 20 -175 ohm-m, interbedding of shale and sandstones with 60 – 500 ohm-m, saturated sandstones with 40 – 1000 ohm-m, thick sandstones with 500 – 1000 ohm-m and gravel deposits with 175 - 1000 ohm-m. Groundwater table depth range from 4 meters to 8.5 meters, with potential unconfined aquifer in Kg Melangkap and Kg. Kebayau, respectively, is thick sandstone and fractured sandstones. All water samples showed good quality with most parameters and heavy metals concentrations are within permitted range by Malaysia Groundwater Quality Standard (Table 3).

Table 3: Summary of groundwater potential and water quality of the study area

Station	Survey Line	Resistivity (Ohm-m)	Material	Ground-Water Table (m)	Type of Aquifer	Water Sampling Station	Water Quality
1	Kg. Melangkap	20 - 40	Shale	4	Unconfined thick sandstone	BH1	Good quality
		40 - 1000	Water saturated sandstone				
		< 60	Groundwater				
		175 - 1000	Gravels deposit				
2	Kg. Kebayau	20 – 175	Fractured sandstone	8.5	Unconfined fractured sandstone	BH2	Good quality
		< 175	Groundwater				
		500 – 2000	Gravely topsoil				
3	Kg. Tambatuon	500 – 1000	Thick sandstone	-	-	BH3	Good quality
		60 - 500	Interbedded thin sandstone and shale				

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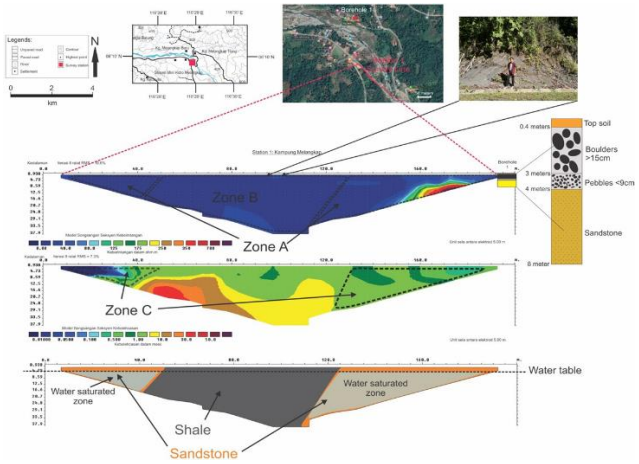

Figure 5: Cross section of resistivity in Kg. Melangkap

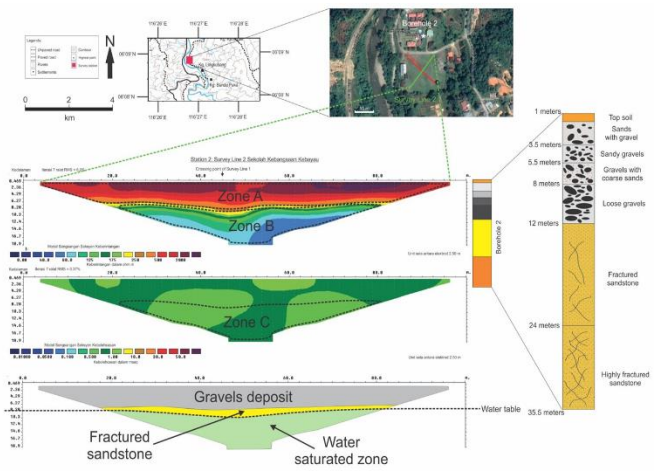

Figure 6: Cross section of resistivity in Kg. Kebayau

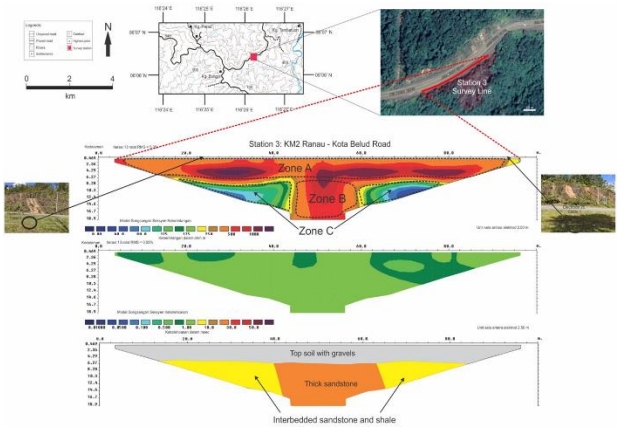

Figure 7: Cross section of resistivity in Kg. Tambatuon

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