Application of Electrical Resistivity Method in Mapping Sand and Gravel Beds along Njaba River Bank, South-Eastern Nigeria

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Abstract :- **Electrical resistivity method was adopted in mapping sand/gravel beds for commercial mining and delineation of water table in Njaba river bank and environs. To achieve this, 10 vertical electrical soundings (VES) were carried out within the study area. Along the Njaba river bank, one profiling using the Wennerelectrode array was also carried out to determine the lateral extent of the sand/gravel beds. Field data were acquired using the Ohmega-500 resistivity metre and accessories. The Schlumberger electrode configuration with maximum electrode spread of 700m was adopted. At each VES point, the coordinates and elevation were measured using the Global Positioning System (GPS). The field data were interpreted using Advanced Geosciences Incorporation (AGI) 1D software and the Schlumberger automatic analysis version. The results revealed that the area is underlain by multi-geoelectric layers with about 7 to 9 lithologic units identified. Sand and gravel were mapped along Njaba river bank to a depth of about 5 to 10 m and at Amucha erosion site. The beds are thick enough for commercial mining for building and construction materials. The profiling along Njaba river bank shows the lateral extent of the sand/gravel bed with concentration increasing towards the river. The depth to aquifer varied across the study area while aquifer resistivity ranged from 0.10Ωm to 14978.2Ωm. The aquifer is thick enough especially around Njaba area for drilling water boreholes as alternative source of potable water to the polluted Njaba river.**

Keywords: **Resistivity, Gravel bed, Groundwater, Sand, River bank.**

I. INTRODUCTION

Alternation of sand and gravel beds is more pronounced along river banks. Gravel bed is expected to show high resistivity over sand even at varying moisture content. Sand and gravel are widely used in the construction of roads, buildings and erection of other engineering structures. They could be sold or exported to generate revenue. Akaolisa and Selemo (2009) observed that over the years, there has been limited interest in the exploration of sand and gravel minerals by Geoscientists and other investors in the solid mineral industry within the sedimentary formation of Nigeria, particularly in areas with thick vegetation and non-existence of outcrops. The major constituents of any engineering structure, by volume or weight are aggregates (sand and stone). Very few structures in their permanent forms are made without the aggregates. Before these aggregates get incorporated into the structures, they undergo series of processes which entail multiple handling, involving various types of labour and machines. This no doubt gives rise to a multiplier effect on the socio-economic life of the society (Idiake, 2016)

The demand for sand and gravel has continued to increase owing to increasing rate of urbanization and industrialization. Local mining of sand and gravelat shallow depths has been going on along the bank of Njaba River for many years now as building and construction materials (Fig.1 and Fig.2).It has therefore become necessary in this study to explore deeper deposits using electric drilling method.

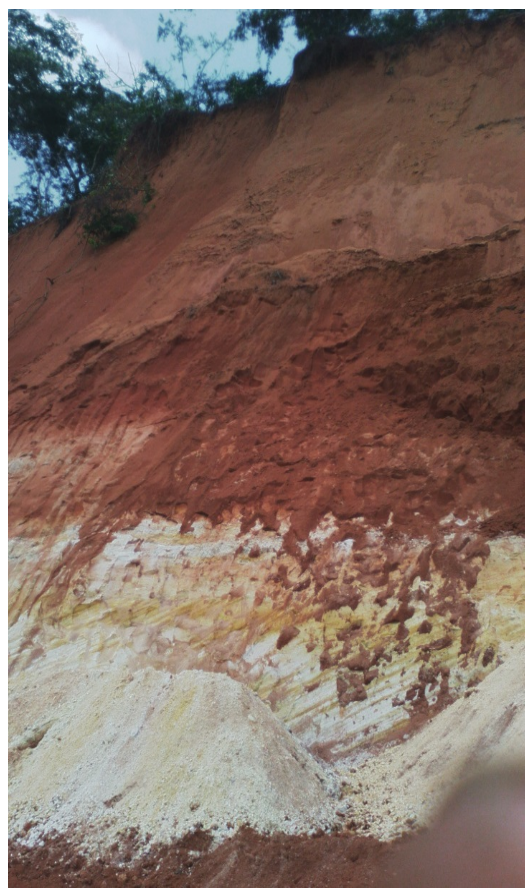


Fig.1 Sand and Gravel local mining site at Njaba river bank

It is worthy of note that if proper mining method is not adopted, extraction of gravel and sand can give rise to adverse ecological consequences (Akaolisa and Selemo, 2009). Some abandoned pits resulting from mining activities are threats to public safety due to their dangerous vertical walls that are prone to landslides after heavy rains that enhance saturation and liquefaction (Fig.2). In some places, abandoned pits are filled with runoff water from adjoining lands to become ponds. More often children use the ponds as swimming pools, and many can drown in the process (Nwachukwu and Mbaneme, 2012). Also such pits containing stagnant water become breeding ground for vectors like mosquito and tsetse fly. Often abandoned pits not containing water serve as dump sites of unserviceable vehicles. They can also be used for illegal dumping of urban wastes and hide-out for criminals. When these situations arise close to residential areas, more socio-environmental problems confront residents (Nwachukwu *et al*., 2017). Hence there is need to explore the mineral deposit in nearby communities in order to reduce concentration of mining activities in a particular location.

Fig.2 Sand and Gravel local mining site at Njaba river bank

Furthermore, the commercial mining activities apart from the economic benefits have made the NjabaRiver vulnerable to contamination. The river which is the major source of water for the communities in Njaba has become polluted and shown discoloration (Fig.3). Sand and gravel have high porosity and permeability and so are good aquifers. Hence, delineation of sand and gravel is therefore an indication of groundwater potential of the study area.

In this study, effort is made to map sand and gravel beds along Njaba river bank and environs; and at the same time assess the groundwater potential of the communities for development of alternative source of potable water supply.

Fig 3 The Njaba River

This study will delineate sand and gravel beds in neighbouring communities other than Njaba river bank. This will assist in formulating policies that will shift concentration of mining activities at Njaba river bank which may result in land slide apart from the pollution of the river. The result of this study will provide site for productive water boreholes as alternative to polluted surface water.

Location and Description of the Study Area

The study area is located in Imo State in the South-eastern part of Nigeria. It lies between latitude $5^0$30'N to $6^0$00N' and longitude $7^0$20'E to $7^0$50E(Fig. 4).

The area is accessible and has both tarred and un-tarred link roads. The Orlu/Mgbidi road, Owerri/Orlu road join Orlu/Okija road and Orlu/Uruala road at Orlu main town. The main river that drains the study area is Njabariver(Fig.3) which flows through the communities around Okwudo and Amucha. Flanking the Northern part of the study area around Mgbee community is the Orashi River. The study area is characterised by vast flat land and few ridges. Thus the terrain is characterised by two types of land forms, the high undulating ridges and nearly flat topography with elevation ranging from about 90m to 180m.

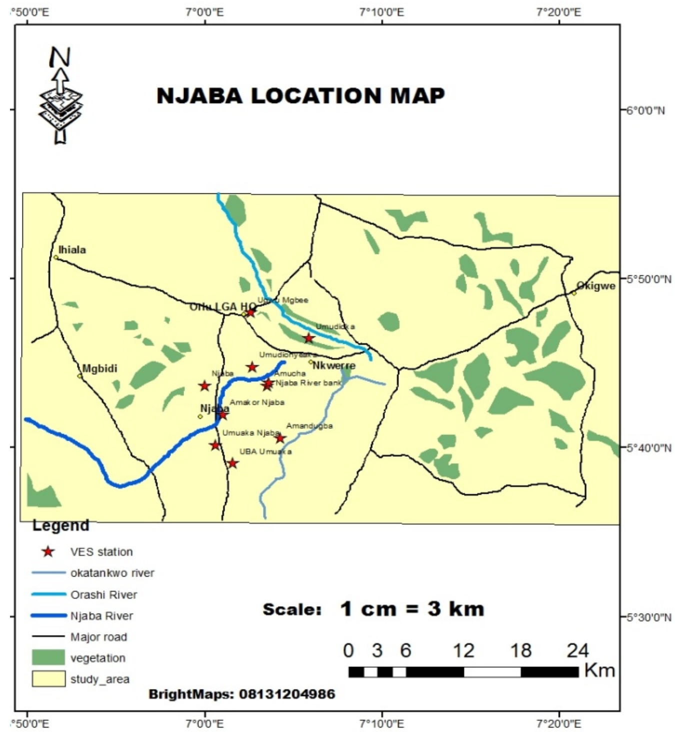


Fig . 4: Map of Imo state showing Njaba and environ

Geology of the Study Area

Figure 5 is the geological map of Imo River Basin in which the study area is located. The stratigraphic units that form the sedimentary sequence are: The Benin Formation, Ogwashi-Asaba Formation, Bende-Ameki Formation, Imo shale Formation, Nsukka Formation and Ajali Formation.

The greater part of the study area is underlain by the Benin Formation. The formation which is Pliocene to Miocene in age consists of Coastal Plain Sands with minor clay beds. The Formation contains some isolated gravels, conglomerates, and very coarse sandstone in some places. Thickness of the Formation is about 800m at its depocenter while the mean depth to water table is about 24m (Nwachukwu*et al*, 2010). The Benin Formation is overlain by alluvium deposits and underlain by Ogwashi-Asaba Formation which consists of lignite, sandstones, clays and shale. The Benin Formation provides the condition for groundwater storage because of its high porosity and permeability.

The sand units which are mostly fine-medium-coarse grained and poorly sorted contains lenses of fine grained sands (Whiteman, 1982; Uma and Egboka, 1985; Nwosu*et al*., 2013).

The youngest deposits in the basin are alluvium of recent age found mainly at the estuary of the Imo River at the Atlantic Ocean and on the flood plains of the river (Onwuegbuche, 1993). The Imo river basin has a large amount of recharge;

estimated at 2.5billion cubic meter per annum, coming mainly from direct infiltration of precipitation. Average annual rainfall is about 200mm (Onwuegbuche, 1993). The Benin Formation is by far the most aquiferous units consisting mainly of massive continental sands, sandstone and gravels. It has very extensive deep unconfined aquifer which covers more than half of the Imo river basin. The aquifer consists of thick complex inter-bedded units of fine, medium and coarse-grained quartz and gravels (Uma, 1989).

(A)

Map of Study Area within Imo River Basin, South-Eastern Nigeria

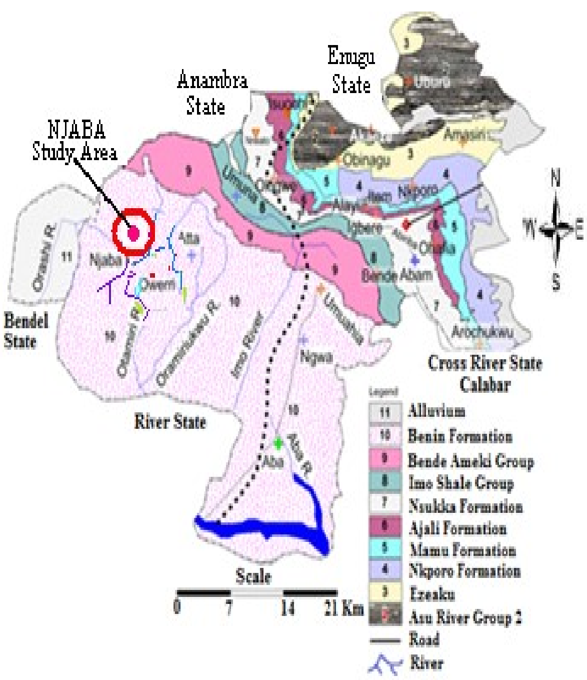


Fig.5 : Geology Map of Imo River Basin showing the Study Area – NJABA, *After Nwachukwu et al. (2017)*

The Ogwashi-Asaba Formation is made up of variable successions of clays, sands and grits with seams of lignite.

The Ameki Formation consists of greenish-gray clay sandstones, shale and mudstones with inter-bedded limestone. This formation in turn overlies the impervious Imo shale group characterized by lateral and vertical variations in lithology. The Imo shale of Paleocene age is laid down during the transgressive period that followed the cretaceous. It is underlain in succession by Nsukka Formation, Ajali Sandstones and NkporoShales.

Due to the porous and permeable nature of the Benin Formation coupled with the overlying lateritic earth and weathered top of this formation as well as the underlying clay/shale member of the Bende-Ameki Formation series, this geologic zones provides the hydrologic condition that favor aquifer formation (Mbonu, 1990).

The sediments of Imo shale Formations consist of well laminated plain shale with grey to light green color. The shale contains occasional intercalations of thin bands of calcareous sandstones, marls and limestone. The Imo shale Formation is of Paleocene age. Groundwater exploration is very difficult in this formation.

II. LITERATURE REVIEW

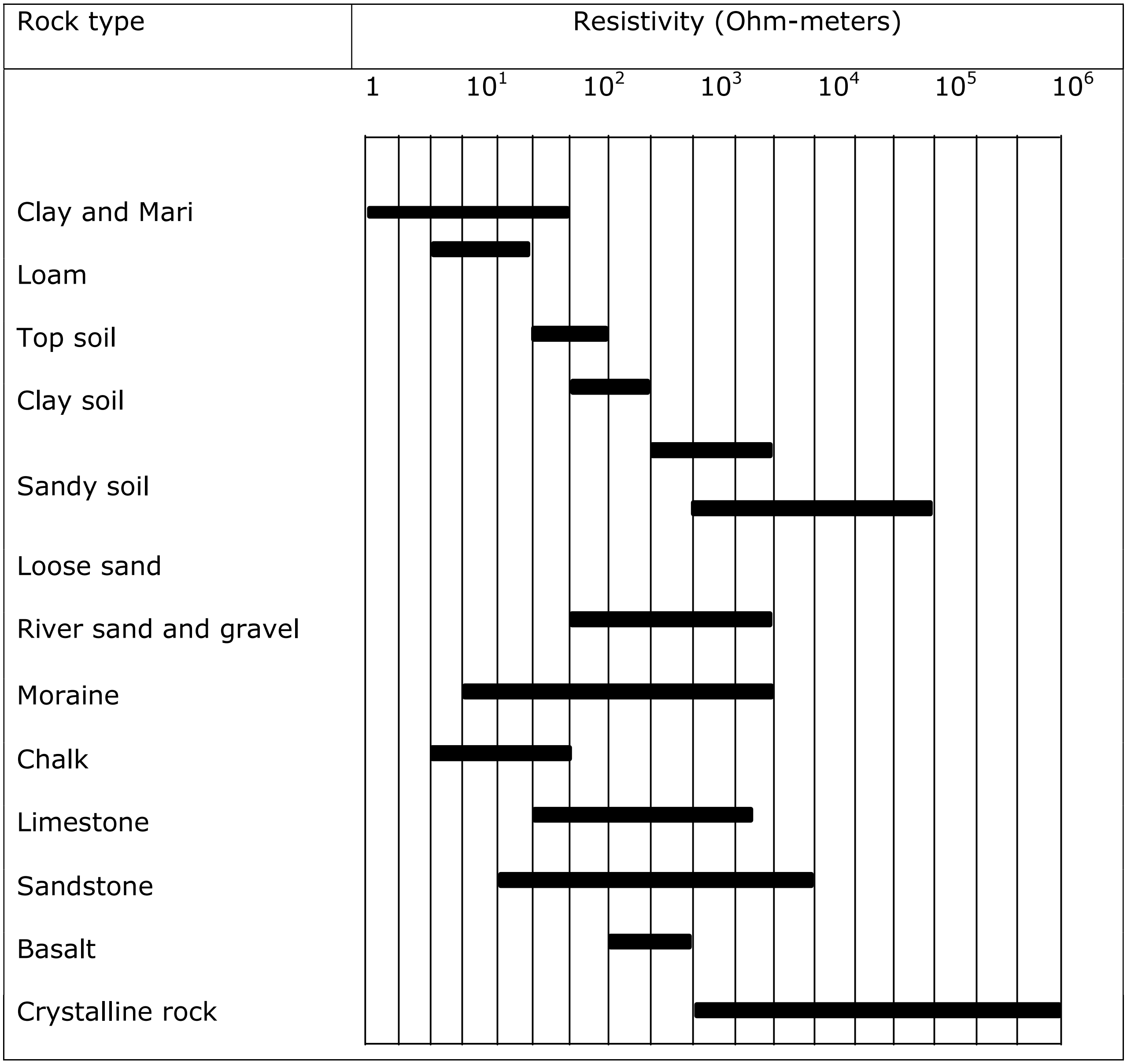
Sand and gravel beds are good aquifers due to their high porosity and permeability. Hence sand and gravel beds are usually delineated during groundwater exploration. The use of vertical electrical sounding (VES) has become very popular in groundwater prospecting due to the simplicity of the technique. Several groundwater resource investigations have been completed in so many places using this geophysical method of exploration which is increasingly being used for subsurface data acquisitions. Akaolisa and Selemo (2009) used vertical electrical sanding to map sand and gravel beds along Otamiri River in the permanent site of the Federal University of Technology Owerri (FUTO).

Brousse (1963) cited the effectiveness of the electrical resistivity method in the investigation for groundwater in complex granite areas. The study used the method to map fractures and faults which act as water reservoirs. Olorunfemi and Fasuyi (1993) used the electrical resistivity method in the investigation of geo-electric and hydro-geologic characteristics of areas in southwest Nigeria.

Oloruniwo and Olorunfemi(1987) used the electrical resistivity method for groundwater investigation in parts of the basement terrain in southwest Nigeria and concluded that the weathered layer and the fractured basement constitute the aquifer zones. Vertical electrical sounding method was successfully used in locating the site for successful borehole drilling and for the confirmation of the Bende-Ameki Formation in Agbede South-Western Nigeria (Adetola and Igbedi, 2000).

Vingoe (1972) gave the range of resistivity of soil and rock which together with available borehole information enhanced data interpretation in this study (Table 1).

Table 1.Resistivities of some rock minerals (Vingoe, 1972)



III. MATERIALS AND METHODS

Instrumentation

The instruments used for the field survey include: Ohmega-500 electrical resistivity meter,

Four stainless steel electrode (two potential and two current electrodes), A 12 volts DC power supply,

four reels of cables, Harmers, Measuring tapes, Clips and the Global Positioning System (GPS).

Field Procedure

This survey was carried out along Njaba River Bank and environs in Imo State. The field procedure adopted in the course of this survey is Vertical Electrical Sounding (VES) using the Schlumberger electrode configuration. Four electrodes consisting of two current electrodes A and B, and two potential electrodes M and N were placed along a straight line on the land surface such that the current electrode AB is greater than or equals five times the potential electrode MN. This technique involves the measurement of variations in ground apparent resistivity with depth at a fixed point of expanding spread.

A total of ten (10) Vertical Electric Soundings(VES) were run in selected communities within the study area(Fig. 4) using the Schlumberger electrode array with a maximum current electrode spread of 700m. The Ohmega-500 electrical resistivity meter was placed in between the potential electrodes M and N and its terminals P1 and P2 connected to the terminals M and N respectively using the ABEM sounding set. The current electrodes A and B were connected to the terminals C1 and C2 respectively using the ABEM sounding current cables wound on two separate metal reels mounted on the stand. The electrodes which were about 0.7m long were driven to a reasonable depth into the ground using a hammer before completing the circuit.

AtNjaba river bank, an additional profiling was carried out using the Wennerelectrode array to determine the lateral extent of sand and gravel there. The readings of the field resistance displayed on the screen of the resistivity meter were then recorded against the corresponding current and potential electrode spacing.

After the first measurement has been taken, the potential electrodes were not altered while the current electrode spacing was expanded in opposite direction on a straight line for subsequent measurements. However, the potential electrode spacing was increased whenever the value of measured resistance became too small to be reliable while the length of the configuration was generally increased.

At each VES station, elevation and coordinates were measured using the global positioning system (GPS) which enabled the development of the digital map of the study area.

Data Processing

All field data were subjected to manual computation by first obtaining the geometric factor and apparent resistivity using equations 1 and 2 as follows:

Apparent resistivity,

$$\rho a = K * R\ (\Omega m), \qquad 1$$

where *K*= geometric factor;

R =mrasured field resistance = V/I (Ohms).

I = current passed to the earth through electrodes, and

V = voltage

Equation (1) can be expressed as:

$$\rho a\ (\Omega\text{-}m) = \pi \frac{(L/2)^2 - (l/2)^2}{l} * R \qquad 2$$

L = Current Electrode spread or AB

I = Potential Electrode spread or MN

Finally, the manually computed field data were subjected to full computer processing techniques, applying the Advance Geosciences Incorporation (AGI) ID software and the Schlumberger automatic analysis package for the interpretations of apparent resistivity curves which assumes horizontal layering of the earth with defined thickness and resistivity.

The Analytical result presented by the AGI ID software and the Schlumberger Automatic analysis package revealed 12 layers with their various resistivity and depth and are later constrained to a certain number of sub-layers depending on the significant values of the resistivity and thickness. The tiny layers with comparable resistivity values were grouped together with average resistivity obtained to form single geologic layers.

III. RESULTS AND DISCUSSION

Results

Typical modelled results of the VES data interpretation of the studyare shown in Figures 6,8 and 9 while Figure 7 shows lateral resistivity variation along Njaba river bank delineated using the Wenner electrode configuration. Tables 2 to 4 show the analytical results presented by the software package. Table 5 is the summary of the modelled results obtained for all the sounding stations with respect to the parameters obtained for the aquiferous layers in each VES location. Geoelectric section constructed for the study area based on the modelled VES results is displayed in Figure 10. The variation of resistivity of the aquiferous layers is shown in Figure 11 in resistivity contour map while Figure 13 is the water table contour map showing the variation of depth to water table in the study area. Figure 12 shows the isopach map of the aquiferous layer.

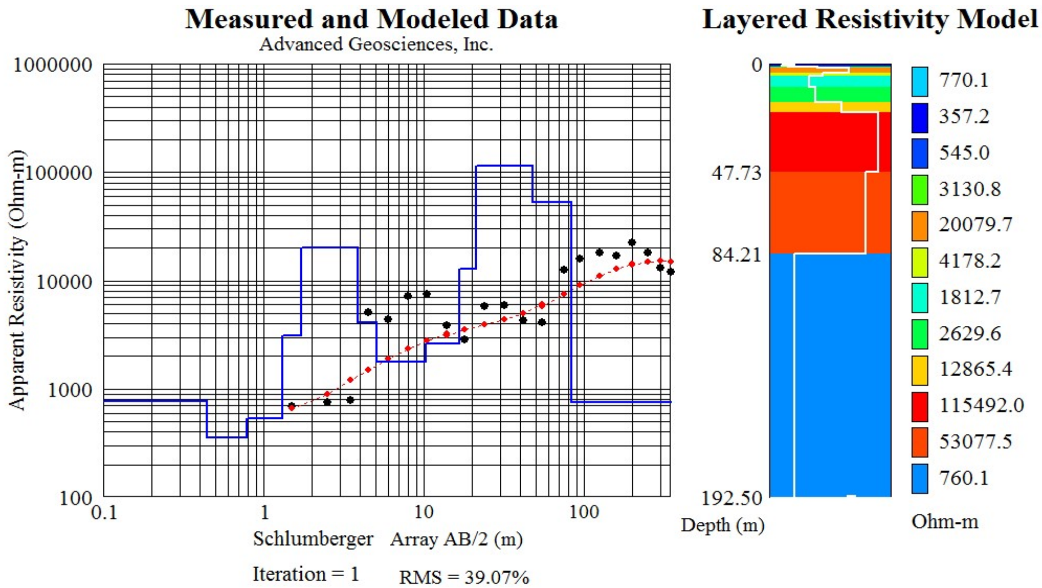


Fig. 6: Modeled VES results for Amandugba near Njaba

Table 2 Analytical result presented by the AGI 1D Software and the Schlumberger Automatic analysis package reveals eight sub-layers as follows

LAYER	DEPTH (m)	RESISTIVITY	LITHOLOGY	COLOR
1	0.40	770.0	Topsoil	Mixed Blue
2	5.09	4178	Silty-Sand	Orange
3	10.2	1812	Sand	Blue
4	16.6	2629	Sand	Green
5	21.3	12865	Sand/Gravel bed**	Yellow
6	47.7	115492	Shale-Lignite/Sandstone	Red
7	84.2	53077	Shale-Sandstone	Red
8	192	760	Sand (Prospective horizon)	Blue

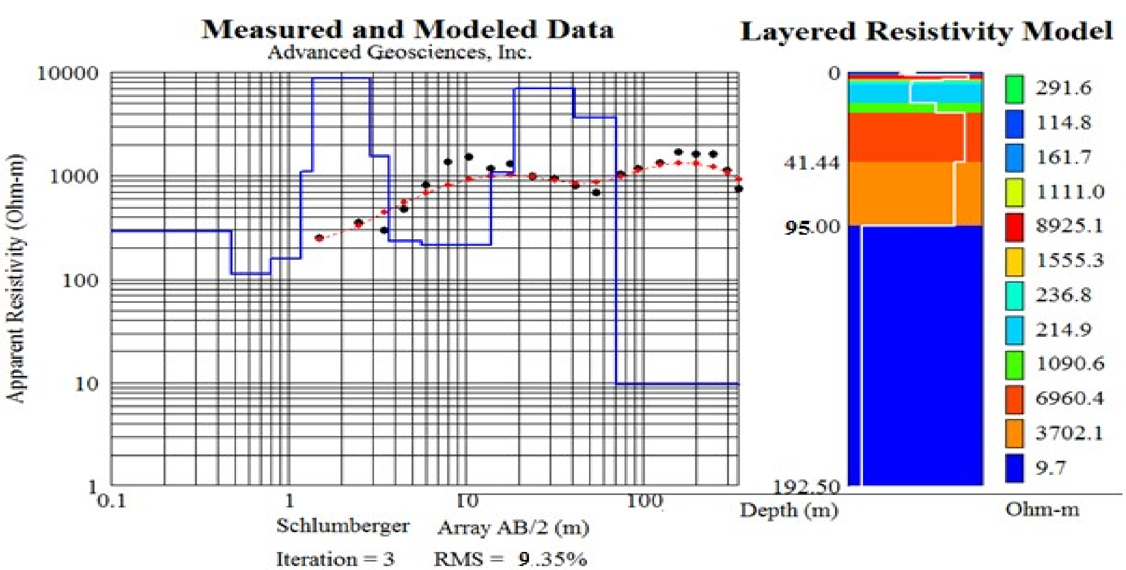


Fig. 7: Modelled VES results for Njaba River bank

Table 3 Analytical result presented by the AGI 1D Software and the Schlumberger Automatic analysis package for Njaba River bank reveals eight sub-layers as follows

LAYER	DEPTH (m)	RESISTIVITY (Ohm-m)	LITHOLOGY	COLOR
1	0.60	291.5	Topsoil	Blue
2	2.14	161.7	Silty-Sand*	Light Blue
3	6.4	1111	Mixed sand**	Orange
4	10.521	8925	Sand/Gravel bed***	Red
5	14.5	236	Sand**	Light blue
6	18.1	214	Sand**	Blue
7	23.6	1090	Clay-Shale	Green
8	41.44	6960	Sandstone	Off-Red
9	95.34	3702	Siltstone	Red-Brown
10	192.50	9.7	Sand (Prospective horizon)	Blue

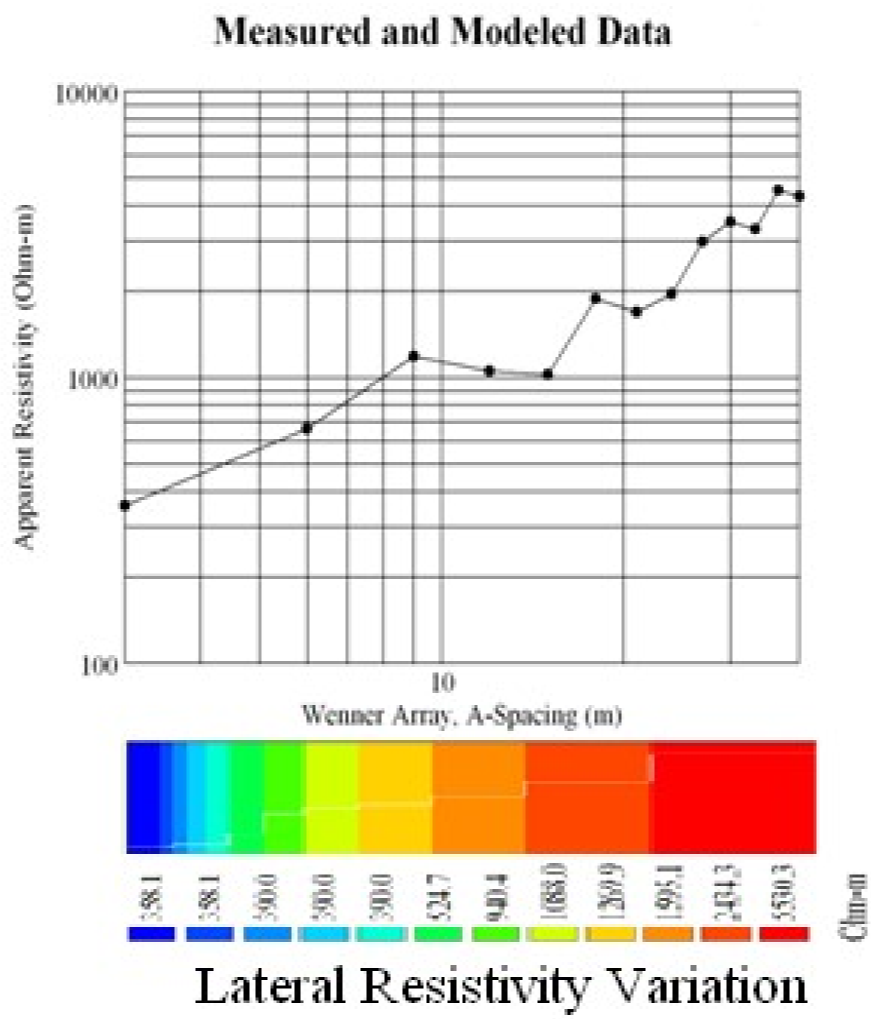


Fig 8: Lateral Resistivity Variation along Njaba River Bank

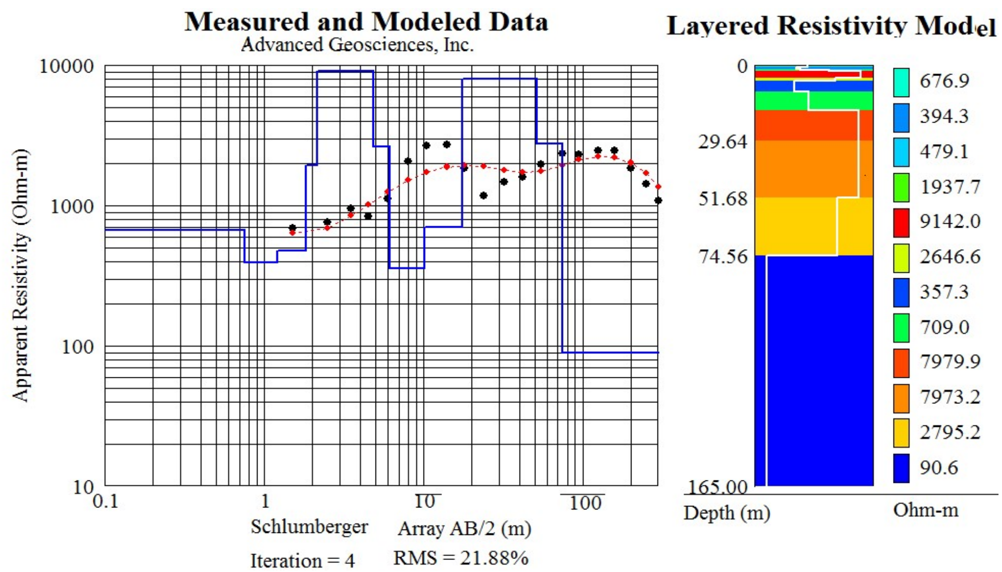


Fig. 9: Modeled VES results for Ubeleaka Njaba

Table 4. Analytical result presented by the AGI 1D Software and the Schlumberger Automatic analysis package for Ubeleaka Njaba reveals eight sub-layers as follows

LAYER	DEPTH (m)	RESISTIVITY (Ohm-m)	LITHOLOGY	COLOR
1	0.75	675	Topsoil	Mixed Blue
2	1.8	479	Silty-Sand*	Light Blue
3	4.8	9142	Sandstone	Red
4	6.1	2646	Siltstone	Orange
5	10.2	357	Silty Sand*	Blue
6	17.5	709.0	Sand*	Green
7	29.6	7979.9	Sand/Gravel bed	Red
8	51.6	7973	Sandstone	Red
9	74.5	2795	Sandstone	Yellow
10	>165	90.6	Sand (prospective unit)	Blue

Table 5: Summary of the VES Modelled result for Njabaand environs

S/No	VES Location	Latitude (E)	Longitude (E)	Resistivity (Ωm)	Depth to Water Table (m)	Thickness (m)
1	Amandugba	5.6761	7.0710	760	84.21	10.78
2	Amucha Erosion site	5.7279	7.0589	14978.2	25.00	43.48
3	Njaba	5.6959	7.0005	90.60	74.50	90.50
4	UBA BrachUmuakaNjaba	5.6510	7.0265	9.70	95.00	96.50
5	Njaba River Bank	5.7304	7.0605	2.20	36.21	128.73
6	UmuakaNjaba	5.6693	7.0102	0.10	64.37	128.13
7	UgwuMgbee	5.8003	7.6432	238.00	36.00	52.00
8	UmuduruibeAmakorNjaba	5.6993	7.0176	460.60	39.86	59.00
9	Umudioka	5.7746	7.0979	866.00	95.01	96.99
10	ubalekeNjaba	5.7464	7.6451	90.60	74.56	90.44

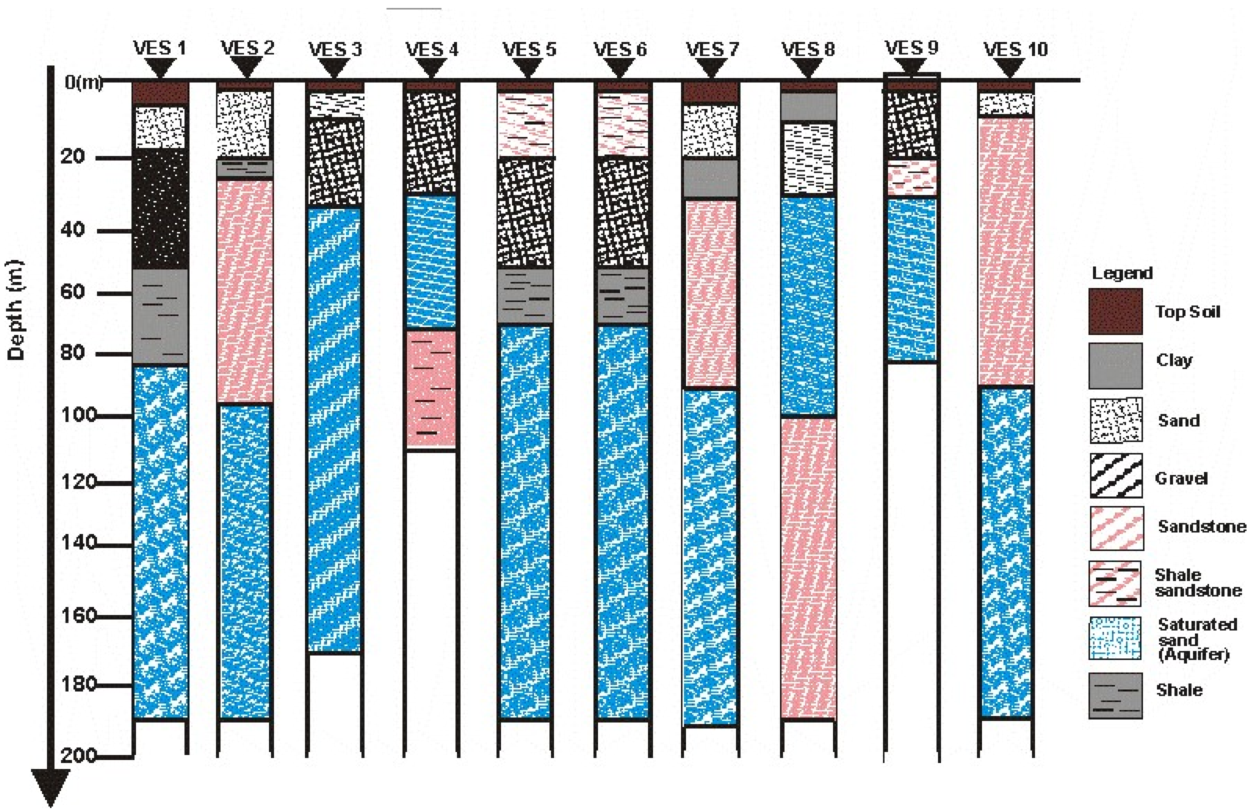


Fig. 10: Geoelectric Section of the VES Stations in the Study Area

Discusssion of Results

In the study area, electrical resistivity varies with depth and also laterally (Fig 8). The geoelectric sections (Fig 10) constructed for all the VES stations revealed the delineated lithologic units underlying the study area. Sand and gravel beds with relatively high resistivity were delineated in some of the VES stations namely:Njaba river bank (VES 5),Umuakor(VES 6), Amucha erosion site (VES 2) and Umuaka (VES 9). At Njaba river bank, sand and gravel were delineated at shallow depths (Fig 7) just below the top soil overburden from a depth of 2.14m extending to about 7.40m with resistivity ranging from 1111Ωmto 8925Ωm. Underlying this layer is another layer of wet sand extending to about 18m deep. This agrees with observation on ground at the local mining site (Fig.1). Around Amandugba (VES 1), sand and gravel beds were delineated at the 2nd and 3rd geoelectric layers respectively at corresponding depths of 5m to 16.6m with resistivity values of 1812Ωm and 12865Ωm respectively. At UbeleakaNjaba (VES 3), sand bed was delineated at a depth of 10.2m to 17.3m and gravel bed from 17.3m to 29.6m.The beds are reasonably thick to encourage mining of the mineral deposit in any of these communities as alternative site to Njaba river bank if proper and approved mining methods are adopted to avert adverse ecological consequences and degradation of surface water quality that result from mining activities. This can be achieved by adopting the following measures: As soon as mining operation at a site is ended, the resultant pit should not be left open and abandoned. Reclamation should commence immediately. Reclamation is commenced by moving the spoil heap back to the pit, followed by moving adjoining topsoil to fill the pit. There is no importation of fill material required (Nwachukwu *etal.,* 2017). This operation goes with compaction of the fill material using roller and testing the compacted earth to achieve the original soil characteristics and ground condition and finally, accomplished by turning the reclaimed site green. In such situation, Nwachukwu *etal.*(2017) further prescribed that the reclaimed site should be completed by planting flowers, grass and trees to improve the natural look of a reclaimed site and improve ecosystem services. The study concluded that reclaimed site can be used for structural development such as recreational activities, holiday resort and community gardens.

This reclamation is important because the cleaner, more porous and weakly cemented sands of an abandoned pit are the most prone to initiate erosion and landslide (Akpokodje and Akaha, 2010). In line with this (Ezezika and Adetona, 2011)in a similar study recommended that community-based low-technology land management practices and public awareness programs through workshops could halt the development of many gullies from abandoned pits. Also human activities that trigger erosion such as roadside excavation, abandoned borrow pits, and roadside waste disposal must not be allowed.

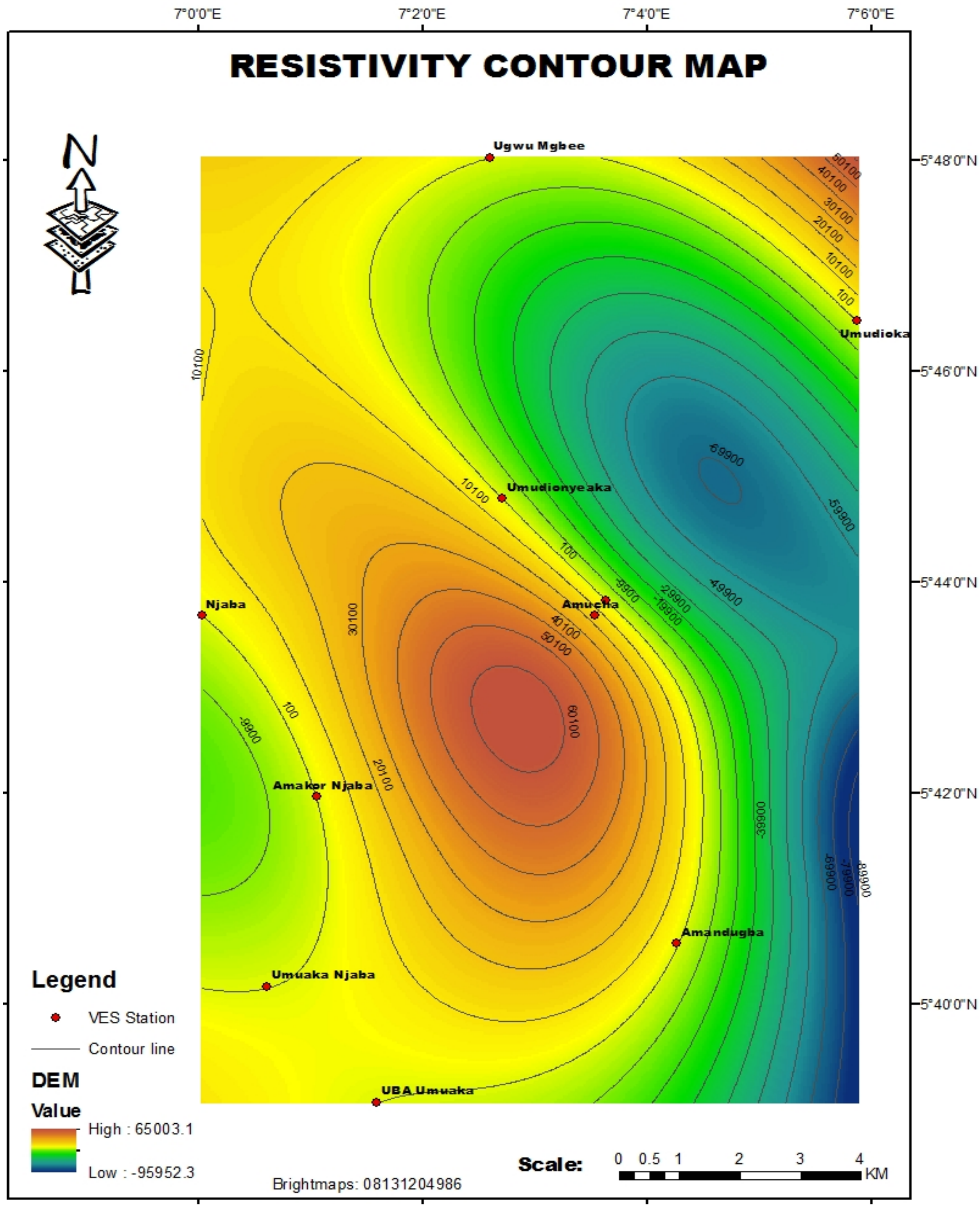


Fig. 11 Map of resistivity contour

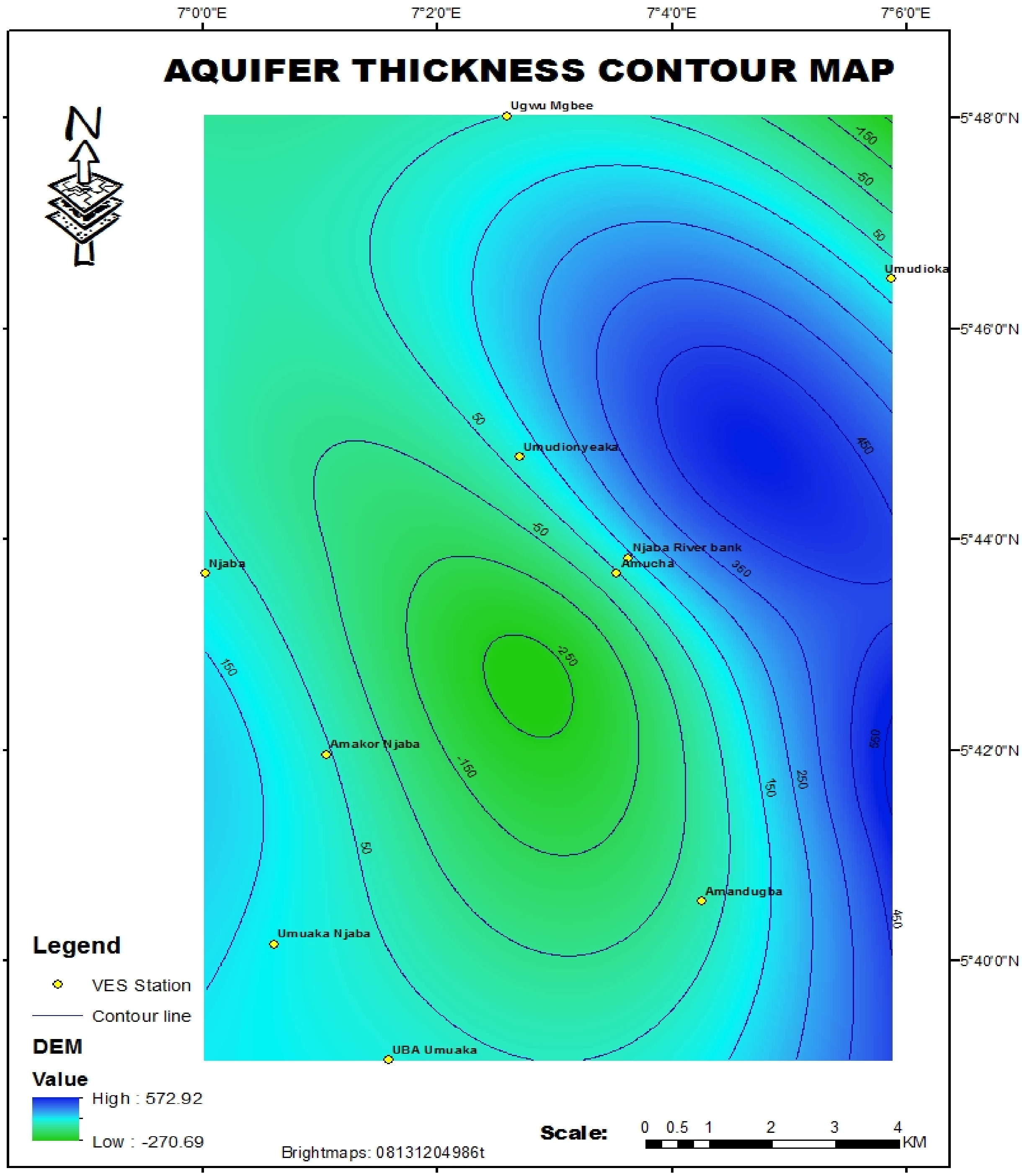


Fig. 12 Map of Aquifer thickness

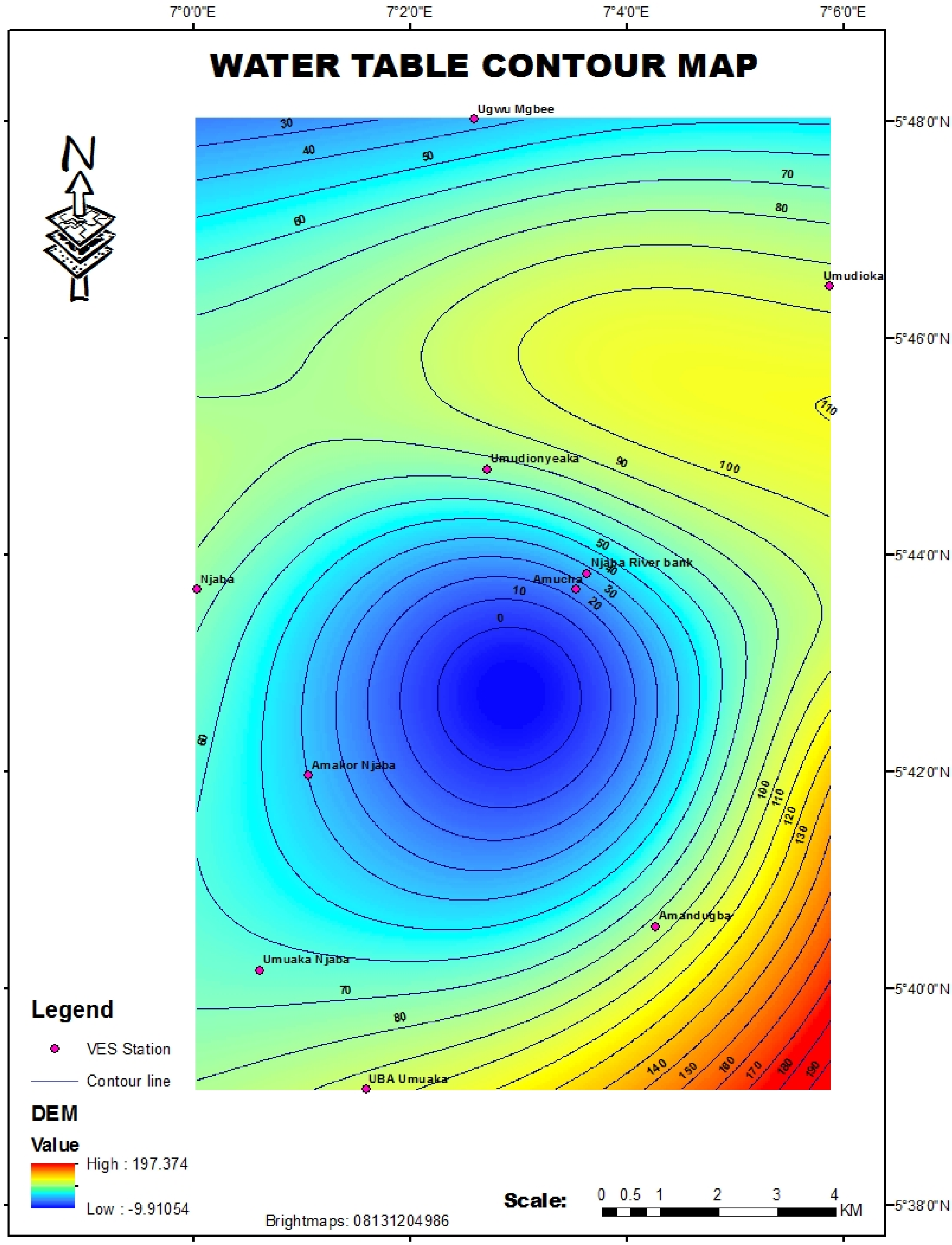


Fig. 13 Map of Water table contour map

To provide alternate source of water that is potable for both domestic and commercial use, the water table was delineated in this study. It varied across the study area (Fig 13) and ranges from a depth of 25m recorded at Amucha (VES 2) to 95m observed at United Bank of Africa (UBA) Njaba Branch (VES 4) and Umudioka (VES 9) respectively. The aquifer resistivity equally varied within the area (Fig 11) ranging from 0.1Ωm measured at UmuakaNjaba (VES 6) to 14978.2Ωm recorded at Amucha erosion site. The low resistivity value observed around Umuaka could be due to highly saturated sand that constitutes the aquifer, while the high value measured at Amucha erosion site could be linked to the presence of saturated gravel/sandstones aquifer material.

The aquifer thickness varied within the study area (Fig 12). It ranges from a value of 10.78m observed at Amandugba to 128.73m recorded at UmuakaNjaba. Generally, aquifer is thick enough at Amandugba, UBA Njaba Branch, UmuakaNjaba, Umudioka and Ubaleke communities implying high groundwater potential. These areas are promising for siting standard water wells for sustainable groundwater development for the inhabitants of the area.

IV. CONCLUSION

The result of this study is reliable and consistent with the geology of the study area. Sand and gravel beds have been delineated for commercial mining, for economic development of the communities and the State. This study also assessed the groundwater potential of the area, which will assist in overcoming the challenges posed by polluted surface water arising from mining and other human activities. If proper mining policies and methods are adopted, the shortcomings associated with mining will be highly reduced.

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