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Water table regime in parts of Obio-Akpor local Government area of Rivers State, Nigeria

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Abstract

This research was conducted within Obio-Akpor Local Government Area of Rivers state to determine its groundwater potential due to the increasing demand for potable water arising from steep population growth. To enhance supply, in view of its urgency, the overburden thickness and water table distribution were determined in the area using the electrical resistivity method. The vertical electrical sounding (VES) technique, Schlumberger configuration and ABEM Terrameter SAS 300 with good sensitivity were employed to investigate the overburden thickness and layer resistivities. A total of ten (10) VES stations were randomly sampled within the study area. The current electrodes separation ranged from 200 to 700m permitting a depth probe of about 230m. The measured field data were plotted on a log-log paper to obtain the initial parameters which were uploaded into Schlumberger software for interpretation. The results offer valuable information on the variation in thickness and resistivities of the layers penetrated and equally indicate the groundwater potential of the area of study. Overburden thickness was found to range from 3.0 to 79.2m. The results of the VES data interpretation and water table measurements in the surrounding hand-dug wells consistently show that the North-western part of the area has higher depth values than the North-eastern part. This study reveals that the area is prolific for sustainable water resources supply and management. Besides, it shows that exploring for water within the North-eastern part will be cheaper than other parts of the prospect due to the shallow water table.

Keywords: Overburden Thickness, Water Table, Obio-Akpor L.G.A and Nigeria.

Introduction

In the Niger Delta, underground rather than surface water is the key source of water supply for human survival, as well as for commercial and industrial purposes. With the increasing population, high level of commercialization and industrialization in Obio-Akpor Local Government Area (L.G.A.) of Rivers State, great challenges to the exploration, exploitation and management of potable water exist. This is in view of the limited knowledge of water table regime in the area. This situation demands urgent attention as lack or insufficient supply of water may lead to several environmental problems and possible economic stagnation in the area.

The presence of some locally hand-dug wells (circular holes, approximately 1 m in diameter and 10 to 30 m in depth) and surface water bodies such as rivers, streams, ponds, and so on within the study area is grossly inadequate to address the potable water needs of this area.

Therefore, the application of geophysical techniques to effectively explore for groundwater is indispensable to understanding the hydro-geological characteristics of this area. Research has shown that geophysical methods are the most reliable and most accurate means of all surveying methods for subsurface structural investigations and rock variations[1].

The aim of this study is to determine the thickness of overburden and the zone of saturation in Obio-Akpor L.G.A. To this end, ten Vertical Electrical Sounding (VES) stations were sampled and twenty water table measurements were conducted. This serves as index for exploration of groundwater and its management in the area using electrical resistivity method and Schlumberger configuration.

Geology and hydrogeology: Niger delta: The study area is located within the Niger Delta region which is characterized by its beaches, mangrove swamps and barrier bars[2]. The Niger Delta Basin is located in Southern Nigeria between latitudes 3^oN and 6^0N and longitudes $4^030'E$ and 9^oE. The Delta covers an area of about 105,000km^2 and it is large, arcuate, and of the destructive wave dominated type. It is divided into the continental, transitional and marine environments. A sequence of under compacted marine shale (Akata Formation, depth from 11121 ft. Paleocene in age) is overlain by paralic or sand/shale deposits (Agbada Formation, depth from 7180-11121ft, Eocene to Pleistocene in age) are present throughout. The paralic interval is overlain by a varying thickness of continental sands (Benin formation, depth from 0-6000ft, Oligocene to Recent in age). The Akata shales are mobile, under compacted and typically overpressured. They are considered to be the main source rock of the Niger Delta with the upper part considered matured source rock[3]. The Akata Formation formed during lowstands in sea-level and in oxygen deficient conditions[4]. The Akata shales are mobile, under-compacted and typically overpressured. The Agbada Formation comprises marine facies defined by both freshwater and deep sea characteristics. The hydrocarbons in this layer formed when this layer of rock became subaerial and was covered in a swamp type of environment that contained lots of organics[5]. This is the major oil and natural gas bearing facies in the basin. Growth faults strongly influenced the sedimentation pattern and thickness distribution of sands and shales. The Benin formation contains no commercial hydrocarbons although several minor oil and gas stringers are present[6]. The unconsolidated and highly porous sands of the Benin Formation have been identified as the fresh water bearing unit. The sands and sandstones are poorly sorted and range from coarse to fine grain. Oil and gas are trapped by roll-over anticlines and growth faults[5]. The Niger Delta Basin is very complex, and it carries high economic value as it contains a very productive petroleum system[4].

Climate and Vegetation: Generally, Nigeria has a tropical climate that is dominated by two major seasons, namely, dry and rainy seasons. The high temperature recorded in the region is occasioned by its proximity to the equator. A mean temperature of 27°C is obtained, while temperatures in the coastal states are highest in February, March and April and lowest in January and August. Relative humidity near the coast is about 85 to 100% at dawn and about 70-80% at noon. The Niger Delta is the rain forest belt of Nigeria. Rainfall controls the water content of a basin. The annual rainfall in the Niger Delta is high and varies from 500 mm per annum at the coasts, to about 300 mm at the northern parts of the Delta, and it peaks during the months of June, July and September[7]. The area has a very thick vegetation cover which enhances evapo-transpiration effect. Within the area, run-off is scarce; resulting in significant recharge and storage of groundwater. Limited knowledge of the true geological condition prevailing within the groundwater domain of the Niger Delta has been a major challenge in understanding its complex distribution, extractability and quality. The hydrology of the area is that of the coastal alluvium and the mangrove fresh water swamps. The Deltaic plains (upper and lower) and Benin Formation are the main aquiferous Formations. The area is dominated by both confined and unconfined aquifers at different depths and they contain highly saline groundwater. As a result of high permeability, high recharge potential and the enormous thickness of the aquifers, groundwater is found to be very high. Water table distribution within the area is in the range of about 1.6 to 9.0 m.

Obio-Akpor: Obio-Akpor Local Government area is situated in the Eastern Niger Delta Basin. It is located between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E. The Local Government Area covers 260km^2, and is generally a lowland area with average elevation below 30m above sea level. Its geology comprises basically of alluvial sedimentary basin and basement complex. The thick mangrove forest, raffia palms and light rainforest are the major types of vegetation. Due to high rainfall, the soil in the area is usually sandy or sandy loam. It is always leached, underlain by a layer of impervious pan. It lies in the tropical wet climate zone, characterized by abundant rainfall with little dry season. The monsoon season occurs between April and October, bringing heavy rainfall ranging from 2000 to 2500 mm with temperatures up to 25°C and a relatively constant humidity[8]. Some of the towns sampled include Rumueme, Nkpolu, Rumukwurushi, Mgbuoba, Elelenwo, Alakahia. Water table measurement was also taken from different localities within the study area. Access to the area is made possible through several major road networks within and around the Local Government Area. Other areas still have some untarred footpaths by which access is made possible.

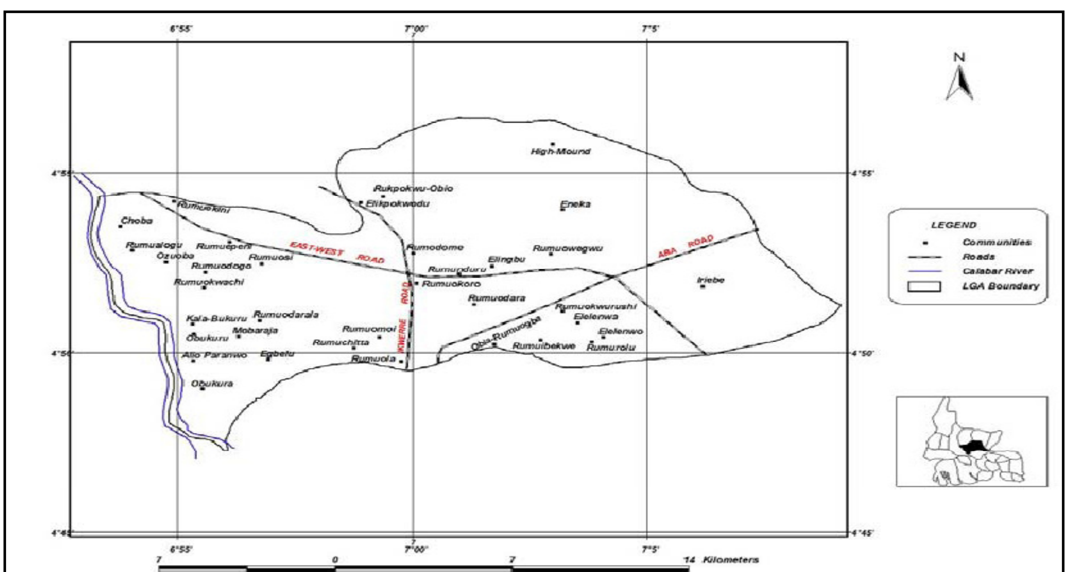

Figure-1: Map of Obio/Akpor Local Government Area, River State[9].

Methodology

The instruments employed in the acquisition of data for this work include the following: A 12-volts D.C. power source, resistivity meter (ABEM Terrameter SAS 300), Electrodes and Cable reels, GPS Garmin 16 CSX model, Tapes and Hammers. The ABEM Terrameter SAS 300 is a digital averaging instrument with the transmission and reception units integrated in the same case. It has the ability to display directly the values of apparent resistance. For the Schlumberger array, the distance between the potential electrodes MN is small compared to that between the current electrodes (i.e AB ≥ 5MN).

Figure-1 shows the survey area. Ten (10) vertical electrical sounding (VES) stations were occupied with the Schlumberger electrode array. The range of current electrode separation used was from 200 m to 700 m, permitting a depth probe of about 230m. The value of the apparent resistance (Ohm) corresponding to the electrodes separation at each setting was recorded. With these results, the apparent resistivity was calculated using the geometric factor for Schlumberger configuration. The water table distribution was determined using a simple method of gradually lowering a rope to which a weight is attached into hand-dug wells until the weight touches the surface of the water. The immersed length serves as the depth to water table. The water table measurement was taken from twenty locations in the study area during the months of September/October, 2010. The co-ordinates of the sampled locations were captured by the use of GPS 16 CSX model. These co-ordinates were used to produce the contour map of the water table measurement with the aid of Surfer-8^{M} software.

Results and discussion

In order to determine the depth of overburden in the area surveyed, ten (10) stations were randomly sampled and VES data obtained. Twenty (20) sample locations were also taken for water table measurements. From the results of the soundings, an electrode separation versus apparent resistivity plot was made on a logarithmic graph paper. The data was manually filtered and the initial parameters obtained served as input for computer aided interpretation using the Schlumberger software. Through the process of re-iteration, the software generated the curves that were used for final interpretation. The model parameters were iteratively modified to obtain a reasonable fit between the observed and calculated curves. The results obtained from computer modeling for all sounding stations and water table measurements are shown in Table-1, while Table-2 shows the data for the aquifer zone. Water table measurements from hand-dug wells are presented as Table-3.

Table-1A: Computer Modeling Results for Ten (10) VES Stations.

VES Station No.	No of Layers	Resistivity of Layers (Ω-m)							
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8
01	5	130.0	2160.0	153.0	2160.0	523.0	-	-	-
02	5	126.0	2110.0	148.0	2030.0	521.0	-	-	-
03	7	840.0	326.0	2230.0	266.0	1170.0	2350.0	13100.0	-
04	5	410.0	10600.0	387.0	5290.0	48500.0	-	-	-
05	7	151.0	262.0	385.0	6190.0	608.0	603.0	575.0	-
06	5	1380.0	2650.0	1990.0	696.0	2370.0	-	-	-
07	5	850.0	115000	3780.0	106000	161000	-	-	-
08	5	1040.0	5370.0	3430.0	830.0	238.0	-	-	-
09	5	510.0	1880.0	1590.0	554.0	1810.0	-	-	-
10	8	486.0	1310.0	417.0	1410.0	1780.0	632.0	230.0	1290.0

Table-1B: Computer Modeling Results for Ten (10) VES Stations.

Thickness of Layer (m)								Overburden Thickness (m)	Curve Type
h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8		
0.4	1.3	4.7	26.1	-	-	-	-	1.7	KK
0.3	1.4	4.6	27.1	-	-	-	-	1.7	KK
0.3	3.6	30.1	68.0	92.1	124.0	-	-	34.0	HHA
1.7	8.2	26.5	57.4	-	-	-	-	9.9	KA
0.5	9.5	12.5	35.9	94.7	170.0	-	-	10	AKQ
0.4	1.4	55.1	131.0	-	-	-	-	56.9	KH
0.3	2.7	16.6	99.7	-	-	-	-	3.0	KA
1.0	3.0	39.3	197.0	-	-	-	-	43.3	KQ
0.4	1.6	77.2	218.0	-	-	-	-	79.2	KH
0.4	2.8	6.4	32.8	51.2	72.5	178.0	-	3.2	KAQA

Table- 2: Summary of VES Results at Obio-Akpor Local Government Area, Rivers State, Nigeria.

S/N	Location	LAT(Deg)	LONG(Deg)	Direction	Overburden thickness (m)	Aquifer thickness (m)	Aquifer resistivity (Ohm-m)
1	Rumueme	4.824078	6.971918	NE	1.7	4.7	153
2	Nkpolu	4.858522	6.984384	NE	1.7	4.6	148
3	Rumukwurushi	4.890602	7.044347	NE	9.9	26.5	387
4	Mgbuoba	4.842128	6.969233	NE	10.0	12.5	385
5	Elelenwo	4.850079	7.053764	NE	3.0	16.6	3780
6	Alakahia	4.885090	6.924939	NW	34.0	68.0	266
7	Rumuogba	4.842679	7.040434	NE	3.2	6.4	417
8	Ogbogoro	4.845116	6.928964	NW	56.9	131.0	696
9	Ozuoba	4.865668	6.934332	NW	43.3	197.0	830
10	Rumuosi	4.880674	6.940432	NW	79.2	218.0	554

Table-3: Water Table Measurements from Hand-Dug Wells.

Depth to Water Table (m)	Elevation (m)	Latitude (^{o})	Longitude (^{o})	Sample points
4.70	16	04.80659	006.97416	Mgbu Osimini, Rumueme
2.20	16	04.80824	006.97446	Rd 24, FHE, Rumueme
9.10	16	04.88526	006.92452	Mission Rd, Alakahia
4.95	19	04.85083	006.99228	Echele close, Rumuigbo
5.13	28	04.90463	007.00101	Rumuakpu, Rukpokwu
1.62	34	04.86705	006.99731	Rumuodomaya
2.40	26	04.86927	006.99276	Rumuagholu
4.16	23	04.89522	007.04031	Rumuosita, Eneka
4.95	30	04.87442	007.05657	Rumuorluotubo, Atali
2.29	31	04.86984	007.05565	Minichinda Str, Elimgbu
2.64	05	04.86058	007.02200	Woko Compound, Eliozu
4.22	23	04.86069	007.01912	Amadi Compound, Rukpakwolusi
2.70	22	04.86350	007.01576	Miniaza Str, Eligbolo
5.54	07	04.87859	006.94095	Rumumba, Rumuosi
5.44	21	04.88300	006.94137	Rumuari, Rumuekine
6.09	06	04.87143	006.93151	Ikegwuru Compound, Ozuoba
5.40	11	04.84781	006.92924	Eneka, Ogbogoro
0.38	10	04.86689	006.92799	Igbogo Rd, Rumuokwachi
8.57	29	04.88032	006.90713	Owhipa, Choba
8.92	11	04.86702	006.91041	Omah Str, Rumuokparali

From the results of the VES resistivity values, it is clear that the study area has characteristic sounding curves of mainly five layers. VES curves obtained show two KKs, two KAs, two KHs and HHA, AKQ, KQ, and the complex KAQA/KAQK. The top-soil appears dry sometimes with thickness of about 0.3 to 1.7m. This layer is underlain by the fairly resistive unsaturated zone. Most hand dug wells tap their water from this zone (Table-3). The third layer is a saturated zone comprising weathered basement rocks. The variations observed in the area are attributed to changes in the local geology and topography of the place. However, the problem of interpreting multi-layered curves was resolved with the aid of information about the geology of the area. The interpretation of vertical resistivity profile assumes that the underlying formations are horizontally layered and parallel to the earth's surface. The overburden is described as the total material from the top-soil to the bottom of the weathered basement. Beneath this layer lies the top of fresh water called the water table. This layer has been found to range between 3.0 to 79.2m depth in the area.

Some of the locations such as VES 6, VES 8 and VES 9 seem to have anomalous overburden depth considering the Niger Delta environment, where water is found within the Benin Formation. The resistivity values of VES 7 seem to suggest that getting water may be difficult if not impossible. However, this may be true only in principle. The aquiferous zone is described as the total material interpreted to be water-bearing. In the area surveyed, the thickness of the aquifer varies from 4.6m to 77.2m.

Map of Overburden Thickness: Figure-2 shows the overburden thickness in the area. The overburden thickness in the area generally increases toward the Northwestern part of the area with a high of over 75m (Blue colour). The topography undulates since there exists a high (light blue) in-between two relatively lows (Yellow and green) zones on the map. Good locations for sustainable boreholes are the Yellow, light Blue and Blue zones when expense is not a drawback.

Isopach Map of Aquifer: The trend of the thickness of the Aquifer zone (Figure-3) is similar to what obtains in the case of the overburden. The isopach map shows the thickness of the aquifer units at different locations in the area. It indicates the groundwater potential and facilitates knowledge of structural growth of the area. Figure-3 reveals the contours of the aquifer units. It is clear from the map that the aquifer thickness of the area is sufficient to make for prolific supply of water when a borehole is drilled.

Iso-Resistivity: The iso-resistivity of the area also indicates that the area has good potential for groundwater exploitation (Figure-4). The differences in the resistivity values could be as a result of variations in the topography and geology of the area. Except VES 7, all other stations are promising sites for drilling of boreholes.

The deduction from the maps is that for sustainable and prolific aquifer, the NW zone is preferable, when expense is not a problem. However, for low expense and fairly sustainable Aquifer, the NE zone should be considered. However the ground water potential of the area is good.

Water Table Distribution: The result of water table distribution was used to produce the contour map of the sampled areas (Figure-5). The map essentially defines areas of equal water table. The water table distribution reveals that the North-western part of the study area has high water table. The implication of this is that drilling around these regions would mean deeper penetration compared to the North-eastern part of the area with low water table level although the Aquifer units in the NW part are thicker.

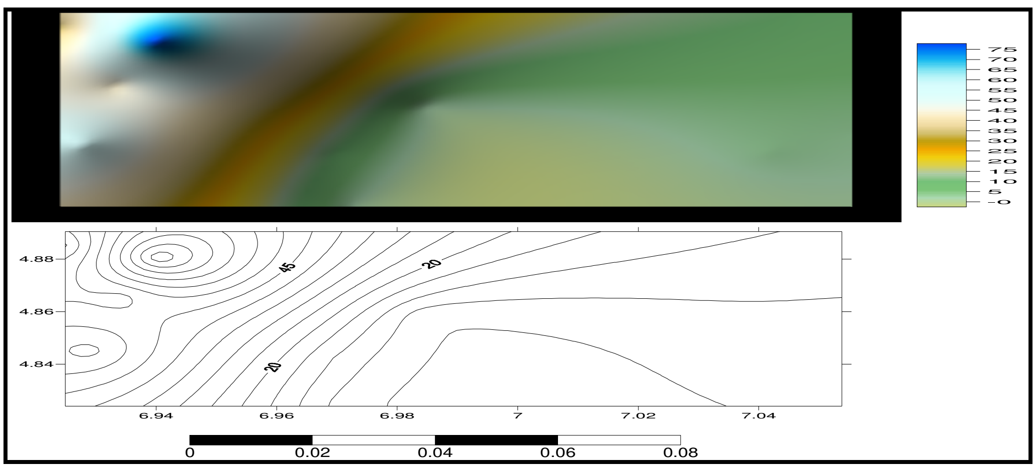

Figure-2 : Map of Overburden Thickness(m). The overburden increases in the Northwestern (NW) direction.

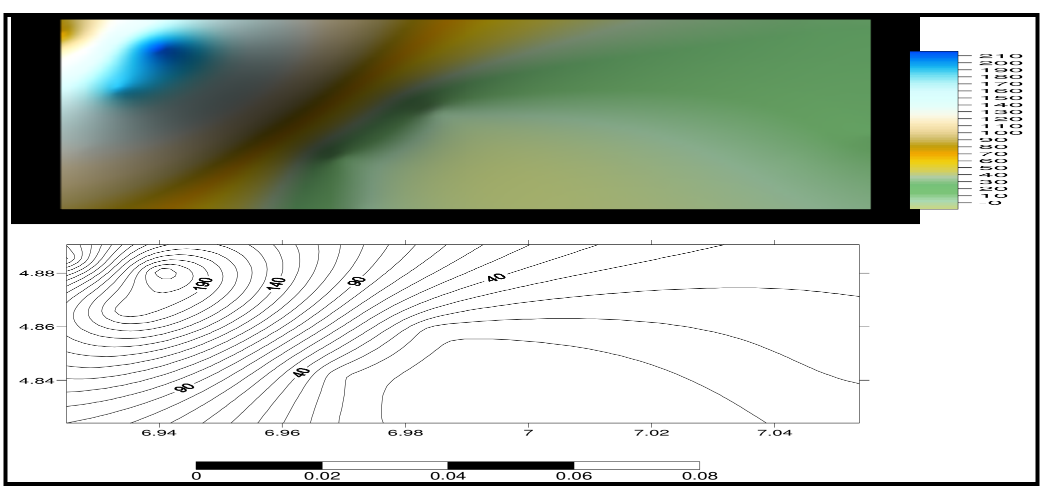

Figure-3: Isopach Map(m) of Aquifer. The Aquifer units thickens toward the Northwestern (NW) direction.

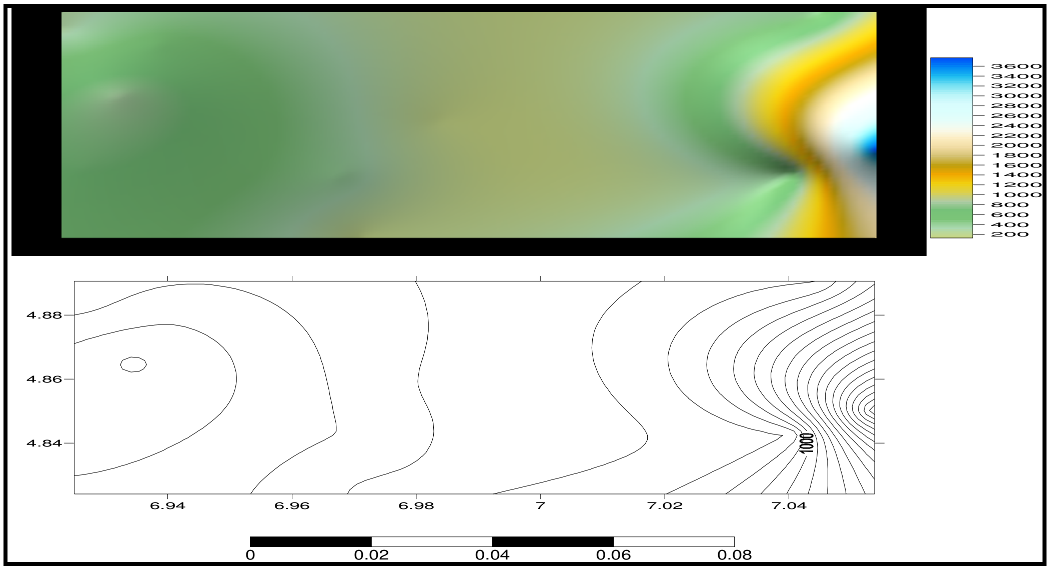

Figure-4: Isoresistivity Map (Ohm-m) of Aquifer Top by VES.The anomalous Blue location in the North Eastern(NE) part is unlikely to be suitable for sustainable Aquifer since the area is resistive and has thin Aquifer units.

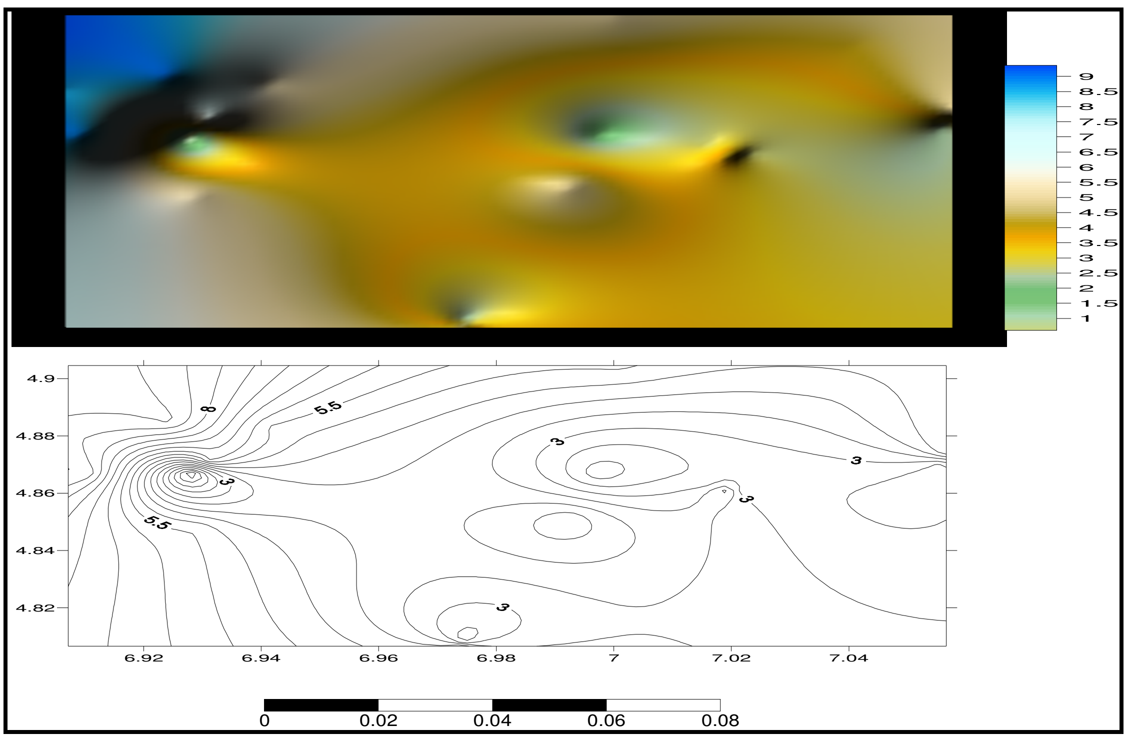

Figure-5: Depth(m) to Water Table Obtained in Hand-Dug Wells. The depth to water table in the hand–dug wells are generally low, implying shallow Aquifer units.

Summary: The ten vertical electrical sounding results indicate that the area of study is predominantly a five-layer model except in a few localities. The overburden depth has been found to range from 1.7 to 79.2 m approximately. The variation in the overburden depth may be attributed to changes in topography and local geology of the area. The aquifer unit comprises mainly of fine, medium, and coarse sands and gravels. The aquiferous zone in most cases, lies in the third or fourth layer. The interpretation of the result provided significant information on the subsurface formations and water-bearing aquifers. The water-bearing aquifers are composed mainly of sands, gravels and/or weathered rock materials. The results of the water table measurements corroborate the observed trend from geo-electrical sounding as regards the determination of the overburden depth.

Conclusion

The correlation between the different layer models of the VES data facilitates comprehensive interpretation of the equivalent subsurface lithology and occurrence of groundwater. With a thorough geological mapping and other geophysical methods of groundwater exploration, more reliable information concerning the subsurface will emerge. This research aids in the estimation of the saturated zones with their approximate thicknesses. The results of this study offer immediate information about the area in terms of drilling a borehole. The probable depth to the zone of saturation in the area can now be estimated with some level of certainty. This study also provides reasonable guide to water resources personnel to come-up with plans that can make for sustainable supply of water in the area of study.

Recommendation: Besides the usefulness of this research, it is recommended that other methods of geophysical exploration such as seismic refraction method and the gravity method be carried out in this area. These will serve as alternative ways of delineating the subsurface layers and reinforcing the conclusions of this study. To achieve a robust interpretation of the area, a combination of several ideas such as layer correlation of various sounding curves, clear geological knowledge including well information within the area is recommended.

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