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The use of electromagnetic and vertical electrical sounding methods in groundwater exploration

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Research Article

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ABSTRACT

Electromagnetic (EM) profiling and Vertical Electrical Sounding (VES) studies were carried out for groundwater exploration in the Twifo – Hemang Lower Denkyira Districts of Ghana. These two geophysical methods were used for exploring the groundwater potentials beneath Achiase Community, Mbaa Mpe Hia Community and Moseaso Community. This paper seeks to encourage the use of inversion for interpreting electromagnetic data rather than the usual qualitative interpretation method using line graphs and also the use of apparent resistivity maps as 2D pseudo resistivity maps to support interpretations of the 1D inversion results (in cases where the available budget could not permit 2D and or 3D inversion). These would help in enhancement of obtained results, reduce ambiguity and help decision making. The EM results revealed that; the three communities are underlain by two layers with the first layer having the thickness range between 2 to 10 m and the second layer is a half space. The results from VES studies indicate that; Achiase Community and Mbaa Mpe Hia No. 2 community are underlain by three geoelectrical layers and Moseaso Community is underlain by four geoelectrical layers. On the basis of this study the Moseaso Community is ranked highest in terms of groundwater potential followed by the Achiase community and finally the Mbaa Mpe Hia No.2 Community. Several sites were recommended for drilling boreholes for water supply in these communities.

1. Introduction

The availability of quality water for both drinking and domestic usage is of primary concern to people living in rural communities. Most rural communities in the Sub – Saharan Africa depend mostly on surface water and water from hand-dug boreholes whose qualities are questionable and some of these sources dry out during long dry seasons.

The exploration for clean groundwater is therefore necessary. There are some fundamental questions concerning groundwater which needs to be answered and some of these questions are; how much groundwater is available, and what is its quality? These are exploration and production questions for which geophysical techniques can help to answer (Fitterman and Stewartj, 1986).

Geophysical techniques have proven to be successful in groundwater explorations. Electromagnetic Methods and Direct Current Resistivity (DRC) Methods have been successfully used for decades in the investigation of groundwater resources. The Electromagnetic equipment, the EM 34-3 equipment (Geonics) is one of the most popular EM field systems used in groundwater prospecting. It is a portable EM device which directly measures conductivity at shallow depths.

The fundamental of Slingram System or HLEM method are described in several applied geophysical papers such as; McNeill 1980; Frischknecht et al. 1991; Spies and Frischknecht 1991; Keller and Frischknecht 1977.

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The EM data obtained from most geophysical investigations and studies such as Carrasquilla et al., 2007; Chegbeleh et al., 2009; Menyeh et al., 2005; Somiah, 2013; Tsikudo Kwasi, 2009; Anechana, 2013, which were conducted using Slingram techniques or HLEM method were interpreted qualitatively although inversion programs such as 1D laterally constrained inversion (Monteiro Santos, 2004) and AEMINV (Pirttijärvi, 2014) are available to public.

The conventional VES used in this work, has also been used in several works to produce good results. The electrical resistivity gives reasonably accurate results among other methods that can be used to understand the subsurface layers and basement configuration in groundwater prospecting (Olakunle Coker, 2012). In this work, dc resistivity data were interpreted by the use of the catalogue of master curve types, by 1D inversion approach and by apparent resistivity map approach as used by Nejad et al. (2011).

This paper emphasizes the importance of the use of EM inversion in the interpretation of EM34-3 data and its integration with the conventional qualitative interpretation of data obtained from EM34-3 for groundwater explorations. It demonstrates the usefulness of apparent resistivity maps in VES data interpretation together with the 1D inversion of VES data, particularly in the case where there is limited data for 2D or 3D inversion and in a project with limited funds.

1.1. Study Area

The study area comprises of three communities namely; Achiase, MbaaMpeHia No 2 and Moseaso (Figure 1) which are located within the Twifo – Hemang Lower Denkyira district of the Central Region of Ghana. The district is located between latitudes 5°50’N and 5°51’N and longitudes 1°50’W and 1°10’W. The district lies in the semi - equatorial climate zone marked by double maxima rainfall. The mean annual rainfall range between 1,750 mm and 2,000 mm with the wettest period in June and October and the driest in March. It has fairly high uniform temperatures ranging between 26° C (in August) and

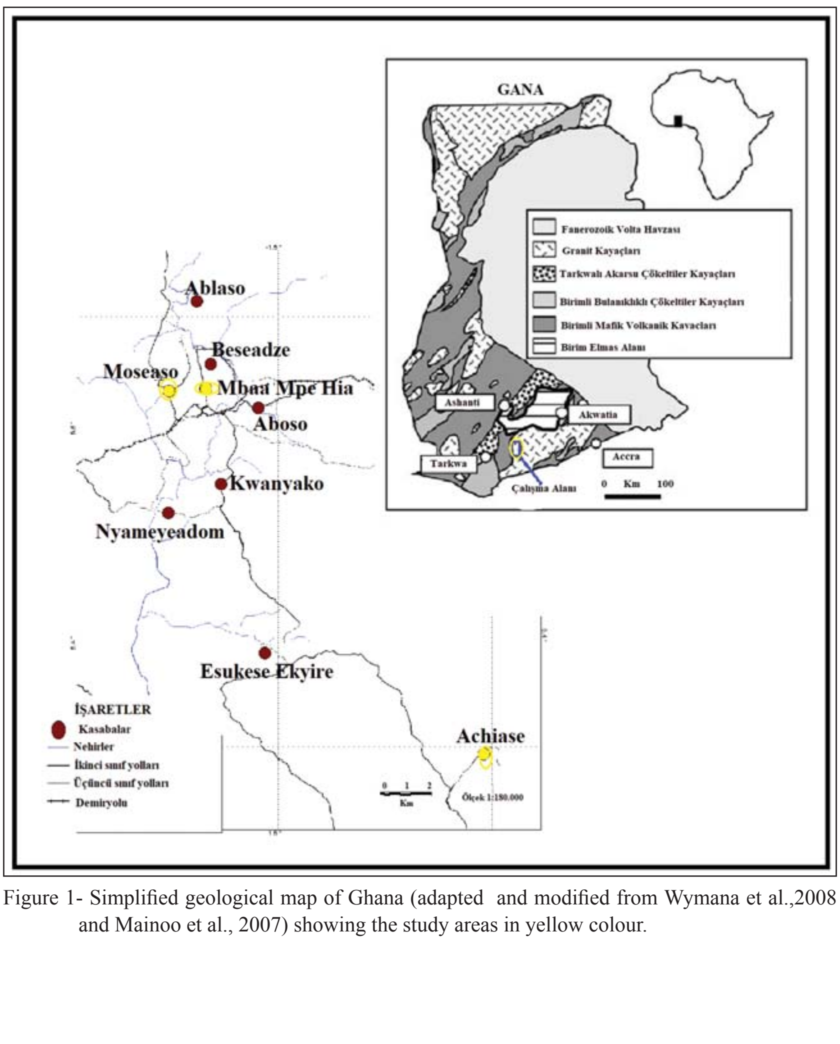


Figure 1- Simplified geological map of Ghana (adapted and modified from Wymana et al.,2008 and Mainoo et al., 2007) showing the study areas in yellow colour.

30°C (in March). The vegetation in the district consists of basically two forest types; the tropical rainforest to the South and the moist semi-deciduous forest to the North. The vegetation has been largely disturbed by human activities through farming and logging among others (Anon, 2012).

Basic granitic intrusives and granites underlie almost all the study area. Major rock types comprise of well - foliated, medium-grained, potash-rich muscovite-biotite granites, granodiorites and pegmatites (Figure 1). Granites found in the study area are Post-Tarkwaian and can be divided into three groups: Bongo Granites, Dixcove Granite Complex and Cape Coast Granite complex.

The Cape Coast granites are often associated with schists and gneisses, and intrude the Lower Birimian meta-sediments. One characteristic of the granite is that it is not inherently permeable, but secondary permeability and porosity have developed as a result of fracturing and weathering (Gyamera and Kuma, 2014).

Intense weathering along fractures and veins had permitted water percolation to form groundwater reservoirs. Aquifers are therefore located where secondary porosity has developed. The two main aquifer types are (i) the weathered zone or 'regolith', which develops on the crystalline basement rocks, and (ii) fracture zones within the bedrock (Mainoo et al., 2007).

2. Methodology

Two geophysical methods namely; DCR and Slingram (HLEM) were used in this work.

2.1. HLEM Survey

Electromagnetic apparent conductivity values were obtained using both horizontal dipole (HD) and vertical dipole (VD) modes at 20-meter spacing.

Graphs of apparent conductivities or the terrain conductivity (in mhos/m) on vertical axes versus station intervals (in meters) on horizontal axes were plotted. Our interest is in the vertical conductors and since VD orientation is relatively sensitive to vertical conductors (Thamke et al., 1998), therefore points where the VD conductivities exceeded the HD conductivities were noted for VES measurements. Other points were also selected for VES point based on experience. Points near waste dumps and toilet facilities or under a roofing of buildings were avoided, although these points may have high conductivities or crossover points.

AEMINV (Pirttijärvi, 2014) computer program was used for inversion and interpretation of the obtained data. The computer program was originally developed for geophysical interpretation of frequency-domain airborne electromagnetic (AEM) data using one-dimensional (1-D) layered earth model, it can also be used to interpret ground EM data as was used here.

According to the user's guide to the program (Pirttijärvi, 2014); the model parameters are the electrical resistivity and thickness of the layers and the resistivity and magnetic susceptibility of the basement layer. The inversion is made independently for each profile point using one-dimensional layered earth model. A resistivity pseudo-section is obtained by plotting the resistivity-thickness values below adjacent data points with coloured rectangles. Starting from an initial model an iterative linearized inversion with adaptive damping is used to update model parameters so that the data error, i.e., the difference between the measured and the computed data is minimized. Laterally constrained inversion is achieved by minimizing the roughness of the model, i.e. the variation of the model parameters between neighbouring points together with the data error. As a result of the constrained (Occam) inversion, a smoothly varying resistivity-thickness model is obtained. The roughness and/or the fix/free status the parameters can be set manually to allow discontinuities and to incorporate a priori data in the model (Pirttijärvi, 2014).

2.2. DCR Survey

The VES measurements were done in selected locations along the EM profiles and they were carried out using an ABEM Terrameter SAS 1000C and the Schlumberger electrode array with a maximum AB/2 spacing of 83.0 m.

The quantitative interpretations were done using RES1D inversion (Loke, 2001). The model parameters of the 1D inversion are the electrical resistivity, the thickness of the layers and the depth of the layers from the Earth surface.

Two qualitative methods of interpretation were used. These methods are the catalogue of master curve types method and the apparent resistivity map (2D pseudo resistivity maps) method. Corrected apparent resistivity values were used in creating the apparent resistivity maps. The aim of the project which is to locate points of high groundwater potential for hand dug or drilling of groundwater for public water supply. Because of this aim, the apparent resistivity maps were created using a specific colour scale.

Based on available data information on existing boreholes in and around 5 Km radius of the study areas (see table 1) and the estimated 1D earth models based on 1D inversion results the VES, presence of groundwater within aquifers in the study areas were classified as; high amount of groundwater (0 – 200 Ωm); moderate amount of groundwater (200 – 500 Ωm); little amount of groundwater (500 – 800 Ωm); very little amount of groundwater (800 – 1100 Ωm) and lastly zones with no water ground (≥1400 Ωm). With the estimated 1D earth models as the main models and supported by apparent resistivity maps as 2D pseudo resistivity maps, recommendation for drilling a well at a point is given when the point falls within the first three classes or groups. Unless the community has generally low level of groundwater, points within the fourth class never get recommended. The main aim for using this kind of model is to recommend points where well could run throughout the year.

The apparent resistivity maps as used in this work, reflect the lateral variation of apparent resistivity of subsurface over a horizontal plane at a certain depth (Nejad et al., 2011). The concept utilised in creating the apparent resistivity maps is the rule-of-thumb that; the maximum exploration depth or depth of penetration of AMNB method is 1/3 to ¼ of the maximum distance of AB (Frohlich et al., 1996). Safest exploration depths according to ¼ of max AB/2 were used to construct

Table 1- Available data information on existing boreholes in and around 5 Km radius of the study areas.

Available data on existing boreholes in and around 5 Km radius of Achiase Community			
Community	**BH No.**	**Depth (m)**	**Lithology**
WATRESO	27/I/51-1	26	Gneiss
WATRESO	27/I/51-2		
NYAMEBEKYERE	27/H/68-1	28	Quartz Diorite
NYAMEBEKYERE	27/H/68-2	34	
NYAMEBEKYERE	27/H/68-3	40	
NYAMEBEKYERE	27/H/68-4	37	Granite
NYAMIENI	27/H/59-1	40	
NYAMIENI	27/H/59-2	40	
Available data on existing boreholes in and around 5 Km radius of Moseaso Community			
Community	**BH No.**	**Depth (m)**	**Lithology**
NYENASI	48/E/79-2	73	
Available data on existing boreholes in and around 5 Km radius of Mbaa Mpe Hia No. 2 Community			
Community	**BH No.**	**Depth (m)**	**Lithology**
NYENASI	48/E/79-2	73	
TWIFO PRASO	48/F/74-1	27	Schist
TWIFO PRASO	48/F/74-2	28	Schist
TWIFO PRASO	48/F/74-3	31	Schist
TWIFO PRASO	48/F/74-4	28	Schist
TWIFO PRASO	48/F/74-5	37	Schist
TWIFO PRASO	48/F/74-6	28	Schist
TWIFO PRASO	48/F/74-7	25	Schist

the apparent resistivity maps at distances AB/2 = 1.5, 6.3, 27.0, 58.0 and 83.0 m. The drilling decisions were made based on the estimated 1D earth model and the apparent resistivity maps as a support to the estimated 1D earth model.

3. Results and Discussions

The EM 34-3 equipment was used for EM profiling to outline shallow conductive structures which might be associated with local groundwater circulation. EM profiling was conducted along eleven (11) profiles across the three communities.

Three EM traverses were run in the Achiase Community (Figure 2). One of the traverses has a length of 350 m and the other two have the length of 250 m. Generally the curves of traverse A and C display high terrain conductivity for HD than VD which is interpreted to mean general decrease in weathering with depth. Both HD and VD curves of all the traverses are erratic in nature which is interpreted to mean a complex subsurface structures beneath the study area. There are few crossover points on the graphs (see Figure 3) and these points together with a point with high VD conductivity values were recommended for further investigations.

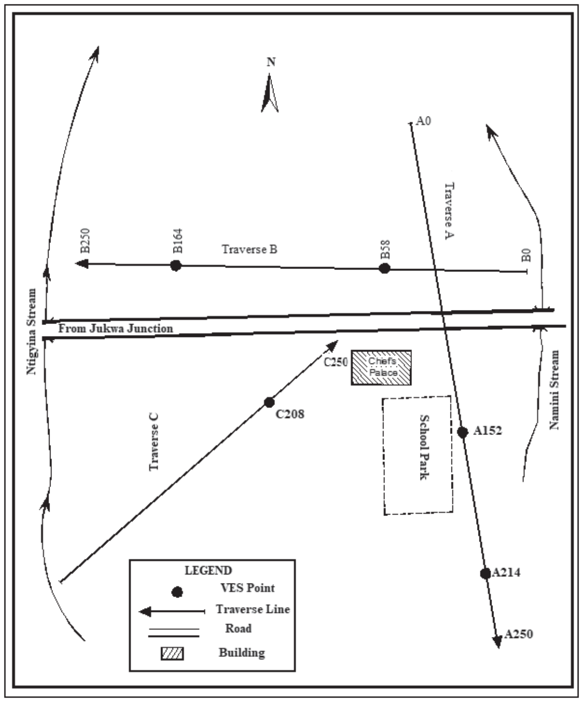


Figure 2- Schematic layout of Achiase Community (not to scale).

The VD inversion results (see Figure 4) revealed two layers beneath the study area with the first layer having a thickness range of 1 – 10 m and the second layer's thickness is half space. The resistivity values is

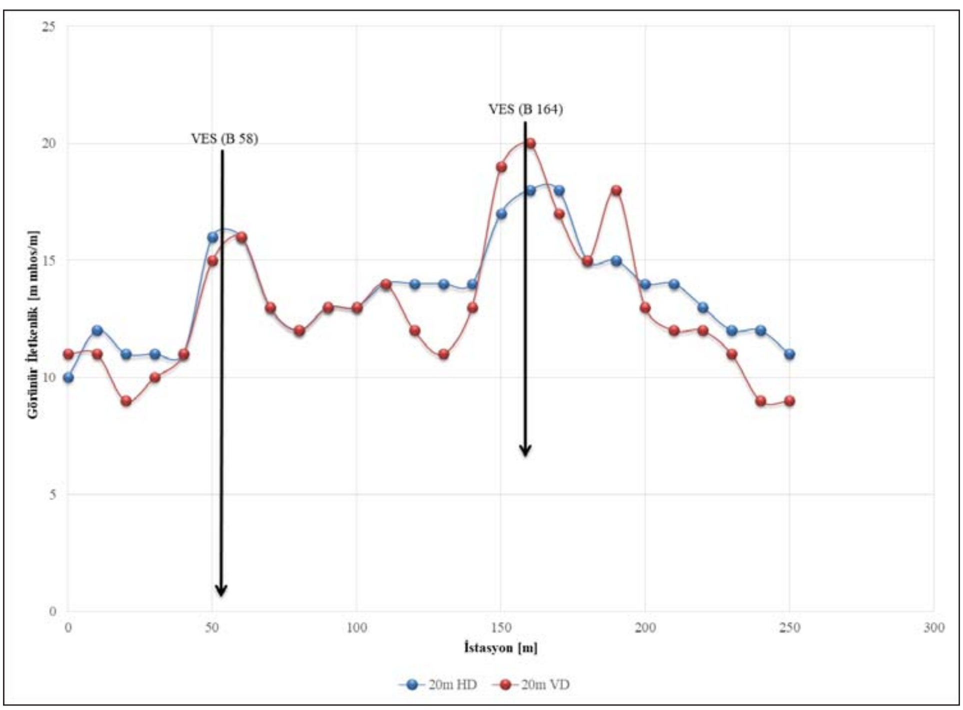


Figure 3- Terrain conductivity curves along traverse B in Achiase Community.

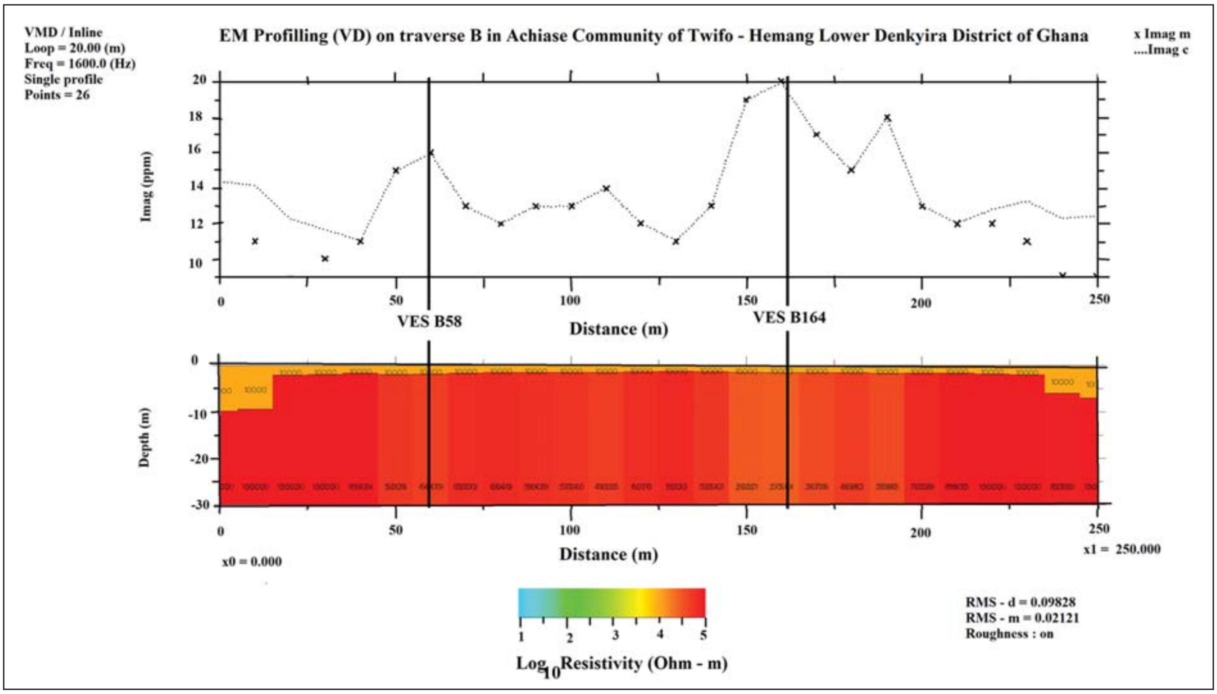


Figure 4- EM inversion result (VD mode) on traverse B in Achiase Community.

in logarithmic scale and the resistivity value of the first layer ranges from 2.5 – 3.5 Ωm. The resistivity value of the second layer is between 3.0 – 5.0 Ωm. There is a good agreement between the inversion results and the terrain conductivity graphs.

In Mbaa Mpe Hia No.2 Community, the EM profiling was conducted along four traverses (Figure 5). The traverse A was run in SSE – NNW direction, traverse B in NNW – SSE direction, traverse C in N – S direction and traverse D in SE – NW direction. The terrain conductivity distribution obtained from this community shows relatively high conductivity ranging between 7 mS/m and 18 mS/m. The profile lengths of all traverses run in this community were 250 m. figure 6 and 7 show the EM terrain conductivity and EM inversion along traverse B respectively.

In the Moseaso Community four traverses were conducted across it (Figure 8). Traverses B and D were conducted in E – W direction, traverse A in W – E direction and traverse C in the S – N direction. The traverse lengths in this community range between 200 m and 250m. The maximum terrain conductivity value is 16 mS/m and the minimum terrain conductivity value is 7 mS/m. The terrain conductivity values in this community are generally low. Figure 9 and 10 below display the EM terrain conductivity and EM inversion along traverse D respectively.

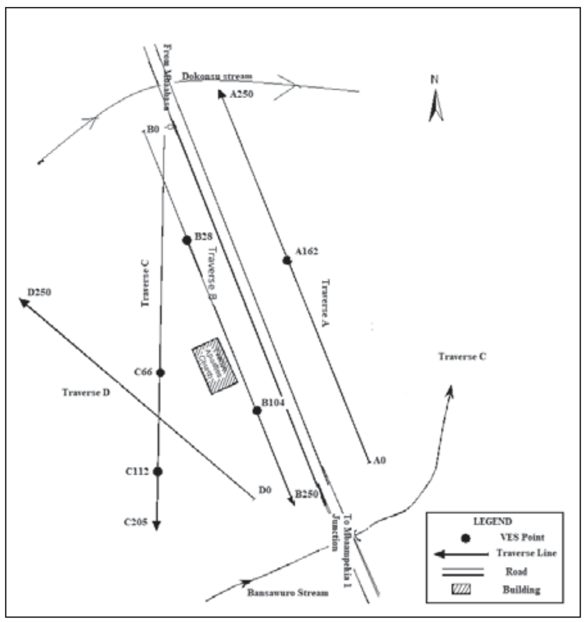


Figure 5- Schematic Layout of Mbaa Mpe Hia No. 2 Community (not to scale).

The EM inversion produced two-layered earth model for all profiles in the study areas. The model resistivity values range from 100 Ωm to 100000 Ωm, logarithm resistivity with an average 0.10% RMS difference between the measured and the calculated values. The study area is located within

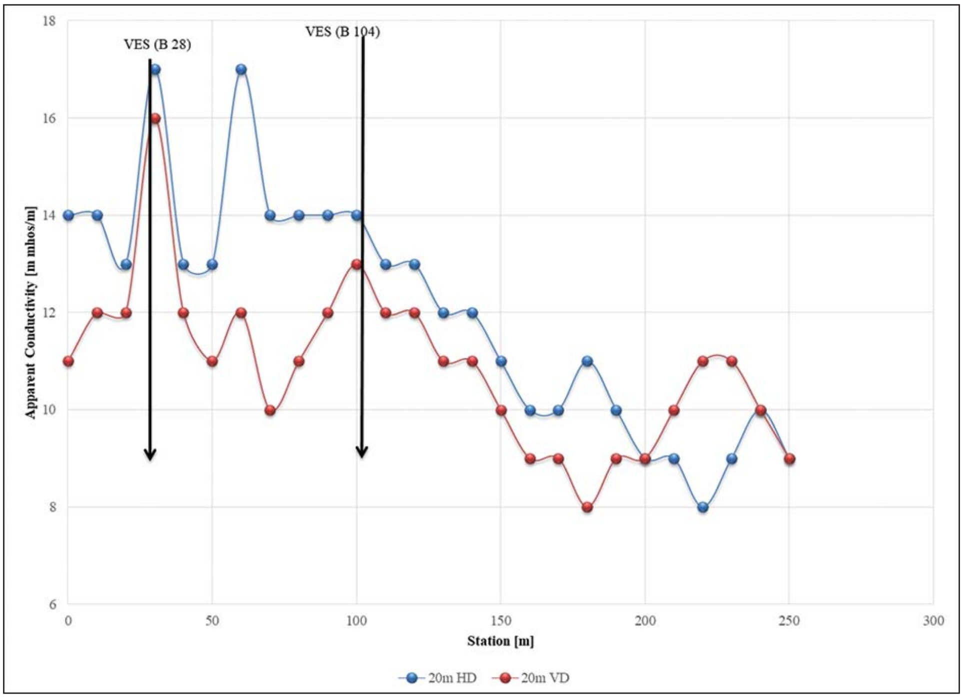


Figure 6- Terrain conductivity curve along traverse B in Mbaa Mpe Hia No.2 Community.

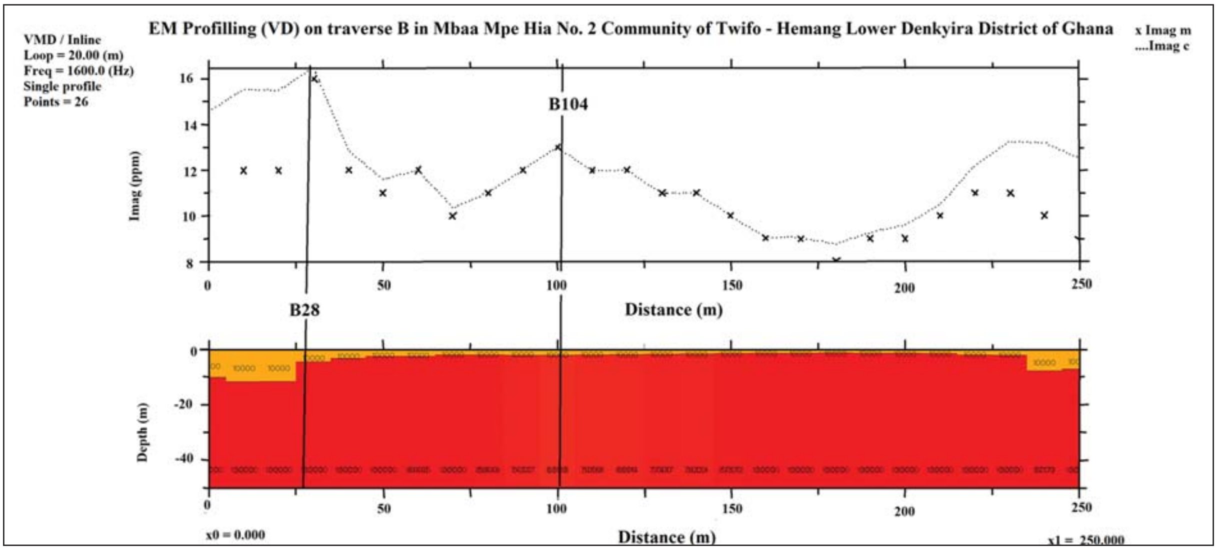


Figure 7- EM inversion results (VD mode) on traverse B in Mbaa Mpe Hia No.2 Community.

granite formation and the nominal resistivity values for granite ranges between $3x10^2$ to $3x10^6$ Ωm. The nominal resistivity values for weathered granite also ranges between $3x10^{-5}$ to $3x10^2$ Ωm (Reynolds, 1997). Increase in the interconnection of pores (permeability) and fractional volume of the rock occupied by water lead to the decrease in resistivity values. In this regard, sections on the EM inversion (Figures 4, 7 and 10) that displayed relatively low resistivity are interpreted to be associated with fractures and or weathering within the subsurface and are of interest in this work. Some points displayed low resistivity values but were not selected for further investigation, because they were located at points which have a high probability of groundwater contamination.

A total of 16 VES stations were recommended for further investigation using the DCR method across

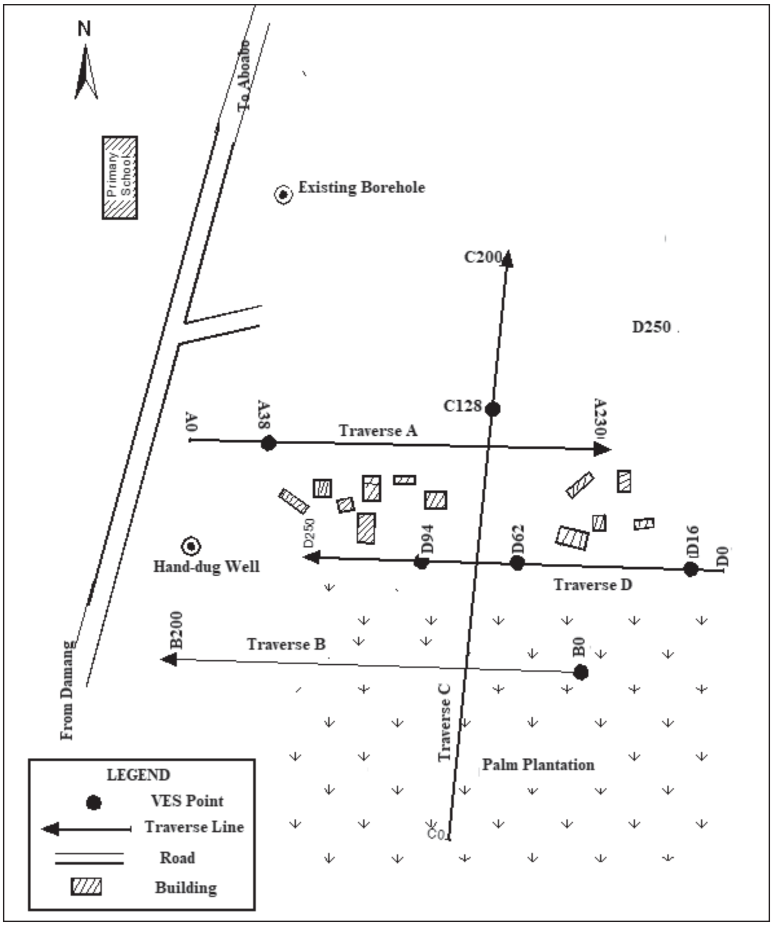


Figure 8- Schematic layout of Moseaso Community (not to scale).

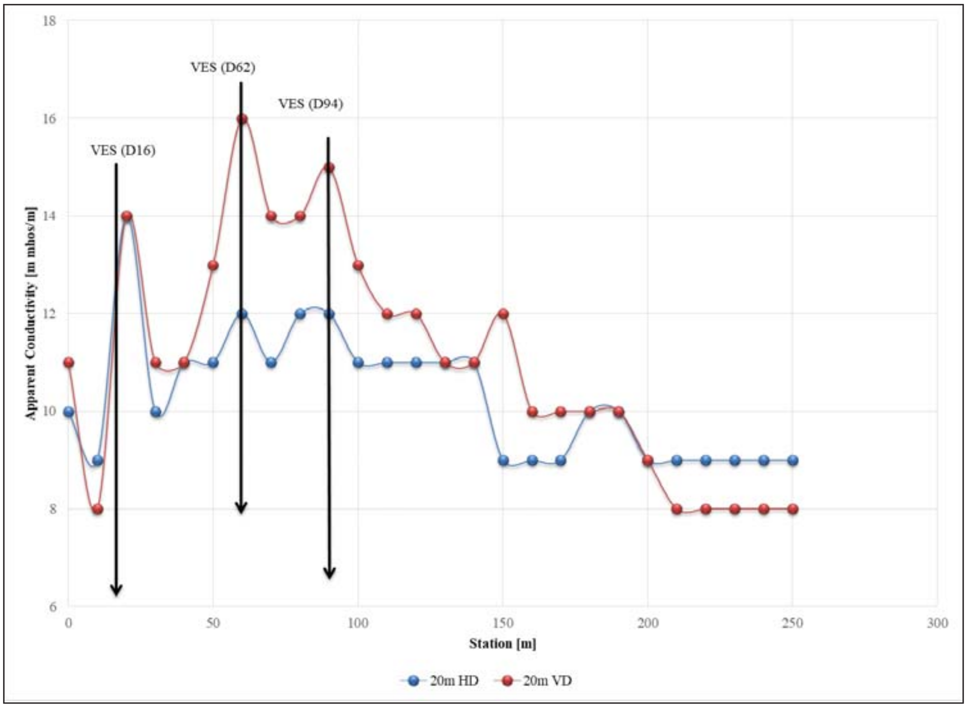


Figure 9- Terrain conductivity along traverse D in Moseaso Community

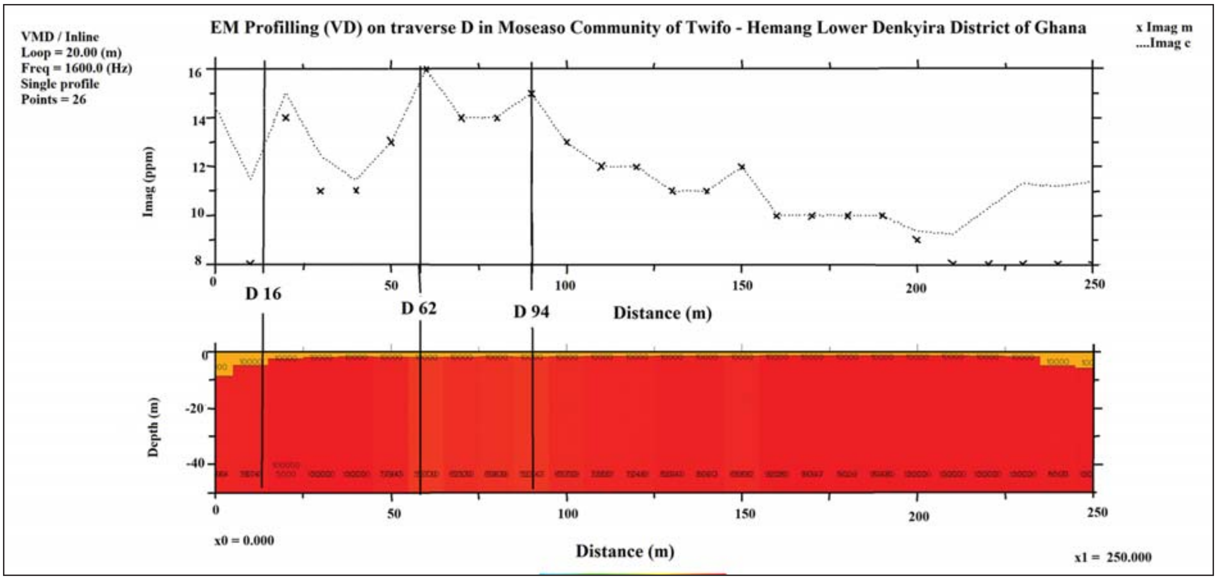
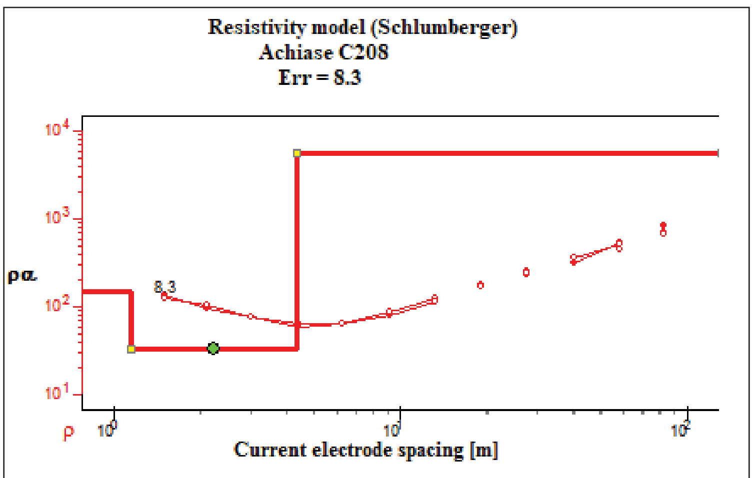


Figure 10- EM inversion result (VD mode) on traverse D in Moseaso Community.

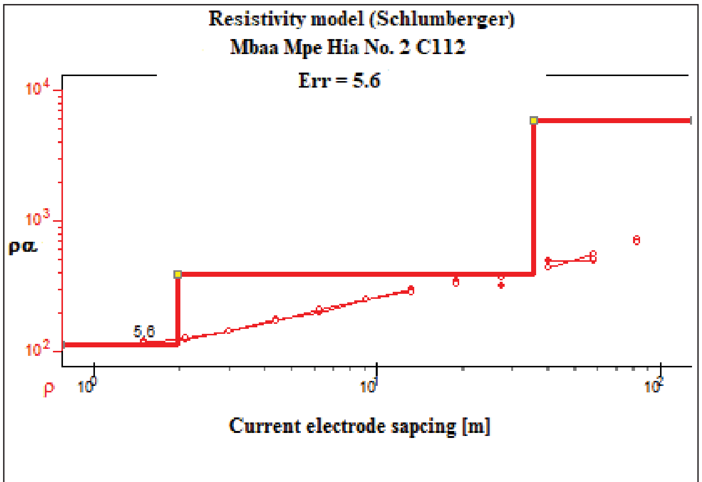
the three communities. See figures 11, 12 and 13 for some of the estimated 1D earth models based on 1D inversion results obtained from these communities. Six VES stations in the Moseaso Community and five VES stations each in Mbaa Mpe Hia No. 2 Community and Achiase Community.

The curve types obtained in the study include H, A, KH and QH. The dominant curve type is the H curve type with 43.75% occurrence, which is followed by the QH type having 25.00% occurrence. The A curve type has 18.75% and the KH types have 12.50% occurrence respectively. The H and KH curve types



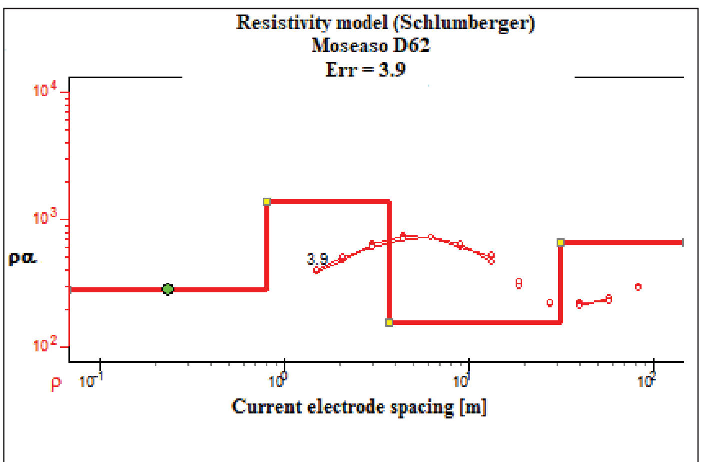
N	ρ	h	z
1	148.91	1.14	0/0
2	33.45	3.22	1.14
3	5721.62		4.36

Figure 11- 1D inversion result at station C208, Achiase Community



N	ρ	h	z
1	112.20	1.98	0/0
2	388.45	33.57	1.98
3	5962.44		35.55

Figure 12- 1D inversion result at station C112, Mbaa Mpe Hia No.2 Community.



N	ρ	h	z
1	283.27	0.80	0/0
2	1400.88	2.90	0.80
3	154.57	27.50	3.70
4	671.13		31.20

Figure 13- 1D inversion result at station D62, Moseaso Community.

are often associated with groundwater possibilities (Omosuyi, 2010, Okafor and Mamah, 2012).

Analysis of VES curves conducted within the Achiase Community revealed a 3 – layered structure. The first layers have thicknesses ranging from 1.10 – 5.82 m and resistivity values between 59.55 – 1204.4 Ωm. The second layers also have thicknesses ranging between 3.22 – 19.65 m and resistivity values ranging between 33.45 -289.28 Ωm. The bedrock has resistivity values from 2479 – 9815 Ωm. The shape of the sounding curves revealed only one A- type and four H- typed. According to the available data (Table 1) on 8 existing boreholes around the Achiase Community, the borehole depths are within the range of 26.0 – 40.0 m and average of about 35.0m. This depth range are comparable to the depths of aquifers as obtained from the VES inversion results in table 2.

Generally, from the 1D inversion results in table 2, it could be inferred that; the subsurface of the study area in the Achiase community is underlain by a good aquifer. This is because of the geology of the area. In this type of geology generally areas with low resistivity values are associated with aquifers. All VES stations might contain enough groundwater for public water supply beneath them. As it could be seen from figure 11, VES stations such as B164, A152 and C208 that show relatively low resistivity values as summaries in table 2. Also as it could be seen from both table 2 and figure 14 VES C208 might contain groundwater but because of the depth of the first two layers, it was ranked last in groundwater potential. Table 2 provides a summary of the VES results including a rank-list of the selected points for drilling.

The analyses of the VES curves from Mbaa Mpe Hia No.2 Community suggested that; the community is generally underlain by three geoelectrical layers although two VES station revealed four-layered structure. The first layer has resistivity value raging 112.2 – 653.70 Ωm and may be intercepted at a mean depth of 1.51 m. The second layer which is generally expected to be the water-bearing layer has a thickness range of 3.10 – 33.57 m has a mean resistivity value of 256.65 Ωm. The third layer has resistivity value ranging 120.97 – 9347.90 Ωm.

From table 1, the 8 existing boreholes around the Mbaa Mpe Hia No.2 Community have depths ranging from 25.0 – 73.0 m and the average depth of about 34.5 m. Comparing the information in table 1 with the VES results in table 3, only one out of the five VES station have expected aquifer depth within that range. The boreholes reported in table 1 are in and around 5Km from Mbaa Mpe Hia No.2 Community and that there

Table 2- Ranked VES points (summary of 1D inversion results) for borehole drilling at Achiase Community

VES Point	Layer	P(Ω-m)	Depth (m)	Thickness (m)	Rank	Location (GPS)	Curve Type
B 164	1 2 3	59.55 89.84 9815.42	1.1 20.75 -	1.1 19.65 -	1	5.29323 K 1.30728 B	A
B 58	1 2 3	1232.85 240.06 43868.7	0.83 22.29 -	0.83 19.65 -	4	5.29356 K 1.30728 B	H
A 214	1 2 3	756.05 289.28 2479.11	2.91 13.63 -	2.91 10.72 -	3	5.29275 K 1.30651 B	H
A 152	1 2 3	752 180.71 8310.8	5.82 13.33 -	5.82 7.51 -	5	5.29303 K 1.30833 B	H
C 208	1 2 3	148.91 33.45 5721.62	1.14 4.36 -	1.45 3.22 -	2	5.29256 K 1.30833 B	H

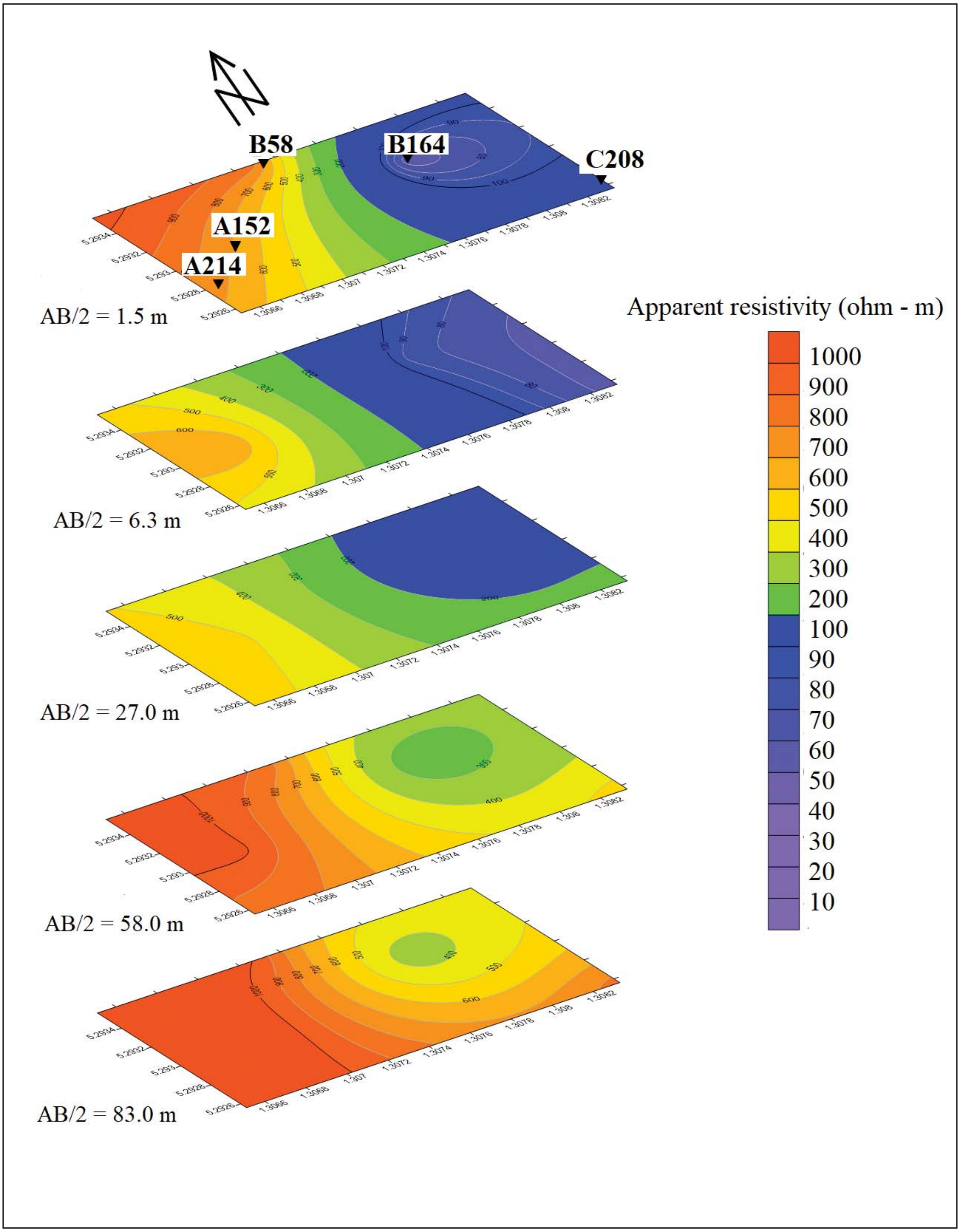


Figure 14- Apparent resistivity maps in Achiase Community.

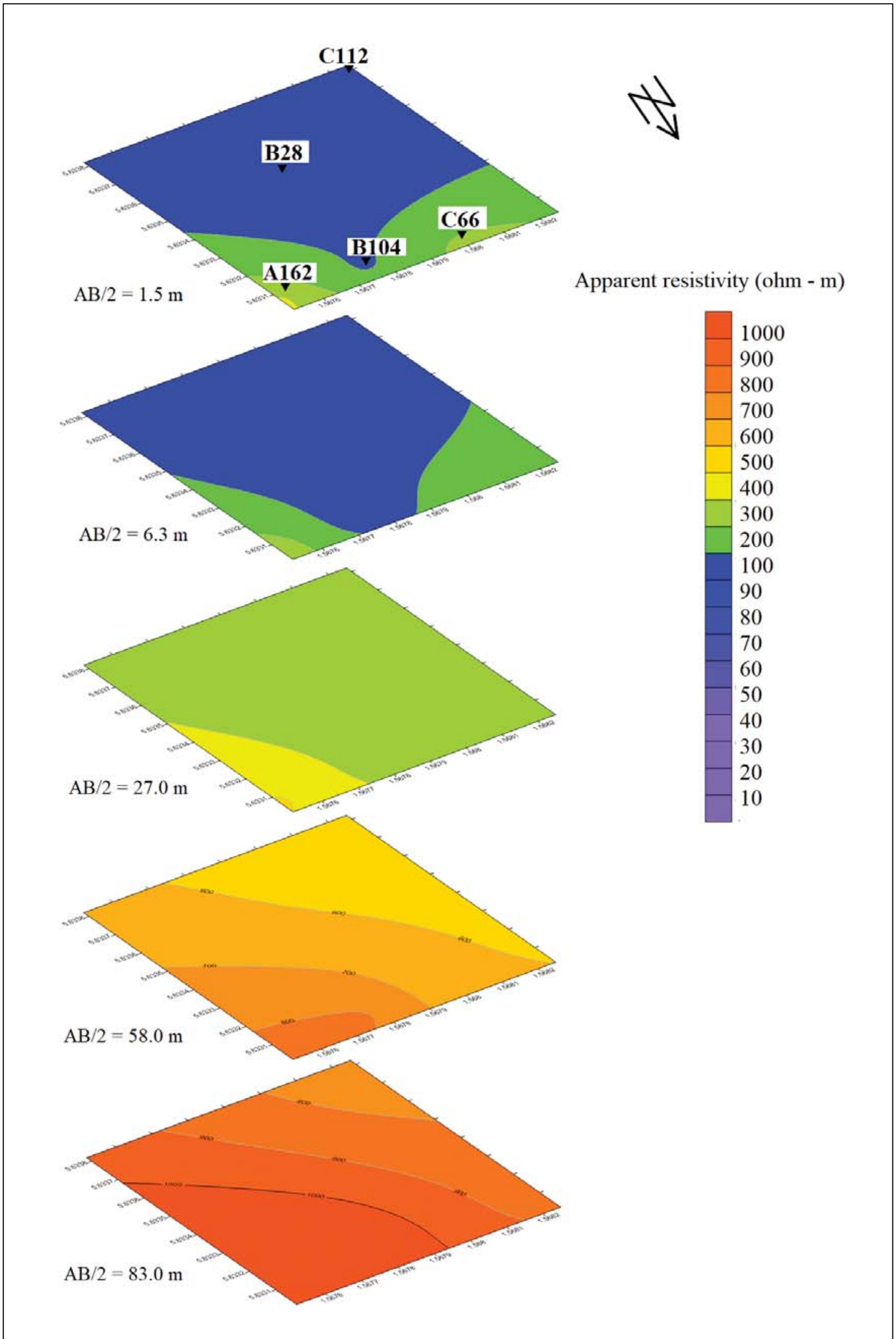


Figure 15- Apparent resistivity maps in Mbaa Mpe Hia No.2 Community.

Table 3- Ranked VES (summary of 1D inversion results) points for borehole drilling at Mbaa Mpe Hia No.2 Community.

VES Point	Location (GPS)	Layer	P(Ω-m)	Thickness (m)	Depth (m)	Rank	Curve Type
C 112	5.63382 K 1.56825 B	1 2 3	112.2 388.45 5962.44	1.98 33.57 -	1.98 35.55 -	1	A
B 28	5.63352 K 1.56786 B	1 2 3	122.32 148.35 3573.44	1.88 9.1 -	1.88 10.98 -	2	A
B 104	5.63308 K 1.56776 B	1 2 3	192.54 121.85 9347.9	1.6 6.77 -	1.6 8.37 -	3	H
A 162	5.63307 K 1.56752 B	1 2 3 4	438.54 391.37 296.56 4061.89	1.5 3.1 11.67 -	1.5 4.6 16.27 -	4	H
C 66	5.63302 K 1.56800 B	1 2 3 4	653.7 233.21 120.97 4241.54	0.6 3.5 6.9 -	0.6 4.1 11 -	5	QH

might be a change in lithology. Generally, in Mbaa Mpe Hia No.2 Community the expected aquifers are shallower than those boreholes reported in table 1.

It can be seen from table 3 that; all the first three layers have relatedly low resistivity values with maximum aquifer depth of 16.27 m. Base on the 1D inversion results as summarized in table 3, it could be inferred that; generally, all the VES points investigated might contain an appreciable amount of groundwater. This could also be seen on the apparent resistivity maps in figure 15. VES C112 is ranked first, followed by VES B28, B104, A162, and C66.

The VES results suggested that Moseaso Community is generally underlain by four geoelectrical layers. Out of the five VES stations investigated, only one station revealed three layered model for the subsurface. Generally, the first layer has resistivity values ranging from 179.63 – 1206.62 Ωm and can be intercepted at a mean depth 2.83 m. The second layer has a thickness range of 2.90 – 12.36 m, and a mean resistivity value of 892.73 Ωm. The third layer which is expected to be water-bearing has a thickness ranging from 12.20 - 28.8 m and a mean resistivity value of 794.21 Ωm. The fourth layer has resistivity values ranging between 671.13 Ωm and 2572.31 Ωm (Figure 16).

In table 1 information of only one borehole around 5 Km from this community is shown and that the depth of the borehole is 73 m. Two wells are shown in the Schematic Layout of Moseaso Community (Figure 8) but information from only one well (Existing borehole) is available. And that the information on the existing borehole which is available is the VES result and it is shown in table 4 below. From the table 4 we can see that the existing borehole (EBH) has a shallow depth compared to results we obtained from this work. 1D inversion results in table 4 and the support of figure 12 show that areas around the existing borehole might contain good aquifer than areas we investigated. In future groundwater exploration project, interest should be given to areas towards the north of this community around the existing borehole as could be seen in figure 8.

By comparing 1D inversion results in tables 2 – 4, it could be inferred that Moseaso Community has the best aquifer among the three communities.

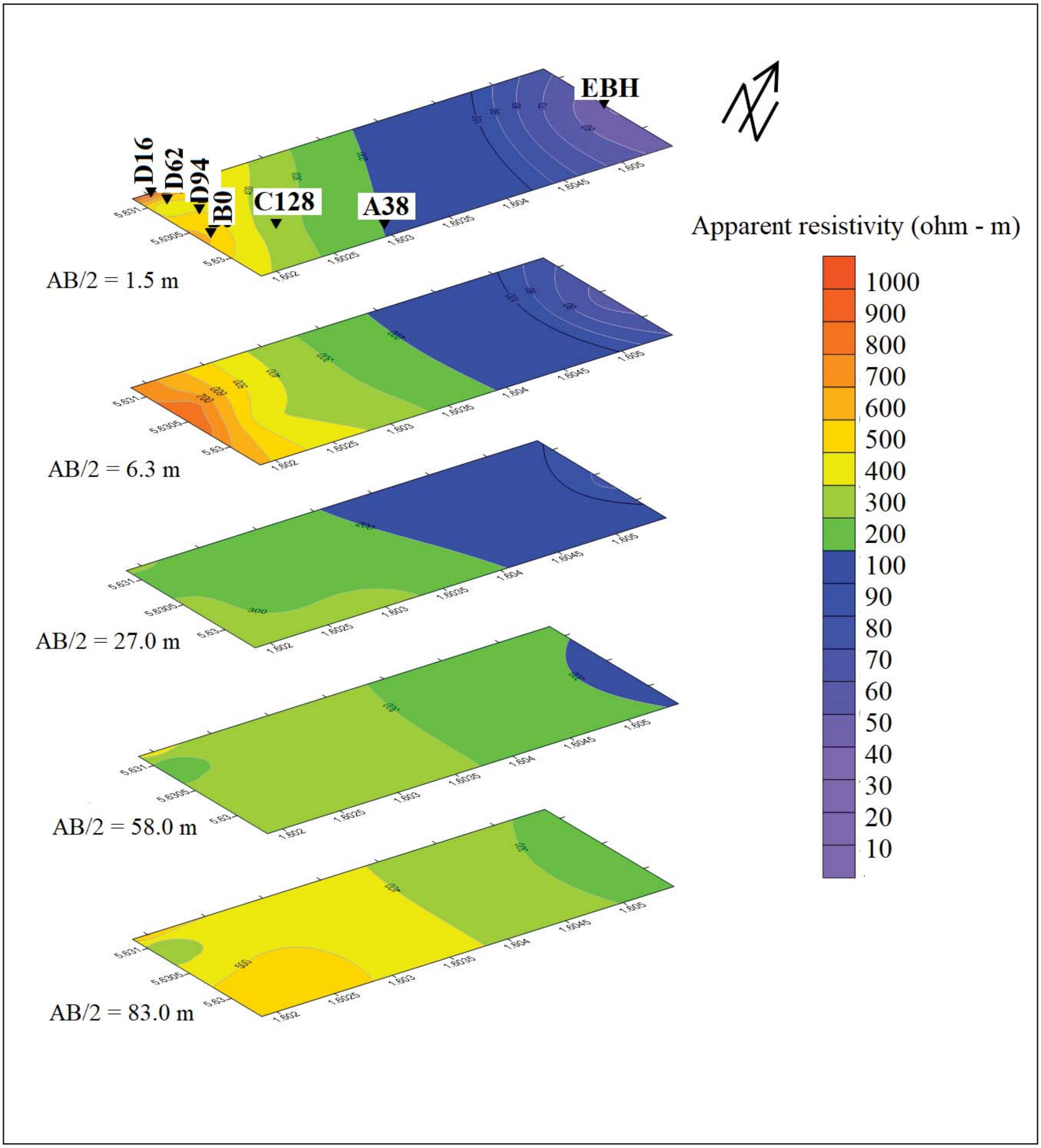


Figure 16- Apparent resistivity maps in Moseaso Community.

Table 4- Ranked VES (summary of 1D inversion results) points for borehole drilling at Moseaso Community.

VES Point	Layer	P(Ω-m)	Depth (m)	Thickness (m)	Rank	Location (GPS)	Curve Type
A 38	1 2 3 4	179.63 940.32 199.98 1287.38	1.66 6.46 27.36 -	1.66 4.8 20.9 -	6	5.62964 K 1.60300 B	KH
D 62	1 2 3 4	283.27 1400.88 154.57 671.13	0.8 3.7 31.2 -	0.8 2.9 27.5 -	1	5.63095 K 1.60199 B	QH
D 94	1 2 3 4	399.13 1422.52 216.74 895.42	0.77 3.84 32.64 -	0.77 3.07 28.8 -	2	5.63069 K 1.60206 B	QH
D 16	1 2 3 4	1206.62 521.33 209.14 1992.83	2.49 9.8 25.6 -	2.49 7.31 15.8 -	5	5.63118 K 1.60200 B	QH
B 0	1 2 3 4	643.81 986.1 83.51 2572.32	0.95 8 12.2 -	0.95 8 12.2 -	3	5.63036 K 1.60187 B	KH
C 128	1 2 3	417.77 115.21 3901.36	10.34 22.7 -	10.34 12.36 -	4	5.63024 K 1.60238 W	H
Mevcut Makine Kazılmış Kuyu (EBH)	1 2 3	61.5 34 1568.7	5.8 12.7 -	5.8 6.9 -		5.63035 K 1.60544 B	

4. Conclusion

The importance of water to us as living things cannot be underestimated, because it is a basic necessity of life. Although we depend on water for both our domestic and industrial activities most people and communities are not ready to pay much for groundwater exploration using geophysical methods as they could pay for other exploration methods, because of some economic factors. Electromagnetic methods especially the EM 34-3 and electrical resistivity methods still remain the cheapest and effective methods for geophysical exploration of groundwater. Data interpretation methods such as the use of inversion for interpreting electromagnetic data rather than the usual qualitative interpretation method using line graphs and use of apparent resistivity maps as 2D pseudo resistivity maps to support the 1D resistivity inversion results (in case the available budget could not permit 2D and or 3D inversion) would help enhance the quality of obtained results, reduce ambiguity and help decision making based on the obtained results.

The quantitative interpretations of EM method were used in the selection of points for the VES investigation of groundwater in this study. The EM results show that all the three communities were underlain by two geological substrata. The first layer is the topsoil with depth ranging from 2 to 10 m and the second layer is a half space. The decision on selection of the traverse for further investigation is based on the resistivity of the second layer. The resistivity values of the EM inversion results range between 100 Ωm to 100000 Ωm.

16 VES stations were selected across the three communities for further investigations and their results revealed that; Achiase Community and Mbaa Mpe Hia No. 2 community are underlain by three geological substrata and Moseaso Community is underlain by four geological substrata. All VES points investigated show evidence of groundwater availability and hence are recommended for drilling or hand – dug wells. Boreholes or wells are to be drilled or hand-dug based on the rank stated in tables 2-4. From the results of VES investigations, Moseaso Community is ranked highest in terms of groundwater availability followed by Achiase community and finally Mbaa Mpe Hia No.2 Community.

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